Original Research Article

Predicting and grading the degree of difficulty of cochlear implant surgery by evaluating temporal bone using high resolution computed tomography and magnetic resonance imaging

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ABSTRACT

Background: The current study was designed to assess the challenges that arise during cochlear implantation. Hence imaging based grading system, using a structured, 12-point scoring chart was developed with an aim to assess various anatomical factors of temporal bone helpful in contemplating complications involved in surgery and to assess various congenital and acquired abnormalities if detected during scan which can affect cochlear implant surgery.
Methods: This was a descriptive study done on 60 patients with sensorineural hearing loss. They were evaluated preoperatively by using HRCT and MRI findings and subsequently underwent cochlear implantation. A 12-point scoring chart was developed based on imaging findings. Surgical times were noted in each case and each imaging point on the scoring chart was correlated with the surgical times.
Results: Eleven out of 12 points in the scoring chart proved to be statistically significant in predicting the degree of difficulty of the surgical procedure. One point was not correlating with the surgical timings. Based on the grading system, in the present study, there were 37 patients (61.66%) classified as Grade 1, 16 patients (26.67%) classified as Grade 2 and 7 patients (11.67%) classified as Grade 3.
Conclusions: These radiological image findings and its related grading system are relatively easy and quick to assess on readily available pre-operative temporal bone CT scan and MRI. They can form a pre-operative checklist that provides a formalized approach for the surgeons and, in particular surgical trainees, predict and, thus prepare for, potentially challenging cochlear implant cases.

Keywords: Cochlear implant, High resolution computed tomography, Magnetic resonance imaging, Sensorineural hearing loss

INTRODUCTION

The incidence of sensorineural hearing loss (SNHL) occurs in about 1.4 to 3 people per 1000 live births annually in the world.[1,2] Hence, it is necessary to identify a proper diagnostic method to treat this disorder in early stages. About 20% of the children with SNHL are impaired in the anatomy of labyrinth of the ear.[3] Cochlear implant is the important intervention procedure done in the children with SNHL.[4,5] But before the cochlear implant, it is necessary to undergo radiological assessments to diagnose or to identify the congenital abnormalities, cochlear nerve anomalies and/or to detect temporal bone abnormalities.[6]

High resolution computed tomography (HRCT) scans and magnetic resonance imaging (MRI) are important radiological techniques used to evaluate bony structures and provide accurate information related to the temporal bone diseases. HRCT of the temporal bone is helpful in

determining variants of anatomy of temporal bone. MRI temporal bone is helpful in determining cochlear nerve and facial nerve anatomy.[7] The current study was designed using a grading system to assess the challenges that arise during cochlear implant based on HRCT and MRI findings. The imaging based grading system, using a structured, 12-point scoring chart, would be useful to a trainee and experienced implant surgeon.

Table 1: Potential difficulty scoring system.

Criteria	Score
1. Degree of mastoid pneumatisation	
Well pneumatized	0
Hypo/non-pneumatized	1
2. Facial recess anatomy	
Narrow (<3 mm)	2
Wide (>3 mm)	0
3. Descending segment of facial nerve canal	
Normal	0
Overhanging the round window	2
4. Position of the jugular bulb	
Normal	0
High riding/dehiscent	1
5. Posterior wall of external auditory canal/sigmoid sinus lines	
Favourable	0
Not favourable	1
6. Posterior wall of external auditory canal/long axis of the basal turn line	
Favourable	0
Not favourable	1
7. Relative position of the basal turn of cochlea to the malleoincudal joint in axial plane	
Favourable	0
Not favourable	1
8. Lines along the anterior margin of the IACs (rotated cochlea)	
Parallel lines	0
Angulated and intersecting	1
9. Associated congenital anomalies of the temporal bone	
Not present	0
Isolated LVAS/Mondini/Bulbous IAC	1
IP-I, IP-III, Common cavity	4
10. Associated acquired abnormalities of the temporal bone (labyrinthitis ossificans and otosclerosis)	
Not present	0
LO, Balkany grade 1	2
LO, Balkany grade 2, otosclerosis	4
LO, Balkany grade 3	6
11. Degree of round window bony overhang	
Absent	0
Mild	1
Moderate	2
Severe	3
12. Cochlear rotation	
Alpha angle >50 and beta angle <20	0
Alpha angle <50 and beta angle <20	1
Alpha angle >50 and beta angle >20	2
Alpha angle <50 and beta angle >20	3

The present study was performed with the aim to assess various anatomical factors of temporal bone helpful in

contemplating complications involved in surgery and to assess various congenital and acquired abnormalities if detected during scan which can affect cochlear implant surgery.

METHODS

After obtaining approval from institutional ethics committee, the current descriptive study was done on 60 patients during the study period September 2017 to October 2018. All the patients were evaluated for pre-cochlear implant imaging by using HRCT and MRI.

Selection criteria

All cases with bilateral severe to profound sensorineural hearing loss of any age group being assessed for cochlear implant referred to the department over a period of 12 months were included in the study. Patients with active middle ear disease, congenital aural dysplasia and patients medically unfit for undergoing cochlear implantation, parents or patients not willing to give written informed consent, patients with history of cardiac pacemaker, history of heart surgery or valve replacement, history of aneurysmal or vascular surgery, history of electrical implants or neurostimulators or pumps or electrodes or drains or screws or prosthesis, history of orbital metallic foreign body were excluded from the study.

Study procedure

All the patients in the study were evaluated for HRCT and MRI of the temporal bone after obtaining the written informed consent from the patient or from guardian in case of children, according to the hospital protocol. Risk of contrast examination (less likely) was explained. A detailed clinical history of patient was taken and relevant examination findings and investigation was recorded.

MRI imaging of the patients was performed on a "Philips Achieva 1.5 T MRI Machine" using a neurovascular or head coil. After a localizer series the standard protocol consists of the following sequences: Diffusion sequence T2 axial sequence, T2 FLAIR COR sequence, T1 SAG sequence, axial T2 VISTA sequence and oblique T2 BFFE, sequence.

CT scan was carried out on "Philips Brilliance 64-Slice CT Machine". All HRCT examinations was performed with the following parameters: collimation: 64×0.625, slice thickness: 0.67 mms, increment: 0.33 mms, reconstruction algorithm: 360°, rotation time: 0.5 s, pitch factor: 0.426 and image display matrix: 768×768. Both the axial and multiplanar reformatted images were reviewed on a workstation.

In this study, 12-point scoring chart was used to score each patient based on specific imaging findings. This scoring system uses data based on the principle of

allocating points for individual risk factors thought to increase the level of surgical difficulty. The points are then summated to provide an overall score for each case pre-operatively i.e., a 'potential difficulty score' (PDS) (Table 1).

Statistical analysis

Data is analyzed using statistics package Epi Info™ 7.1.3.3 version for windows. Descriptive data are represented as mean±SD for numeric data and percentages and proportions for categorical data. Appropriate tests of significance were used depending on the nature and distribution of data. We used Pearson's correlation and a linear regression to assess relationships and quantify the effect on surgical timings based on the 10-point scoring system. Values of $p < 0.05$ were considered statistically significant. An analysis of the data based on the above imaging criteria and findings were performed.

RESULTS

Table 2: Age and gender distribution of study participants (n=60).

Age group	Number of patients and gender
Less than 5 years	41 (23 females,18 males)
5-10 years	15 (4 females, 11 males)
More than 10 years	4 (0 females, 4 males)

Table 3: Incidence of risk factors based on imaging finding.

Risk factors	Percentage of incidence
Hypopneumatised mastoid	33.33
Narrow facial recess	11.66
Descending segment of facial nerve canal overhanging the round window	23.33
High riding jugular bulb	26.66
Unfavourable posterior canal wall-sigmoid sinus line	5
Unfavourable posterior canal wall-long axis cochlear basal turn lines	6.66
Unfavourable position of the basal turn of cochlea to the malleo-incudal joint in axial plane	5
Intersecting lines along the anterior margin of IAC	11.66
Associated congenital anomalies of temporal bone.	10
Associated acquired abnormalities of temporal bone	6.66
Degree of round window bony overhang	13.33
Cochlear rotation	8

Table 4: Degree of surgical difficulty and its incidence on patients based on PDS and surgical timing.

Score	Surgical time	Grade	Number of patients	Imaging based prediction
0-3	60-90	1	37	No anticipated surgical difficulty
4-7	91-120	2	16	Anticipated surgical difficulty
8 and above	121-200	3	7	Prolonged and difficult surgery

Table 3 presents the frequency of risk factors in the patients as per 10 point scoring chart. Hypopneumatised mastoid was the common risk factor noticed in 33.33% patients followed by high riding jugular bulb (26.66%). All the 60 patients underwent cochlear implant surgery by the implant surgeon.

A total of 60 patients were evaluated for HRCT and MRI of the temporal bone in the study.

Table 2 presents the age and sex distribution of study participants. Out of 60, 27 were females and 33 were males. Majority of them were children of less than 5 years of age (n=41).

Table 5: Statistical correlation of imaging findings with surgical timings.

Imaging findings in scoring chart	Pearson correlation (r value)	P value
Degree of mastoid pneumatisation	0.284	0.035
Facial recess anatomy	0.548	0.001
Descending segment of facial nerve canal	0.341	0.024
Position of jugular bulb	0.160	0.032
Posterior wall of external auditory canal or sigmoid sinus line	0.295	0.021
Posterior wall of external auditory canal/long axis of the basal turn line	0.232	0.088
Relative position of basal turn of cochlea to malleo-incudal joint in axial plane	0.299	0.016
Lines along anterior margin of IAC	0.427	0.018
Associated congenital anomalies of temporal bone.	0.403	0.022
Associated acquired abnormalities of temporal bone	0.598	0.031
Degree of round window bony overhang	0.242	0.024
Cochlear rotation	0.258	0.019
Total score	0.892	0.027

Table 6: Multiple linear regression showing predictors of surgical timings.

Criteria	Regression coefficient	95% confidence interval for regression coefficient		p value
		Lower bound	Upper bound	
Associated acquired abnormalities	24.598	19.221	29.974	0.0001
Descending segment of facial nerve canal anatomy	16.437	8.473	24.401	0.011
Lines along anterior margin of IAC	69.382	33.445	105.319	0.001
Associated congenital anomalies of temporal bone	15.803	9.040	22.566	0.002
Relative position of basal turn of cochlea to malleo-incudal joint in axial plane	69.642	20.661	118.623	0.0001
Facial recess anatomy	12.728	4.996	20.459	0.027
Posterior wall of external auditory canal /sigmoid sinus line	14.37	0.559	28.180	0.0001
Degree of mastoid pneumatisation	30.143	2.082	58.203	0.036
Position of jugular bulb	43.774	-30.454	118.002	0.024
Posterior wall of external auditory canal/long axis of the basal turn line	53.389	19.986	86.792	0.088
Degree of round window bony overhang	33.374	10.256	45.267	0.0321
Cochlear rotation	18.567	1.453	28.564	0.025

The time taken for the surgery ranges from 60-200 minutes. From Table 4 it was observed that patients with PDS score of 0-3 was graded as grade 1 patients (n=37) and had surgical timings within a range of 60-90 minutes. Those patients with PDS score of 4-7 was considered as grade 2 patients (n=16) and surgical timings ranged from 91-120 minutes and patients with PDS score of 8 and above graded as grade 3 patients with surgical timings ranges from 121-200 minutes (n=7).

In the present study, each imaging point was correlated with surgical time as given in Table 5.

Linear relationship was noted between scoring system and operative timings. Multiple linear regression analysis was done based on the above imaging criteria of PDS score and findings observed during HRCT and MRI (Table 6).

DISCUSSION

This study aims to evaluate the diagnostic efficacy of HRCT and MRI of temporal bone disorders based on 12-point scoring chart. The findings of the study showed that the both HRCT and MRI of the temporal bone had a high diagnostic value in patients with SNHL. The study included 60 patients with congenital sensorineural hearing loss belonging to age group of less than 10 years with most of them below 5 years of age. In elder age group patients, cause of sensory neural hearing loss was acquired mostly post infection and trauma.

In the present study, 12 point scoring chart was used to assess the challenges that arise during cochlear implant by using HRCT and MRI as diagnostic aids (Table 2). Similar to this Vaid et al previously proposed a grading system based on a 10-point scoring chart of HRCT and MRI imaging findings in patients being assessed preoperatively for cochlear implant.[8]

In this study ratio of male and female patients were almost equal. In our study male surpasses female by a small difference. This could be due to different demographic factors of place and patients attending this hospital.

In his study, out of the ten mentioned imaging points in the scoring chart determining the PDS, eight were found to correlate significantly with the surgical timings and, hence, had a direct impact on the degree of surgical difficulty. In this study two points were not correlating with the surgical timings. An insufficient cohort for this study was likely to be the cause for this observation.

However in our study, twelve criteria were taken (Table 2) and studied out of which eleven criteria were found to be significant. The only factor found to be insignificant was- posterior wall of external auditory canal/long axis of the basal turn line which was similar to factor found insignificant in above mentioned study. However another factor which was found insignificant in above mentioned study was position of jugular bulb which is found to be significantly correlating with surgical timings in our study.

Based on the grading system, in the present study, there were 37 patients (61.66 %) classified as Grade 1, 16 patients (26.67 %) classified as Grade 2 and 7 patients (11.67 %) classified as Grade 3. Out of the 37 patients in Grade 1, it was observed that 32 patients had uneventful surgery and five patients had prolonged surgery (sensitivity: 86.5 %; positive predictive value: 100%; specificity: 100%; negative predictive value: 86.5%). Out of these five patients, two patients had dense mastoid sclerosis, two had blood dyscrasias that were not identified on routine, preoperative, haematological investigations and one patient had congested middle ear mucosa.

Out of the 16 patients assigned as Grade 2,12 patients had minor surgical difficulties as predicted by specific imaging findings on the scoring chart, and four had uneventful surgery (sensitivity: 100%; positive predictive value: 75%; specificity: 90%; negative predictive value: 100%). Out of these three, two patients (despite having a hypopneumatized mastoid) had an uneventful surgery. One patient with labyrinthitis ossificans Balkany grade 1 had an easy insertion. One patient with narrow facial recess on imaging had easy access to the round window.

All seven patients assigned as Grade 3 had prolonged and difficult surgery (sensitivity: 100%; positive predictive value: 100%; specificity: 100%; negative predictive value: 100%). The above observations were almost similar to the findings of Vaid et al.[8]

CONCLUSION

Cochlear implant is an accepted and popular treatment for patients with profound bilateral SNHL. The rate of success of the surgery would be good if the degree of associated difficulties were known preoperatively. With this, in mind, the authors of the study designed 12 point imaging based scoring chart and a grading system which alerts the surgeon for likely problems and difficulties they may encounter during the surgery. After grading the patients based on imaging findings, the results of the current study concluded that, patients who have a potential difficulty score between 0 and 3 are more likely to have uneventful and uncomplicated surgery with the lowest intraoperative times. Scores between 4 and 7 alert the surgeon to moderate surgical difficulty and longer intraoperative times. Scores of eight and above indicate a high chance of a prolonged and difficult surgery.

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