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Imaging of Temporal Bone - A Road Map for Cochlear Implant Surgery

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Abstract: ***Introduction: Based on high resolution computed tomography and magnetic resonance imaging findings, a 10 - point scoring and grading system was applied for preoperative assessment of patients planned for cochlear implantation. The study aimed to assess the various anatomical factors of temporal bone which would be helpful in contemplating specific complications faced during surgery. Methodology: This is a prospective study carried out at a tertiary referral center.40 patients with bilateral profound sensorineural hearing loss were evaluated by HRCT and MRI and subsequently underwent cochlear implant surgery. HRCT Temporal bone was performed on PHILLIPS Brilliant ICT 256 CT scanner while MRI was done on 1.5 Tesla MRI scanner. A 10 - point scoring chart was used based on specific imaging findings and all patients were assigned potential difficulty score (PDS). Surgical time was recorded in each case and each imaging finding on the scoring chart was correlated with the surgical timings. All patients underwent surgery via the standard posterior tympanotomy approach. Results: After applying the 10 - point scoring chart, the patients were categorized into three grades. Of the total patients studied 34% were categorized as Grade 1, 12.5 % as Grade 2 and 5% as Grade 3. Six out of the ten points in the scoring chart proved to be statistically significant in assessing the degree of surgical difficulty. Narrow facial recess was the best predictor of increased surgical timings. Conclusion: Radiological scoring and grading system based on HRCT and MRI temporal bone imagingcan prove a useful, systematic and helpfultool to surgeons for anticipating the level of surgical difficulty and plan accordingly. It was found that patients with PDS scores between 0 to 3 had uneventful and uncomplicated surgery with the lowest intraoperative times. Patients with PDS between 4 to 7 alert the surgeon to moderate surgical difficulty and longer intraoperative times. PDS of 8 and above indicate prolonged and difficult surgery.***

Keywords: Cochlear Implant Surgery, High resolution computed tomography, Magnetic resonance imaging, Temporal bone.

1. Introduction

Sensorineural hearing loss (SNHL) occurs in about 1.4 to 3 people per 1000 live births annually in the world[1, 2]. Cochlear implant offers an effective solution in these patients if intervened early. The candidacy criteria have evolved significantly in the past few years with more and more patients benefiting from this technological advancement. However, selecting the right candidate is crucial for optimal performance of the device. Imaging of the temporal bone is one the important selection criteria that plays a pivotal role in preoperative surgical planning, to anticipate any difficulties that may be encountered intraoperatively and preparedness to effectively deal with them. A 10 - point scoring chart was applied to predict the degree of surgical difficulty based on HRCT and MRI findings. The objectives of the study were -

1) To study the various radiological parameters of temporal bone
2) To predict the potential degree of difficulty in surgical procedure based on imaging findings
3) To assess various congenital and acquired abnormalities of temporal bone, if detected that can affect cochlear implant surgery.

2. Materials and Methods

This was a prospective study conducted in the Department of Otorhinolaryngology at a tertiary care centre in Central India during the period of November 2020 to November 2022. The research protocol was approved by the institutional ethics committee. The study included 40 children in the age group of less than 6 years with bilateral severe to profound sensorineural hearing loss. A detailed history, clinical examination & audiological assessments were done in all patients. All children were subjected to radiological imaging, both HRCT & MRI temporal bone performed under sedation or short acting general anesthesia. Patients being minor, a well - informed written consent was obtained from the parents/ guardian.

HRCT Temporal bone was done on PHILLIPS Brilliant ICT 256multidetector 63 slice CT scan machine with a collimation - 0.6 mm and a gantry cycle of 1 gantry rotation/second, helical anode with 0.5 mm slice thickness. Pediatric HRCT protocols were used to keep radiation doses to a minimum. MRI examination was performed on PHILIPS ACHIEVA 1.5 TESLA, MACHINE with a dedicated sense head coil. T1 and T2 weighted images in axial, coronal and sagittal planes were obtained.

All HRCT and MRI Images were studied in axial planes reconstructed parallel to the long axis of the lateral semicircular canals. Coronal sections were viewed perpendicular to the plane of the axial images. The imaging findings were evaluated on a 10 – point scoring chart and divided into three grades depending upon the degree of surgical difficulty. All the surgeries were performed by the standard posterior tympanotomy approach. The implant surgical time from start of drilling to electrode insertion was noted in each case and each imaging parameter was correlated with the surgical time. Table 1 shows the10 - point chart based on specific imaging findings on HRCT and MRI used to score each patient. The points were then

summated to provide an overall score for each case called the 'Potential Difficulty Score' (PDS).

Table 1: 10 Point scoring chart based on HRCT and MRI Findings/Potential Difficulty Score (PDS) (Vaid et al, 2011)

Imaging findings Score	
1. Degree of mastoid pneumatization	
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 [LO] and otosclerosis)	
Not present:	0
LO, Balkany grade 1	2
LO, Balkany grade 2, otosclerosis	4
LO, Balkany grade 3	6
Total Score	20

3. Statistical Analysis

Statistical analysis was done using Microsoft excel 2019 version to calculate the proportions in percentage of various parameters. Appropriate tests of significance were used depending on the nature and distribution of data. We used Pearson's correlation and linear regression to assess relationships and quantify the effects on surgical timings based on the 10 - point scoring system. 'P' value of <0.05 was considered statistically significant.

4. Results

A total of 40 patients fulfilling the inclusion and exclusion criteria were recruited for the study. Gender wise, there were equal number of male and female patients accounting to 50% each. The age group ranged from 1 - 6 years with maximum patients (80%) in the age range of > 3 - 6 years (Table 2). The right ear was implanted in 35 patients (87.5%) and left ear was implanted in 5 patients (12.5%). Bilateral implantation was not done in any case, as all were implanted under the government funded program. The various radiological parameters on HRCT and MRI were studied preoperatively and recorded on the PDS scoring chart. Table 3 shows the incidence of the risk factors based on the radiological observations. The most frequent risk factor encountered was narrow facial recess (<3mm) seen in 45% cases followed by unfavorable posterior wall of external auditory canal and basal turn of cochlea lines seen in 23.5% cases. The unfavorable posterior wall of EAC - sigmoid sinus lines was seen in 17.5% of patients.

It was observed that as the PDS scores increased the surgical difficulty increased, subsequently increasing the surgical duration. In 12.5% patients the PDS score was between 4 - 7 and surgical time between 100 to 140 minutes suggesting moderate surgical difficulty, while in 2.5% patients in whom the PDS score was 8 and above required prolonged and difficult surgical procedure with surgical timing in between 140 - 180 minutes. In remaining patients (85%) with score of 0 – 3 the surgical time was comparatively less with no intraoperative difficulty noted (Table 6). The imaging findings which were associated with difficulty during surgical procedures were hypo pneumatized mastoid seen in 10% cases (FIG 1) where more drilling was required; presence of marrow bone (FIG 2) in 7.5% patients was associated with bleeding which could be well controlled with diamond burr. Other structural abnormalities like Korners septum (2.5%) and high riding jugular bulb (10%) patients (FIG 3) could be well picked up on the scan making the surgeon prepared to deal with these conditions.

The association of width of facial recess was studied with the round window visibility. It was observed that in 50% of patients with narrow facial recess of (<3 mm) (FIG 4) round window was clearly visible while in 44.4% cases it was partially visible. In patients with wide facial recess (>3mm) round window visibility was good in 68.1% and partly visible in 31.8% patients. However, this relationship was not statistically significant. The correlation of the facial recess with the surgical timings, showed that in patients with narrow facial recess the operative time was more than 134.6 minutes as compared to patients with wider facial recess (105 minutes) and this was found to be statistically significant (p=0.024) (Table 4).

Four other parameters were assessed on axial HRCT image to assess the position and rotation of cochlea. Amongst these, three parameters showed statistically significant correlation with difficult surgery and delayed surgical timings (Table 5). The posterior wall of external auditory canal to sigmoid sinus line was found to be unfavorable/ intersecting in 17.5% cases (FIG - 5). The posterior wall of EAC and basal turn of cochlea lines was found to be unfavorable in 23.5% of patients (FIG - 6). Unfavorable position of basal turn of cochlea with respect to malleoincudal joint was seen in 15% patients (FIG - 7). Intersecting lines along the anterior margins of internal auditory canalsin 7.5%patients showed poor round window visibility in 70% of them, however, did not show a statistically significant correlation with delayed surgical timings.

Table 2: Showing Age Distribution of Patients

Age	Number of Patients	Percentage
1 - 3 Years	8	20%
>3 - 6 Years	32	80%
Total	40	100

Table 3: Incidence of Risk Factors based on Imaging Findings

S. NO	Imaging Findings	Number of Cases	Percentage
1	Non /Hypo pneumatization ofmastoid	4	`10%
2	Presence of marrow bone	3	7.50%
3	Korners septum	1	2.50%
4	Middle ear effusion	2	5%
5	High riding jugular bulb	4	10%
6	Narrow Facial Recess (<3mm)	18	`45%
7	Distance Between Facial Nerve to Round Window Membrane < 5mm	5	12.50%
8	Descending segment of facial nerve overhanging round window	1	2.50%
9	Unfavourable posterior canal wall - sigmoid sinus lines	7	17.50%
10	Unfavourable posterior wall of EAC - basal turn of cochlea lines	10	23.50%
11	Unfavourable position of basal turn of cochlea to malleoincudal joint in axial plane	6	15%
12	Intersecting lines along anterior margins of internal auditory canal	3	7.50%

Table 4: Facial Recess with Round Window Visibility and Surgical Time

Facial Recess	Round Window Visibility	Number	Percentage	Average Surgical Timings (Minutes)
< 3mm	Clearly visible	9	50%	134.6
(Narrow)	Partly visible	8	44.40%	
(N=18)	Not visible	1	5.50%	
3 - 6mm (Wide)	Clearly visible	15	68.10%	105
(N=22)	Partly visible	7	31.80%	
	Not visible	0	0%	

Chi square test 9.3
P value 0.024, Significant

Table 5: HRCT Parameters with Surgical Difficulties

HRCT Parameters	Round Window Visibility		P Value
Unfavourable / intersecting lines along posterior wall of EAC and sigmoid sinus	Clear	28.50%	<0.001
	Partly/ No	71.40%	
Unfavourable /intersecting lines along posterior wall of EAC and basal turn of cochlea	Clear	40%	<0.01
	Partly/No	60%	
Unfavourable position o basal turn of cochlea to malleoincudal joint in axial plane	Clear	0%	<0.01
	Partly/No	100%	
Intersecting lines along anterior margins of internal auditory canal	Clear	25%	0.2
	Partly/No	**75%**	

Unpaired t test

Table 6: Degree of Surgical Difficulty based on PDS Scoring

Radiological scoring	Number of patients	Percentage of patients	Surgical timings	Grade	Image based Prediction
0 - 3	34	85%	60 - 100 mins	I	No anticipated surgical difficulty
04-Jul	5	12.50%	100 - 140 mins	II	Anticipated surgical difficulty
8 and above	1	2.50%	140 mins - 180 mins	III	Prolonged and difficult surgery

Chi square test
P Value <0.0001 statistically significant

5. Discussion

The success of cochlear implant surgery depends on a variety of factors. Of them the two most important factors, which determine the candidacy includes, first - the presence of cochlear nerve that can be electrically stimulated and second a surgically accessible route for electrode placement in proximity to the residual neural elements. Advancement in imaging technology today enables us to visualise precise anatomical details of the temporal bone. High resolution computed tomography can provide detailed information about abnormalities of bony otic capsule and position of facial nerve. While the strength of MRI helps in visualisation of fluid content of membranous labyrinth, visualisation of vestibulocochlear nerve in fluid filled IAC and cerebellopontine angle[3]. Some abnormalities which can be detected on imaging and have a definitive impact on surgical procedure outcome are common cavity formation, cochlear hypoplasia, incomplete partition, large vestibular aqueduct syndrome, abnormal position of the facial nerve, cochlear aperture abnormalities, cochlear fibrosis, otosclerosis etc[1]. Surgical technique may need to be altered based on these anatomical abnormalities and pathologies of temporal bone.

The HRCT and MRI scans of 40 children fulfilling the candidacy criteria were studied. All the patients recruited were below 6 years of age with mean age of 3.4 years. Increasing awareness and early identification mayhelp bring down the age. Gender wise, male to female distribution was equal with ratio of 1: 1. Similar observation was seen by other authors like Vaid et al 2011[4]Vipul et al 2019[5]and Bamiou et al[6]. Many previous studies on the other hand demonstrated a male preponderance[7, 8, 9]. This can be ascribed to the fact that in comparison to the past, there is an equal awareness for the wellbeing of female child.

Amongst the different imaging findings studies, 10 % scans demonstrated a hypo/non pneumatized mastoid (FIG.1). As compared to a well pneumatized mastoid, more drilling is required in a hypo/non pneumatized mastoid increasing the surgical difficulty and operative time. The presence of marrow bone was seen in 7.5% cases (FIG.2) and was associated with relatively more bleeding which could be controlled by drilling with diamond burr. In 5 % cases middle ear effusion was picked up on imaging. These cases were treated with an adequate course of antihistamines and mucolytics. In case of persistent effusion not responding to medical treatment, surgical intervention was needed for adenoids obstructing the Eustachian tube prior to cochlear implantation. Thickened, inflamed middle ear mucosa seen intraoperatively lead to poor visualization of round window niche and increased bleeding while working in the middle ear, but this could be easily managed by using gel foam pledges soaked in 1: 1000 epinephrine.

Jugular bulb is considered high riding if it extends and reaches up to the level of basal turn of cochlea. Wooley et al 1997[10]stated that high riding jugular bulb above the inferior bony annulus. We found high riding jugular bulb in 10 % patients (FIG.3), but this was not associated with surgical difficulty as none of them were reaching up to the level of round window niche. However, if the jugular bulb is dehiscent, one must be careful while drilling the cochleostomy to prevent inadvertent trauma to jugular bulb. Wooley et al 1997[10]and Tiwari et al 2020[11]foundhigh riding jugular bulb leading to surgical difficulty.

Width of the facial recess is an important predictor of surgical difficulty and was evaluated on an axial section CT scan of all patients. Facial recess is considered wide if the distance between the mastoid segment of facial nerve and posterior tympanic annulus is >3mm and narrow when this distance measures <3mm. In the present study, patients having narrow facial recess, 45 % patients (FIG.4), partialround window visibility was seenin 44.5 % patients and no visibility in 5.5%. In such condition the surgeon needs to widen the facial recess by drilling anterior and inferior to the facial nerve to visualize the round window niche. Additionally, in case of narrow facial recess, surgeons may also face difficulty in manipulation of instruments through the limited space, compromising the visibility of important structures thus increasing risk of complications. By anticipating these difficulties preoperatively on imaging, the surgeon can plan and modify the surgical technique/approach[12].

The 10 - point scoring and grading chart was based on individual risk factors thought to increase the surgical difficulty. The points are then summated to provide a final score for each patient pre - operatively i. e., a 'potential difficulty score' (PDS) [4]. The surgical duration for all forty patients ranged from 60 to 180 min. A linear relationship was observed between increasing PDS and correspondingly increasing operative times. The patients were categorized into three groups based on the scoring, 85 % classified as Grade 1 with score of 0 - 3, 2.5 % were included in Grade 2 with score of 4 - 7 while 5 % in Grade 3 with score of 8 and above. The increasing grades corresponded to a predictably increased degree of surgical difficulty.

Out of the various imaging points in the scoring chart, six were found to correlate significantly with the surgical timings and, hence, had a direct impact on the degree of surgical difficulty. These include:

1) Degree of mastoid pneumatization.
2) Facial recess anatomy.
3) Descending segment of facial nerve.
4) Posterior wall of external auditory canal/sigmoid sinus lines.
5) Relative position of the basal turn of the cochlea to the malleoincudal joint in the axial plane.
6) Posterior wall of external auditory canal / basal turn of cochlea lines.

PDS scoring chart enables a preoperative study of important surgical landmarks, helps to identify surgically relevant anatomical abnormalities and predicts the probability of surgical outcome.

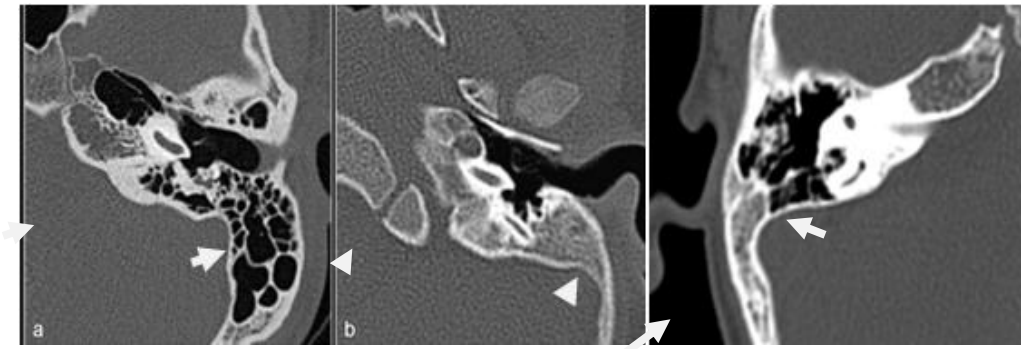

Figure 1: a) Well pneumatised mastoid b) Hypo pneumatised mastoidFIG.2. Presence of marrow bone in mastoid

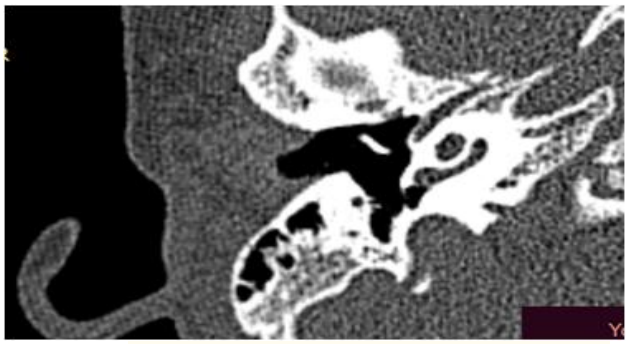

Figure 3: High jugular bulb extending upto the level of basal cochlear turn

Figure 4: Axial HRCT image showing a normal facial recess (<3mm)

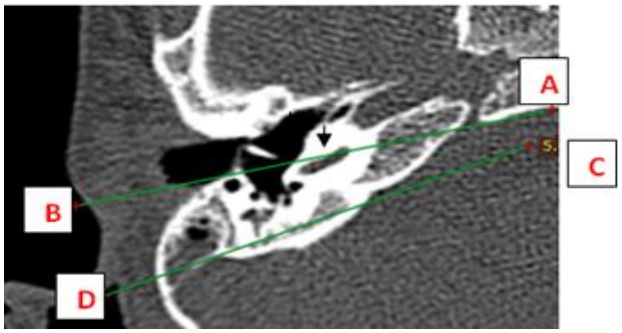

Figure 5: The posterior canal wall/sigmoid sinus lines: Lines drawn along the posterior wall of the external auditory canal (AB) and tangential to the sigmoid sinus (CD). Scored as unfavourable if the basal turn/or any part lies outside the two lines.

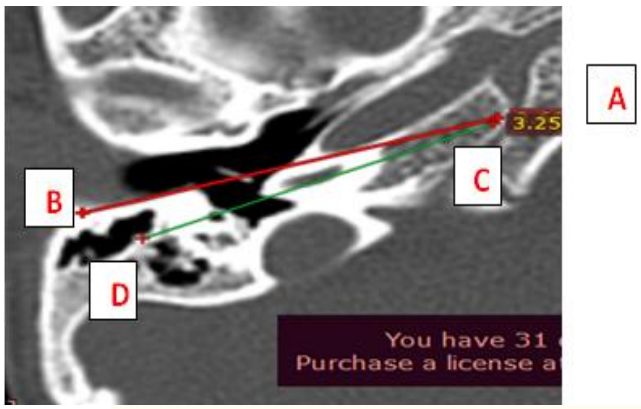

Figure 6: The posterior canal wall/cochlear basal turn lines: Lines drawn along the posterior wall of the external auditory canal (AB) and along the long axis of the basal turn of cochlea (CD). Scored asunfavorable if the lines converge/intersect medially.

Figure 7: Shows relative position of basal turn of cochlea to malleoincudal joint (arrows) which show an unfavorableposition.

6. Conclusion

Preoperative computed tomography and magnetic resonance imaging of temporal bone plays a pivotal role in patient selection for cochlear implant surgery. It helps to identify conditions which may have an impact on the surgical procedure and prepares the operating surgeon to plan and modify the surgical technique. It also helps to rule out findings that preclude surgery. The PDS chart offers an easy, practical and systematic scoring system which canguide the operating surgeonfor possible surgical difficulties and help predict the duration of surgical procedure in complex and challenging cases.

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Compliance with ethical standards

Conflict of interest - The authors declare that they have no conflict of interest.

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