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ORIGINAL ARTICLE

A Clinico-Radiological Study: Veria Technique of Cochlear Implant—A Study of 50 Cases

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Abstract Main limitation of classical technique is limited access to cochlea in terms of cochlear rotations and related structures, thus causing difficulty in electrode insertion. Veria technique allows full access to cochlea after raising tympanomeatal flap. To our best knowledge this is first clinic-radiological study for Veria technique studying distance between tympanic segment of facial nerve and posterior wall of external auditory canal (EAC) demonstrating facial nerve safety. Prospective study was done on 50 patients having bilateral sensori-neural hearing loss. Patients underwent cochlear implant surgery irrespective of age and gender. Preoperative high-resolution computed tomography temporal bone and magnetic resonance imaging head was done, distance between tympanic segment of facial nerve and posterior wall of EAC and basal turn angle were measured. Intraoperative NRT followed by orbitomeatal X-ray was done in post operative period. 25 (50%) were male, 25 (50%) female. 35 patients (70%) showed that the distance between tympanic segment of facial nerve and posterior wall of EAC was more than 3 mm with mean 4.41 mm (± 0.63 SD). Distance calculated was greater in older age group than younger group. Patient having inner ear malformation, mean was 3.96 mm (± .44 SD). Whereas patients having acquired disease, mean distance was 4.30 mm (± .47 SD). On gender comparison of basal turn angle score, no significant difference was observed male (54.34° ± 4.48°) versus female (55.66° ± 4.15°) ($p = 0.282$). Mean of basal turn angle (BTA) in ≤ 5 years age group was 54.89° ± 3.65°, in 6–10 years age group was 55.21° ± 5.23° and in age group ≥ 11 years was 54.93° ± 4° with no significant difference in mean value between the groups ($p = 0.282$). High jugular bulb was seen in 4 patients (2 in right side, 2 in left side), hypoplastic jugular bulb was seen in 10 patients (9 in left, 1 in right), otosclerosis in 2 patients. Veria technique is safe for facial nerve, as preoperatively distance between tympanic segment of facial nerve and posterior canal wall can be identified. It is suitable method for rotated cochlea (identified preoperatively through BTA) and deformed cochlea as it offers a wide visibility and accessibility as compared to posterior tympanotomy approach. BTA and distance between posterior canal wall of EAC and tympanic segment of facial nerve should be done in all cases to see any cochlear rotation and feasibility of surgery.

Keywords Cochlear implant · Veria · Basal turn angle · Facial nerve

Introduction

Ever expanding candidacy criteria for cochlear implant have resulted in an increased number of patients undergoing cochlear implantation. The recent advances in imaging technique lead to various modifications in surgical technique of cochlear implantation for making surgery safe with better outcomes. Preoperative detailed study of temporal bone using high-resolution computed tomography (HRCT) and high-resolution magnetic resonance imaging (MRI) enables us to study important surgical landmarks,

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surgically relevant anatomical variations and full range of congenital/acquired abnormalities. Commonly used techniques of cochlear implant are classical technique and transcanal veria technique. Most frequently used technique by most surgeons is classical technique, which involves cortical mastoidectomy and posterior tympanotomy approach through the facial recess. Main limitation associated with classical technique is limited accessibility to the cochlea in terms of cochlear rotations and related structures thus causing difficulty in electrode insertion [1]. Handling lot of bony framework in classical technique also leads to lot of trauma [2]. Veria technique was designed by Prof. Trifon Kiratzidis as an alternative approach to Classical technique at Cochlear Implant Centre, General Hospital of Veria (named after the Veria City), Greece in the year 2000 [2]. It uses the endaural route for transcanal cochleostomy/round window approach and a tunnel is drilled parallel to posterior canal wall though facial recess for passing electrodes through it to middle ear, without doing mastoidectomy (Fig. 1). Major advantage of this technique is to provide the unrestricted access to cochlea without endangering the facial nerve and disturbing the natural mastoid air cell systems. In both techniques electrodes passes through facial recess. Bell et al. [3] described robot guided minimal invasive cochlear implant technique in which the direct tunnel was drilled with help of robot parallel to ear canal without mastoidectomy and electrodes were directed through this tunnel, passing through facial recess into cochlea. Lot of authors believe that Veria technique is a blind technique and there are chances of damage of facial nerve. Kiratzidis et al. [4] stated that it is a safe technique for facial nerve, we are describing clinic-radiological factors [distance between tympanic segment of facial nerve and posterior wall of external auditory canal (Midpoint between the level of incudo-stapedial (IS) joint and exit of Chordae tympani)—for safety of facial nerve, basal turn angle (BTA)—to see cochlear rotation] and advantages of Veria technique. To our best knowledge this is first clinic-radiological study for Veria technique studying distance between tympanic segment of facial nerve and posterior wall of EAC demonstrating facial nerve safety.

Materials and Methods

Prospective study was done in tertiary care referral institute from November 2015 to October 2017. 50 patients having bilateral sensori-neural hearing loss (not responding to hearing aid) were taken and underwent cochlear implant surgery irrespective of age and sex.

Preoperative Settings

High resolution computed tomography temporal bone (HRCT) and magnetic resonance imaging (MRI) head with temporal bone region were done for evaluation of temporal bone anatomy and status of 7th and 8th nerve complex for cochlear implants. Measurements like distance between tympanic segment of facial nerve and posterior canal wall of EAC at the (Midpoint between the level of incudo-stapedial (IS) joint and exit of Chordae tympani) and BTA (to see any cochlear rotation) were studied with special focus on safety of facial nerve while making the direct tunnel with Trifon perforator. The measurements done in HRCT were not amenable to validation during surgery (due to limited access) but are important preoperatively to prevent intraoperative complications like facial nerve injury and plan electrode placement in rotated cochlea.

(1) Distance between the tympanic segment of facial canal and posterior wall of EAC at the level of I-S joint—We measured the distance between the tympanic segment of facial canal and posterior wall of EAC at the level of incudo-stapedial joint (Fig. 2).

(2) Basal turn angle (BTA)—To estimate the rotation/tilt/alignment of cochlea. We drew two lines—(a) First line

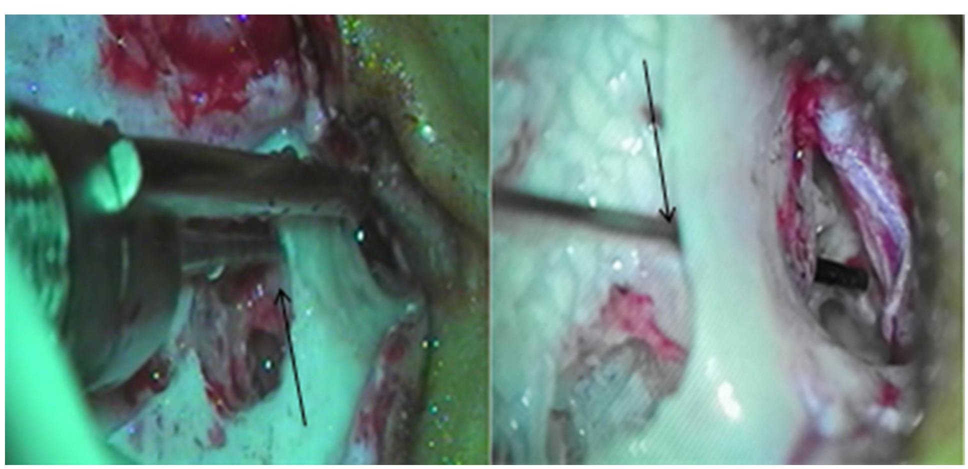


Fig. 1 Tunnel drawn parallel to external auditory canal (EAC) for passing electrodes

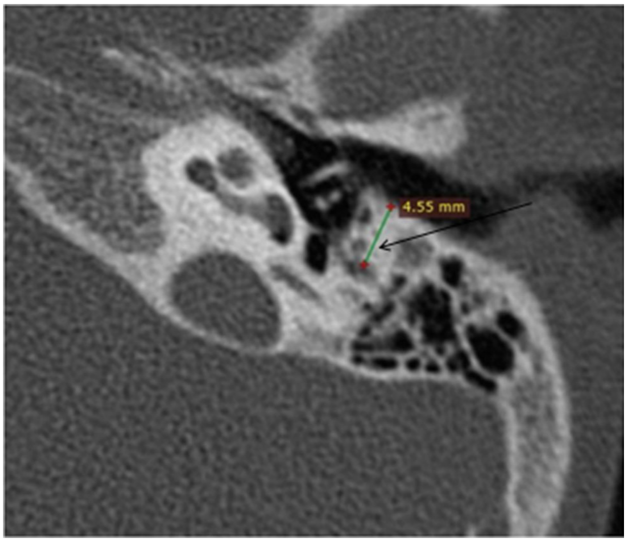


Fig. 2 HRCT temporal bone showing distance between posterior wall of EAC and facial nerve

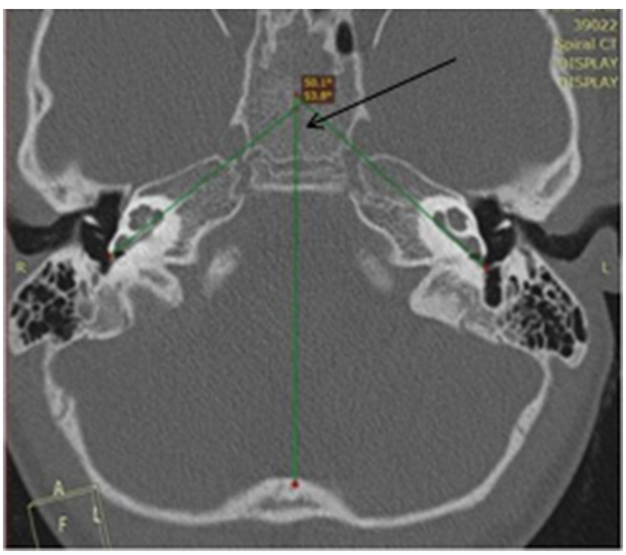


Fig. 3 HRCT temporal bone showing basal turn angle

parallel to the basal turn of cochlea (b) Second line passing through the sagittal mid-plane. Then angle was measured between these two lines (Fig. 3).

Patients having otomastoiditis were adequately treated with antibiotics before the cochlear implant surgery.

Intraoperative

All patients were operated except one with Michel aplasia using transcanal Veria technique. Same standard electrode array (Medel SONATA TI 100+ Standard, Cochlear Nucleus Cochlear Implant CI24RE) were used in all cases. Post electrode insertion NRT (neural response telemetry) was done in all cases.

Post Operative

Orbito-meatal X-ray was done in every patient to confirm position of electrode array in cochlear turns (Fig. 4).

Statistical Analysis

Normality of the Continuous variable's was assessed using Shapiro wilk test. Continuous variables were presented in mean ± standard deviation while categorical variables in frequency (%). To compare the means, between two groups, Independent samples t test while among three or more groups, One Way ANOVA test was used. P value < 0.05 was considered as statistically significant. Data was analyzed using software statistical package for social sciences, version-22 (SPSS-23, IBM, Chicago, USA).

Results

Out of 50 patients 25 (50%) were male, 25 (50%) female. As per radiological findings of HRCT temporal bone and MRI head we divided patients into three categories, normal (n = 35, 70%), patients with acquired disease in ear (n = 7,

Fig. 4 Post opeartive orbito meatal X-ray showing position of electrodes of Cochlear (right) and Medel (left) respectively

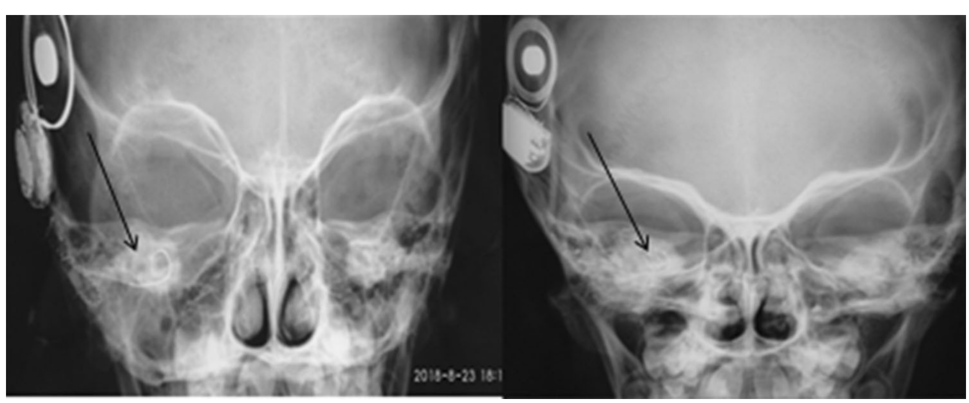
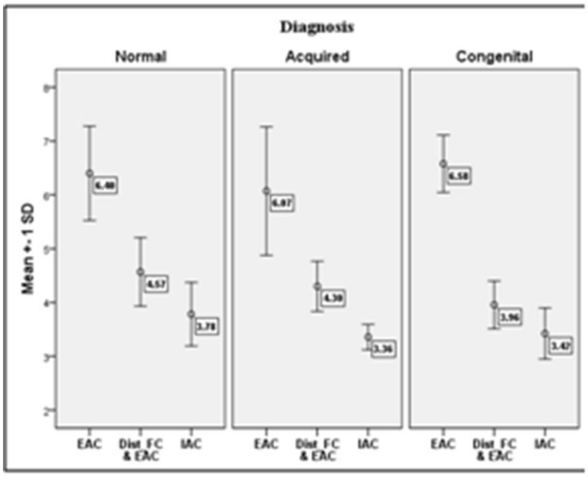


Table 1 Comparison of mean scores of different variables measured on HRCT in the groups—normal, acquired disease, congenital inner ear malformation (ANOVA test)



Variables		No.	Mean	SD	p
EAC (mm)	Normal	35	6.40	0.88	0.517
	Acquired	7	6.07	1.19	
	Cong.	8	6.58	0.53	
	Total	50	6.37	0.87	
Dist. FC & EAC	Normal	35	4.57	0.63	**0.024**
	Acquired	7	4.30	0.47	
	Cong.	8	3.97	0.44	
	Total	50	4.42	0.62	
IAC (mm)	Normal	35	3.78	0.60	0.067
	Acquired	7	3.36	0.24	
	Cong.	8	3.42	0.47	
	Total	50	3.67	0.56	
BTA	Normal	35	55.14	4.30	0.473
	Acquired	7	56.30	2.12	
	Cong.	8	53.65	5.57	
	Total	50	55.03	4.32	

One way ANOVA used

14%), patients with congenital inner ear malformation (n = 8, 16%). Out of 8 cases of congenital inner ear malformation, 1 (12.5%) patient had Michel's deformity, 2 (25%) had Type 1 incomplete partition, 3 (37.5%) had Mondini's deformity, Isolated enlarged vestibular aqueduct was seen in 2 (25%) patients. 49 out 50 patients underwent surgery except patient having Michels deformity which was advised brain stem implant. Out of 50 cases, 35 normal patients (70%) showed that the distance between tympanic segment of facial nerve and posterior wall of EAC 4.41 mm (± 0.63 SD). In patient with inner ear malformation, mean was 3.96 mm (± .44 SD). Whereas patients having acquired disease, mean distance was 4.30 mm (± .47 SD). Only in one case (2%) who had congenital inner ear malformation (Michel deformity), the distance was 2.6 mm. Distance calculated was greater in older age group than younger group. One way-ANOVAs test was used to compare the means among the three groups, result indicated that mean was statistically significantly for the distance between tympanic segment of facial canal and posterior wall of EAC at the level of incudo stapedial joint ($p < 0.05$) (Table 1). The result showed that the distance between tympanic facial canal and posterior wall of EAC at the level of incudo-stapedial joint is wider (mean ± SD 4.41 ± .63) mm in normal groups compared to that of acquired diseased groups (mean ± SD 4.30 ± .24) mm and congenital inner ear malformed groups (mean ± SD 3.42 ± .47) mm. While the result was insignificant for the variables namely: EAC, IAC and basal turn angle ($p > 0.05$) (Table 1). On gender comparison of basal turn angle score, no significant difference in mean value between the groups was observed male(54.34° ± 4.48°) versus female (55.66° ± 4.15°) ($p = 0.282$) (Table 3) i.e. there is no gender discrimination of basal turn angle. In present study, the mean of BTA in ≤ 5 years age group was 54.89° ± 3.65°, in 6–10 years age group was 55.21° ± 5.23° and in age group ≥ 11 years was 54.93° ± 4° with no significant difference in mean value

Table 2 Distribution of BTA and distance between FC to EAC as per age groups

Variable's	Age groups			p value
	< 5 years (n = 31)	6–10 years (n = 8)	>10 years (n = 11)	
Basal turn angle (°)	54.89 ± 3.65	55.21 ± 5.23	54.93 ± 4.60	0.282
Dist FC & EAC (mm)	4.34 ± 0.61	4.24 ± 0.84	4.76 ± 0.50	0.125

FC facial canal, *BTA* basal turn angle)

One Way ANOVA test used, $p < 0.05$ significant

Table 3 Distribution of BTA and distance between FC and posterior wall of EAC as per gender

Variable's	Gender		*p* value
	Male (n = 25)	Female (n = 25)	
Basal turn angle (BTA) (°)	54.34 ± 4.48	55.66 ± 4.15	0.282
Dist FC & EAC (mm)	4.65 ± 0.59	4.19 ± 0.62	0.012

FC facial canal, *BTA* basal turn angle

Independent samples t test used, $p < 0.05$ significant

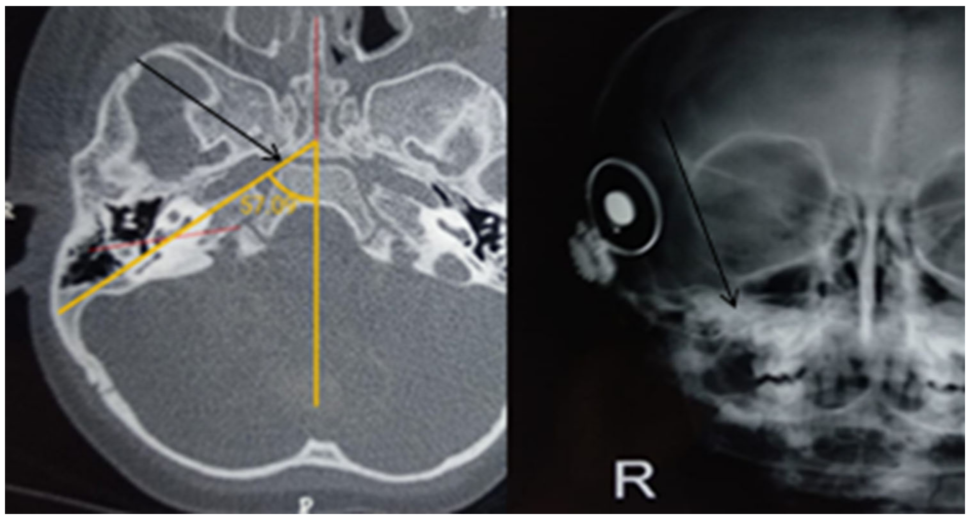


Fig. 5 Right—HRCT temporal bone showing increased basal turn angle (BTA), left—post operative X-ray showing kinking of electrodes

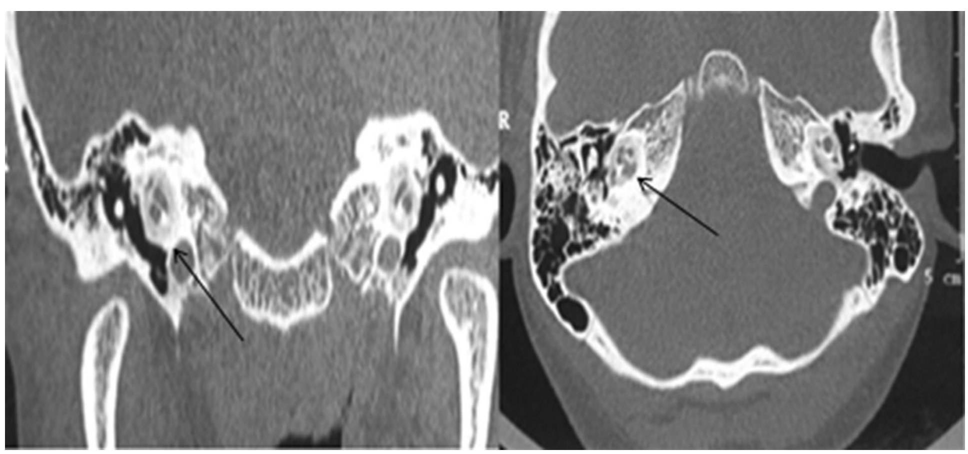


Fig. 6 Cochlear otosclerosis

between the groups ($p = 0.282$) (Table 2) i.e. basal turn angle does not vary with age. Out of 50 cases, 1 case had BTA more than 57° (Fig. 5). Radiological study revealed that poor mastoid pneumatisation was found in 6 patients, otomastoiditis in 5 patients, high jugular bulb in 4 patients (2 in right side, 2 in left side), hypoplastic jugular bulb was seen in 10 patients (9 in left, 1 in right), otosclerosis in 2 patients (Fig. 6). 3 cases had bilateral enlarged vestibular aqueduct. Abnormal facial nerve and hypoplastic vestibule-cochlear nerve complex were not seen in any case.

Intra-operative Adjuncts

No immediate intra-operative complication was noted in any patient. After the activation of the device, good NRT was recorded in all cases. We faced difficulty in inserting electrodes in patient having BTA > 57° leading to kinking of electrodes which could be seen in post operative orbito meatal X-ray (Fig. 5). 3 cases shows forward lying sigmoid sinus but no breech was encountered intra-operatively. Injury to posterior canal wall was identified in 2 cases

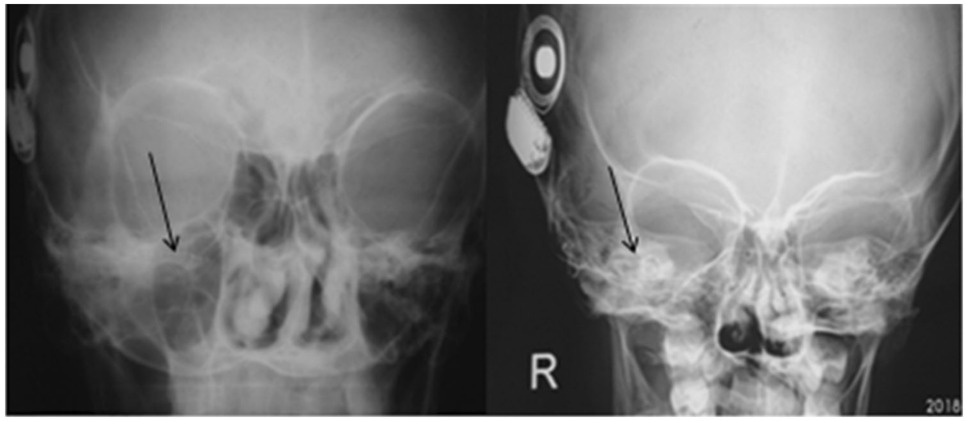


Fig. 7 Right—post operative X-ray showing position of electrodes in internal auditory meatus (IAM), left—revision surgery done and position of electrodes confirmed in

which were repaired using bone dust with overlying fascia to prevent granulation formation. Chorda tympani was damaged in one case due to postero superior bony overhang of EAC, however no taste abnormalities were identified. One case showed intra-operative increase CSF pulsation out of 3 cases having enlarged vestibular aqueduct. However, no definite gusher was noted in any one of the patient. Ossification with poor patency of the cochlea was seen intra-operatively in one case. In this case imaging was done 1 year prior to surgery, radiology was reported normal but intra-operatively we found basal turn ossification. We found difficulty in performing basal turn cochleostomy and accidentally electrodes got inserted into IAM (internal auditory canal) with normal intra operative NRT post electrode insertion (Fig. 7). Revision surgery was done next day with electrode placement in cochlear turns which was confirmed by X-ray (Fig. 7). Hence, the imaging should be performed shortly before the scheduled surgery, to avoid the false negative interpretation of normal cochlea.

Post Operative

No evidence of facial nerve and post operative neurological signs of any meningitis or neurological deficits were identified.

Discussion

Degree of Mastoid Pneumatization

6 out of 50 patients had poor pneumatization. Mastoid pneumatization is of great importance in cochlear implant surgery. Sclerotic mastoid is associated with difficulty in surgery as it is difficult to drill through the sclerotic mastoid than good porous mastoid, especially in classical transmastoid route. Aerated side may be chosen for implantation if the changes are asymmetric. Assessing the configuration and pneu-matization of mastoid air cells and the middle-ear cavity aids surgical planning. Literature states that in children < 2 years tympanic ring is underdeveloped and the mastoid pneumatization is incomplete thus stylomastoid foramen is quite shallow; hence, the facial nerve is vulnerable to injury [5]. However in experienced hands, this reduced degree of mastoid pneumatization is adequate for clear access and successful electrode insertion [6]. However, a hypo pneumatized mastoid indicates a limited surgical exposure to the facial nerve recess in classical technique rather than veria technique [7].

High Jugular Bulb

Superior border of the jugular bulb normally lies below the hypotympanum of the middle-ear cavity. However, in rare cases the jugular bulb may extend upwards, elevating the floor of the hypotympanum and presenting in the middle-ear space with a thin or absent bony septum. This anomaly is known as a high-riding jugular bulb. A jugular bulb is also considered high-riding if it extends superior to the level of tympanic annulus, or encroaches within 2 mm of the internal auditory canal (IAC).High jugular bulb may extend up to round window thus obscuring its view and causing difficult electrodes insertion [8]. Out of 50 cases, 4 cases showed isolated high jugular bulb, 2 in right side and 2 in left side. We found that the prevalence of high jugular bulb (8.0%) in our study to be similar to that reported in the literature (8–32.5%) [9–11]. All cases underwent surgery. Two cases having left sided high jugular bulb had no issue, as cochlear implantation was done in right ear. However, another 2 patients having right sided high jugular bulb, extra care was taken at the time of surgery to avoid any injury to jugular bulb. Thus, this condition should be reported pre-operatively to avoid the intra-operative risk of injuring jugular bulb.

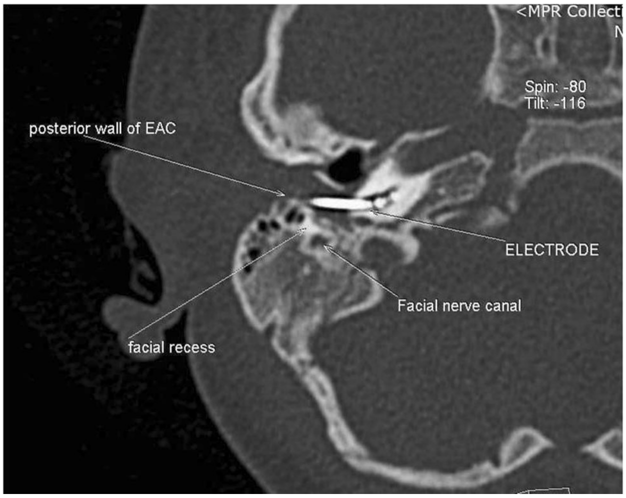


Fig. 8 Post operative CT Scan showing electrode in situ passing through facial recess

Distance Between the Tympanic Segment of Facial Nerve and Posterior Wall of EAC at midpoint between the level of incudo-stapedial (IS) joint and exit of Chordae tympani

Most important anatomical landmark of cochlear implant surgery is facial recess. Facial nerve and chorda tympani defines postero-lateral and antero-medial boundary of facial recess respectively. Electrodes in Veria technique pass through facial recess (Fig. 8). By preoperative evaluation of patient, we can illustrate the facial recess anatomy and distance between tympanic segment of facial nerve and posterior wall of EAC thereby avoiding the incidence of facial nerve injury. In veria technique, a special perforator which has a guard is used. This guard acts as guide for drilling tunnel parallel to EAC (Fig. 1). The distance between the guard and the drill is 0.6 mm and the burr is 1.2 mm. So the safe distance needed to avoid facial nerve injury is approximately 2.0 mm (1.8 mm for drilling + 0.2 mm for heat dissipation). Keeping this in mind, in our study we have measured the distance between the tympanic segment of facial nerve and the posterior wall of EAC. If this distance is enough (wider than 2.0 mm), it would be safe to make tunnel parallel to EAC which passes through the facial recess without any risk of injuring facial nerve.

Basal Turn Angle (BTA) Measurement

We measured an angle called basal turn angle between the line parallel to basal turn of cochlea and mid sagittal plane on axial view of HRCT temporal bone imaging. Llyod et al. studied change in cochlear orientation with age. In their study, the mean basal turn angle was 54.6° (range 46.8°–63.8°; standard deviation 3.5) which is consistent with our study in which we studied that basal turn angle was around 55° irrespective of age and gender. Sharma et al. [1] studied HRCT temporal bone and stated that average α(alpha) angle was 55.95° (range 47.4°–65.3°) in the right ear and was 56.19° (range 47.3°–66.3°) in the left ear. Alpha angle is similar to BTA in our study. Lloyd et al. showed statistically significant reduction in the angulations of the basal turn with increasing age ($F = 10.1$; $p = 0.002$). Our study does not coincide with this finding as we did not found any significant reduction in BTA with age (Table 2). Lloyd et al. considered a rotated cochlea when the measured basal turn angle was more obtuse than that of the normal age standard. They said that rotated cochlea is associated with difficult cochleostomy. Out of 50 cases, 1 case had BTA more than 57° which was outside the normal range suggested by Lloyd et al. [12]. We encountered difficulty in inserting electrodes in these patients.

Radiological Aspect

Outcomes in cochlear implant surgery are improved because of preoperative documentation of anatomical details of ear structures by imaging. CT depicts the various details of osseous structures. CT helps to assess the mastoid pneumatisation and the degree of middle-ear aeration. It displays middle ear variations of surgical importance, such as the bony borders of a malformed labyrinth, high or dehiscent jugular bulb or an aberrant carotid artery. These statements are correlated well with previous studies [13, 14]. This information can be important for the surgeon in order to analyze the direction of insertion of the cochlear electrode preoperatively, and thus minimizing the risk of misplacement or intra-operative injuries. So we recommend that CT should be done close to date of surgery to avoid any changes in temporal bone findings. In labyrinthitis ossificans, ossification may be preceded by fibrosis. It can be diagnosed earlier in MRI compared to CT. Imaging of the temporal bone for potential cochlear implantation is best performed with heavily T2-weighted sequences like FIESTA. It provides optimal contrast between nerves and cerebrospinal fluid (CSF) and between the membranous and bony labyrinth. Number of cochlear turns can be better seen on FIESTA sequences. Cochleovestibular nerve and facial nerve can be best seen in oblique sagittal imaging perpendicular to the plane of the IAC. The cochlea can be further evaluated by MIP (maximum intensity projection) image reconstruction. As in cochlear ossification, fibrosis occurs in initial stages, so MRI would be better compared to CT in identifying early changes of cochlear ossification. CT scan can depict the vestibular aqueduct, although the endolymphatic duct and sac are only imaged by MRI techniques. Preoperative identification and documentation is required to aware the surgeon before the cochlear implantation. In our study, surgery was done in 3 cases having bilateral enlarged vestibular aqueduct, only 1 case showed increased CSF pulsation, however no CSF gusher was noted. MRI provides excellent delineation of the anatomy of the inner ear visualization of the fluid-filled spaces and the 8th nerve so this can be done to confirm candidacy of cochlear implant. Modiolus or other deficiencies can also be more easily identified on MRI. In addition to inner ear abnormality, MRI is also helpful to identify any brain pathology like infarcts which are main etiological factor for bilateral sensory hearing loss. In these situations, brainstem implant is advised instead of cochlear implant.

Clinical Perspective

Most of the cochlear implant surgeon use classical technique for cochlear implants. Then why Veria technique? Kiratzidis et al. [4, 15] described comparison between both these approaches, main highlights were.

Endaural (canal) approach	Mastoidectomy-posterior tympanotomy approach
Ready, offered by nature	Laborious, dangerous
All anatomic variations of the cochlea can be handled	Difficult to handle cases with anatomic variations of the cochlea
Pathway for the active electrode insertion has to be additionally created	Pathway for the active electrode ready

Position of the cochlea shows significant variations in relation to facial nerve, oval window. In extreme cases cochlea may be rotated supero-posteriorly, behind the facial canal, leaving promontory flat(empty promontory). In these cases it is difficult to access cochlea through classical approach as it is a pin hole approach and does not allow access to whole cochlea, whereas Veria technique allows access to whole of cochlea after elevation of tympanic membrane. Miklani et al. [16] studied BTA and said that obtuse basal turn angle of the cochlea relative to the mid-sagittal plane indicates dorsally rotated cochlea, acute angulations of the basal cochlear turn, indicating ventrally rotated cochlea, could also be associated with difficult round window membrane exposure, thus causing difficult insertion. In all over cases we found no difficulty in identifying cochlea for implantation, whether malformed or normal due to wide access to cochlea through EAC. Moreover degrees of development of the mastoid and lateral skull base growth are no longer factors to be considered when endaural approach is used. This technique is totally safe for facial nerve as tunnel is made between posterior wall of EAC and tympanic segment of facial nerve at the midpoint between the level of incudo-stapedial (IS) joint and exit of Chordae tympani. Our study showed that the mean distance between posterior wall of EAC and tympanic segment of facial nerve is 4.41 mm in normal individuals, any distance above 2 mm is needed for safety of facial nerve. Above reading proves that in veria technique there are minimal chances for facial nerve injury. This goes with clinical correlation in our study as none of the cases done had any facial nerve injury.

Conclusions

The Veria technique for cochlear implantation is a non mastoidectomy technique using the endaural approach for the cochleostomy and transcanal wall approach for electrode insertion. It is simple and learning curve is fast. It is safe for facial nerve, as preoperatively distance between tympanic segment of facial nerve and posterior canal wall can be identified. It provide minimal trauma and therefore healing is fast and postoperative complications are reduced. It is suitable method for rotated cochlea (identified preoperatively through BTA) and deformed cochlea as it offers a wide visibility and accessibility as compared to posterior tympanotomy approach. BTA and distance between posterior canal wall of EAC and tympanic segment of facial nerve should be done in all cases to see any cochlear rotation and feasibility of surgery. BTA shows no deviations in terms of age, gender so could be used as a standard landmark. It is a suitable method for very small children where the mastoid has not been well developed.

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