Evaluation of facial nerve course, posterior tympanotomy width and visibility of round window in patients with cochlear implantation by performing oblique sagittal cut computed tomographic scan temporal bone

Mohamed S. Hasaballah, Tarek A. Hamdy

Department of Otorhinolaryngology, Ain Shams University, Cairo, Egypt

Correspondence to Tarek A. Hamdy, MD, 6 M, Square 1224, Elnoor Street, Sheraton Heliopolis, Cairo, Egypt
Tel: +20 122 242 1864;
e-mail: tarekhamdi@hotmail.com

Received 16 February 2014
Accepted 24 March 2014

The Egyptian Journal of Otolaryngology
2014, 30:317–321

Background
Posterior tympanotomy is a well-known otologic procedure that allows surgeons access to the middle ear cavity. During posterior tympanotomy the surgeon can approach the round window niche and promontory, where a cochleostomy is carried out for cochlear implant electrode array insertion. The mastoid segment of the facial nerve and the chorda tympani nerve could be injured in cases of narrow facial recess or inadequate posterior tympanotomy. With the image reconstruction in an oblique sagittal plane and curve reconstructions, the whole tympanic and mastoid segments of the facial nerve can be visualized in just one image. It is necessary to preoperatively estimate both the facial nerve status and the anatomical relationships between the facial recess and the round window, this may reduce the risk of facial nerve injury and influence the decision on which side to implant, which approach to use and whether to enter the cochlea via cochleostomy or round window membrane route.

Objectives
The aim of our study is to evaluate the facial nerve (course and anomalies), visibility of the round window membrane and the width of posterior tympanotomy before cochlear implantation by using oblique sagittal cuts CT scan temporal bone.

Methods
A prospective study; done on 18 consecutive patients with severe to profound sensorineural hearing loss who are candidates for cochlear implantation in Ain Shams University Hospitals during years 2011 & 2012. We focused on oblique sagittal cut CT scan & its role to evaluate the course of facial nerve, posterior tympanotomy width and visibility of the round window.

Results
We tried to make a statistical correlation between CT scan and intraoperative findings. Statistically significant positive correlation between posterior tympanotomy width and 2nd genu angle, distance from facial bony canal to round window and distance from facial nerve to round window. The mean distance from facial bony canal to round window was longer in operatively viewed round window than non-viewed window (4.7 and 4.4 mm respectively) ($P < 0.05$). The mean distance from facial nerve to round window was longer in operatively viewed round window membrane than non-viewed window (5.9 and 5.5 mm respectively) ($P < 0.05$). The mean width of posterior tympanotomy was wider in operatively viewed round window niche than non-viewed window niche (3.1 and 3.0 mm respectively) ($P < 0.01$).

Conclusion
Oblique sagittal cuts CT scan temporal bone is very helpful preoperative radiological tool for evaluation of the facial nerve course and anatomical factors that may determine the field of view or the accessibility of the posterior tympanotomy for either cochleostomy or round window membrane approach. Other approaches can be used with more safety when the position of the facial nerve prevents an adequate posterior tympanotomy.

Keywords:
cochlear implant, computed tomographic scan, facial nerve, oblique sagittal cut computed tomographic scan temporal bone, posterior tympanotomy

Egypt J Otolaryngol 30:317–321
© 2014 The Egyptian Oto - Rhino - Laryngological Society
1012-5574

Introduction

Posterior tympanotomy is a well-known otologic procedure that allows surgeons access to the middle ear cavity. This technique was first described by Jansen in 1958 and is achieved by opening of the facial recess, which is a triangular space defined medially by the mastoid segment of the facial nerve, laterally by the chorda tympani nerve and superiorly by the incudal fossa [1].

During posterior tympanotomy the surgeon can approach the round window niche and promontory, where a cochleostomy is carried out for cochlear implant electrode array insertion [2].

Two sides of this triangle could not be seen from the posterior aspect, and this is a problem during bone drilling. The mastoid segment of the facial nerve and the chorda tympani nerve could be injured in cases of narrow facial recess or inadequate posterior tympanotomy [3]. This complication generally occurs because of a limited understanding of the anatomy of the facial recess and different mastoid segment anomalies [4]; therefore, radiological evaluation of the anatomy, anomalies of the facial nerve course, and anatomical factors that may determine the field of view or the accessibility of the posterior tympanotomy are very important to minimize the risk for nerve injury.

Facial nerve palsy was reported as a complication of cochlear implant surgery at a rate of 1–3%. The knowledge of the anatomical relationship of the facial nerve with various adjacent landmarks in the surgical field may help to avoid this complication [5].

The round window is the most important surgical landmark during electrode insertion either through the round window membrane or even in cochleostomy. Visibility of the round window membrane was graded according to the St Thomas' Hospital classification after an 'optimal' posterior tympanotomy had been performed, and any overhang of the bony round window niche was removed without breaching the round window membrane. In type I, full exposure of the round window membrane is achieved; in type IIa, more than 50% of round window membrane is achieved, whereas in type IIb, less than 50% of the round window membrane is achieved. In type III St Thomas' Hospital classification, the round window membrane lies more posteriorly, and therefore closer to the facial nerve, making it much more challenging to perform a round window approach and most patients will need a conventional bony cochleostomy [6].

With image reconstruction in an oblique sagittal plane and curve reconstructions, the whole tympanic and mastoid segments of the facial nerve can be visualized in just one image. The use of this reconstruction plane can help in the diagnosis of the nerve anomalies and study the relationships of the facial nerve with the surrounding landmarks [7].

The purpose of this study was to visualize the temporal bone structures affecting the posterior tympanotomy using the oblique sagittal view computed tomography (CT) of the temporal bone before performing cochlear implant to assess the width of the facial recess. It is helpful to preoperatively estimate both the facial nerve status and the anatomical relationships between the facial recess and the round window; this may influence the decision on which side to implant and which approach to use and whether to enter the cochlea by cochleostomy or round window membrane route. Other approaches (transcanal or transattic) can be used with more safety when the position of the facial nerve prevents an adequate posterior tympanotomy, as there is no need to open the posterior tympanotomy in these approaches.

Patients and methods

This was a prospective study that included 18 consecutive patients with severe-to-profound sensorineural hearing loss who were candidates for cochlear implantation in Ain Shams University Hospitals during 2011 and 2012. Institutional Review Board approval and patients consent were obtained.

There were 11 male patients and seven female patients. Two of them were adult and 16 were children with a mean age of 8 years (range 3–26 years).

All patients were evaluated preoperatively using pure tone audiometry, auditory brain stem response, otoacoustic emissions, IQ level and multidetector computed tomography, and MRI temporal bone.

The anatomy and pathology of the temporal bone involve small structures; hence, resolution is thus highly important. Collimation is of optimal importance to achieve this high resolution. We routinely used a collimator of 0.6 mm.

The machine used was multidetector computed tomography on Aquilion 64 detector (Aquilion 64, Toshiba Medical Systems Corporation, Otowara, Japan).

CT protocol for temporal bones/internal auditory meatus (IAMs):

Scout	Lateral (90°)
Start	Below mastoids
End	Clear petrous bones
Rotation time	1.5 s
Raw slice thickness	16 × 0.5 mm
Reconstructed slice thickness	0.5/0.3 mm
Window width/window level	4500/500
Multiplanar reconstructions	Axial 1–2 mm thick, coronal 1–2 mm thick

The 0.6 mm raw data were brought up on the console viewer in three orthogonal planes: axial, coronal, and sagittal. The technologist scrolled through the sagittal plane until the view of lateral semicircular canal was obtained represented by the two dots of the anterior and posterior limbs; the axial plane was established by connecting the two dots.

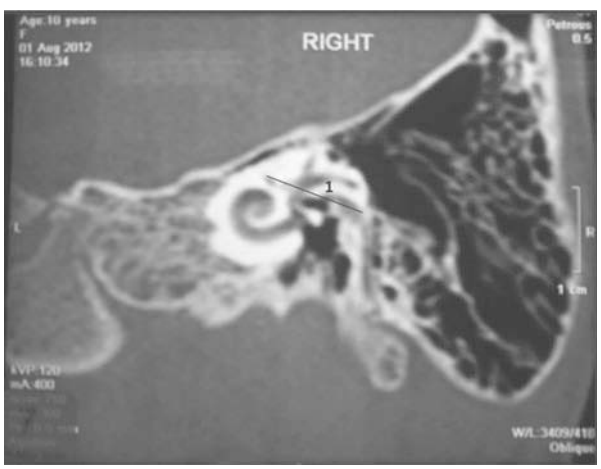
The technologist scrolled through the axial data set until an image of the summit of the superior semicircular canal was viewed. The Stenvers reformats are then made by tracing

a line perpendicular to the long axis of the summit of the superior semicircular canal at 0.6 × 0.5 mm intervals.

We focused on oblique sagittal cut CT scan and its role to evaluate the course of facial nerve, posterior tympanotomy width, and visibility of round window; the following measures were taken (Figs. 1–4):

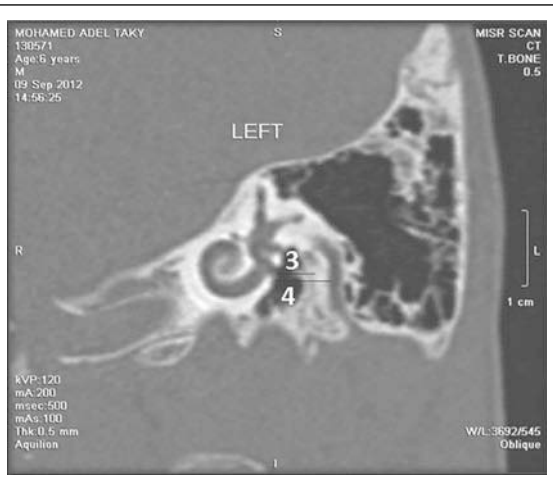
(1) Length of tympanic segment of the facial nerve in millimeters.
(2) Second genu angle in degree.
(3) Distance between the bony facial nerve canal and round window in millimeters.
(4) Distance between facial nerve itself and round window in millimeters.
(5) Width of bony facial nerve in millimeters.

Figure 1



Oblique sagittal view of the facial nerve canal shows the length of the tympanic facial nerve labeled as 1.

Figure 3



Oblique sagittal view of the facial nerve canal shows the distance between bony facial nerve canal and round window membrane labeled as 3 and the distance between facial nerve itself and round window labeled as 4.

Intraoperatively, two variants were measured and observed:

(1) Width of the posterior tympanotomy in its maximal diameter.
(2) Visibility of the round window niche.

We tried to make a statistical correlation between CT scan and intraoperative findings.

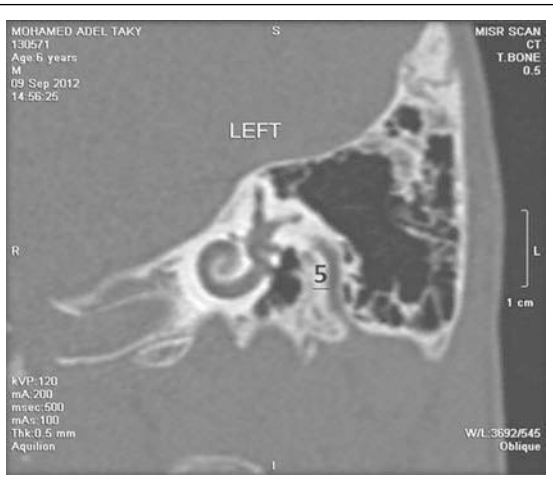
Results

A statistical correlation between CT scan and intraoperative findings was performed. Statistically significant positive correlation was observed between posterior tympanotomy width and second genu angle, distance from facial bony canal to round window membrane, and distance from

Figure 2

Oblique sagittal view of the facial nerve canal shows the second genu angle labeled as 2.

Figure 4



Oblique sagittal view of the facial nerve canal shows the width of the bony facial nerve canal labeled as 5.

facial nerve to round window membrane. The mean distance from facial bony canal to round window was longer in operatively viewed round window niche than in nonviewed window niche (4.7 and 4.4 mm, respectively) ($P < 0.05$). The mean distance from facial nerve to round window was longer in operatively viewed round window niche than in nonviewed window niche (5.9 and 5.5 mm, respectively) ($P < 0.05$). The mean width of posterior tympanotomy was wider in operatively viewed round window niche than in nonviewed window niche (3.1 and 3.0 mm, respectively) ($P < 0.01$) (Tables 1–3).

Least angle associated with operatively viewed round window niche was 92° (Table 4).

Discussion

CT scan with oblique sagittal view of the temporal bone can be of great value in predicting possible difficulties in cochlear implantation and posterior tympanotomy.

Table 1 Basic radiological findings of studied cases

	Mean	±SD	Min.	Max.
Tympanic segment length (mm)	10.8	1.0	9.0	12.3
2nd genu angle (in degree)	105.8	13.2	90.0	130.0
Mastoid part of facial bony canal width (mm)	3.1	0.4	2.1	3.7
Distance from facial bony canal to round window (mm)	4.4	0.8	2.3	5.2
Distance from facial nerve to round window (mm)	5.5	0.8	4.0	6.5
Posterior tympanotomy width (mm)	3.0	0.2	2.4	3.3

This table summarizes the basic radiological findings of studied cases. The Mean (SD) of tympanic segments length was 10.8 (1.0) mm, 2nd genu angle was 105.8 (13.2) degrees, Mastoid part of facial bony canal width was 3.1 (0.4), distance from facial bony canal to round window membrane was 4.4 (0.8), distance from facial nerve to round window membrane was 5.5 (0.8) and posterior tympanotomy width was 3.0 (0.2)

Table 2 Correlation between different radiological measurements and posterior tympanotomy width

Radiological Measurements	Posterior tympanotomy width (mm)	
	Pearson Correlation (r)	*P* value
Tympanic segment length (mm)	0.272	0.137
2nd genu angle (in degree)	0.422	0.041*
Mastoid part of facial bony canal width (mm)	-0.224	0.186
Distance from facial bony canal to round window (mm)	0.44	0.034*
Distance from facial nerve to round window (mm)	0.442	0.033*

*indicates a statistically significant linear correlation; This table shows a statistically significant positive correlation between posterior tympanotomy width and 2nd genu angle, distance from facial bony canal to round window membrane and distance from facial nerve to round window membrane

We concluded that the two factors determining the posterior tympanotomy width and the visibility of the round window niche intraoperatively were as follows:

(1) *The second genu angle*: When it increases this means that the vertical (mastoid) part of the facial nerve is displaced posteriorly in the mastoid away from the chorda tympani and round window, and usually the round window is visible. It was also noticed that, when the second genu angle increases, there is a wider distance between chorda tympani nerve and facial nerve; this means a wide posterior tympanotomy.
(2) *The distance between the facial nerve (bone and trunk) and round window membrane*: When this distance increases, this means also that the facial nerve is displaced backwards in the mastoid away from the

Table 3 Comparison of different radiological measurements in relation to operative view of the round window niche

Radiological Measurements	Operative view of the round window				*t*	*P* value
	Not viewed (*n* = 7)		View (*n* = 11)			
	Mean	±SD	Mean	±SD		
Tympanic segment length (mm)	10.8	1.0	10.9	0.8	0.620	0.544
2nd genu angle (in degree)	105.8	13.2	110.5	11.9	2.030	0.049*
Mastoid part of facial bony canal width (mm)	3.1	0.4	3.1	0.4	0.725	0.479
Distance from facial bony canal to round window (mm)	4.4	0.8	4.7	0.4	2.649	0.018*
Distance from facial nerve to round window (mm)	5.5	0.8	5.9	0.7	2.768	0.014*
Posterior tympanotomy width (mm)	3.0	0.2	3.1	0.1	5.248	0.000*

*indicates a statistically significant difference between groups; This table illustrates the differences in radiological measurements in relation to the operative view of round window niche. The mean distance from facial bony canal to round window membrane was longer in operatively viewed round window niche than non-viewed window niche (4.7 and 4.4 mm respectively) ($P < 0.05$). The mean distance from facial nerve to round window membrane was longer in operatively viewed round window niche than non-viewed window niche (5.9 and 5.5 mm respectively) ($P < 0.05$). The mean width of posterior tympanotomy was wider in operatively viewed round window niche than non-viewed window niche (3.1 and 3.0 mm respectively) ($P < 0.01$)

Table 4 The least angle associated with operatively viewed round window niche

		Operative view of the round window		X^2/ Exact Fisher	*P* value
		Not viewed (*n* = 7)	Viewed (*n* = 11)		
Angle degree	Angle degree <92	3 (42.9%)	0	5.657	0.017
	Angle degree ≥92	4 (57.1%)	11 (100%)		

This table shows that angle less than 92 degree is usually not associated with a visible round window niche

round window membrane and chorda tympani leaving a wider posterior tympanotomy and more visible round window niche intraoperatively.

We suspect that the length of the horizontal part (tympanic) of facial nerve can affect the width of posterior tympanotomy, but we observed that this length has no relationship with the posterior tympanotomy. This may be explained by the following:

(1) Fewer number of patients.
(2) The second genu angle is more critical in determining the position of mastoid part of the facial nerve whether anteriorly or posteriorly displaced.

We cannot accurately detect either the anatomical relationship or the true distance between the facial nerve and round window membrane in this sagittal view to expect if the round window niche will be visible intraoperatively or not. We recommend that performing CT scan axial view of the temporal bone is essential, as it is more informative about the visibility of the round window membrane (Fig. 5).

Conclusion

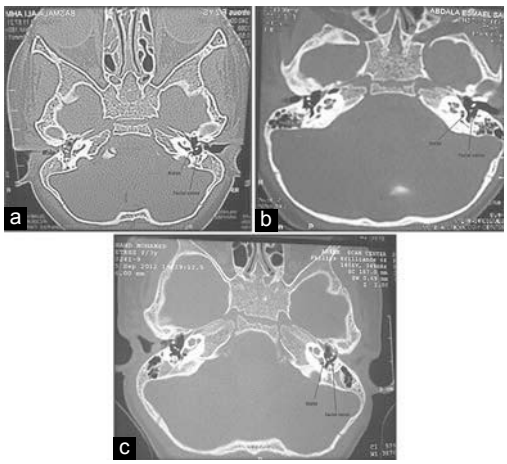
Oblique cut sagittal CT scanning of the temporal bone can be a very helpful preoperative radiological tool for the evaluation of the facial nerve course and anatomical factors that may determine the field of view or the accessibility of the posterior tympanotomy for either cochleostomy or round window membrane approach. Other approaches can be used with more safety when the position of the facial nerve prevents an adequate posterior tympanotomy.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

Figure 5



Computed tomographic scan axial view of the temporal bone showing the actual distance and anatomical relationship between the facial nerve and the round window membrane; here, we can judge the operative view of the round window membrane. (a) The facial nerve is not obscuring the surgical view of the round window membrane. (b) The facial nerve is partially obscuring the surgical view of the round window membrane. (c) The facial nerve is totally obscuring the surgical view of the round window membrane.

References

1 Kim CW, Oh SJ, Kim HS, Ha SH, Rho YS. Analysis of axial temporal bone computed tomography scans for performing a safe posterior tympanotomy. Eur Arch Otorhinolaryngol 2008; 265:887–891.

2 Hamamoto M, Murakami G, Kataura A. Topographical relationships among the facial nerve, chorda tympani nerve and round window with special reference to the approach route for cochlear implant surgery. Clin Anat 2000; 13:251–256.

3 Jeon EJ, Jun B, Song JN, Kim JE, Lee DH, Chang KH. Surgical and radiologic anatomy of a cochleostomy produced via posterior tympanotomy for cochlear implantation based on three-dimensional reconstructed temporal bone CT images. Surg Radiol Anat 2013; 35:471–475.

4 Calli C, Pinar E, Oncel S, Tatar B, Tuncbilek MA. Measurements of the facial recess anatomy: implications for sparing the facial nerve and chorda tympani during posterior tympanotomy. Ear Nose Throat J 2010; 89:490–494.

5 Kronenberg J, Fuchs C, Bendet E. Preoperative radiologic assessment of facial nerve in cochlear implant surgery. Eur Arch Otorhinolaryngol 1994; Suppl:353–355.

6 Leong AC, Jiang D, Agger A, Fitzgerald-O'Connor A. Evaluation of round window accessibility to cochlear implant insertion. Eur Arch Otorhinolaryngol 2013; 270:1237–1242.

7 Chuang MT, Chiang IC, Liu GC, Lin WC. Multi-detector row CT demonstration of inner and middle ear structures. Clin Anat 2006; 19:337–344.