Websites:
http://www.sciencepub.net/nature
http://www.sciencepub.net

Emails:
naturesciencej@gmail.com
editor@sciencepub.net

Nature and Science

MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

# The Possible Role of High Resolution Computed Tomography Imaging (HRCT) in Predicting the Visibility and Position of the Round Window in Cochlear Implantation Surgery

Samer Ahmed Ibrahim [1], Tamer Shoukry Sobhy[2], Togan Wafi Taha[3], Ihab Mohamed Nada [4], Nada Zakaria Zakaria El Sayad El Ablak[5]

[1] Professor of Otorhinolaryngology, Faculty of Medicine, Ain Shams University
[2] Professor of Otorhinolaryngology, Faculty of Medicine, Ain Shams University
[3] Assistant Professor of Diagnostic Radiology, Faculty of Medicine, Ain Shams University
[4] Assistant Professor of Otorhinolaryngology, Faculty of Medicine, Misr University for Science and Technology
[5] M.B.B.C.h, Ain Shams University
Nadazakaria68@yahoo.com

**Abstract: Background:** High-resolution computed tomography (HRCT) magnifies the role of preoperative imaging for detailed inner and middle ear anatomical information. Imaging is essential in the preoperative evaluation of sensorineural hearing loss (SNHL) patients who are candidates for CI. Surgeons need to be alert regarding the anomalies and pathologies that may represent a potential surgical hazard or that may that may require modification of the surgical approach. **Objectives:** To study the possibility of preoperative assessment of round window in relation to the facial recess in order to anticipate the type of round window exposure before surgery by using High-resolution computed tomography (HRCT) scan. **Patients and Methods:** This study included 50 children, aged 3 to 5 years who underwent unilateral cochlear implant with round window electrode insertion and had pre-operative high-resolution temporal bone CT scan. Pre-operative high-resolution temporal bone CT scan contained high-resolution images that are 0.625 mm thick, inter slice gap is 1 mm was done. Two parameters were measured $\alpha$ value (the angle between the line connecting the leading edge of the facial nerve to the midpoint of the round window and the median sagittal line) and d value (the vertical distance between the leading edge of the vertical section of the facial nerve and the posterior wall of the external auditory canal) by using pre-operative high-resolution temporal bone CT scan that was used to predict round window exposure according to ST Thomas classification. A correlation was done between the intraoperative degree of round window membrane exposure and the measured values. **Results:** In the present study; regarding prediction of difficult round window exposure using distance d and angle α parameters for all the cases, results were analyzed by Receiver-operating characteristic (ROC) curve test. Best cutoff point of angle α is an angle α of ≤56 while best cutoff point for distance d is a distance of ≥5.2 mm. According to the recorded intraoperative round window membrane exposure conditions, the round window membrane was completely exposed in 28out of 50 cases (class I), which accounted for the majority (56%). In 19 cases, the round window membrane was partially exposed (class IIa and IIb) (16%, 22%). Only 3 cases (6%) had unexposed round window membranes (class III). The α value was significant in predicating exposure of round window. While the d value was not significant in predicating exposure of round window. **Conclusion:** The angle (α value) between the line connecting the leading edge of the facial nerve to the midpoint of the round window and the median sagittal line measured in preoperative CT scans can help in determining the extent of visibility of the round window seen during posterior tympanotomy round window insertion approach While d value of the vertical distance between the leading edge of the vertical section of the facial nerve and the posterior wall of the external auditory canal was not significant in predicating exposure of round window.

[Samer Ahmed Ibrahim, Tamer Shoukry Sobhy, Togan Wafi Taha, Ihab Mohamed Nada, Nada Zakaria Zakaria El Sayad El Ablak. **The Possible Role of High Resolution Computed Tomography Imaging (HRCT) in Predicting the Visibility and Position of the Round Window in Cochlear Implantation Surgery.** *Nat Sci* 2020;18(1):54-61]. ISSN 1545-0740 (print); ISSN 2375-7167 (online). http://www.sciencepub.net/nature. 9. doi:10.7537/marsnsj180120.09.

**Keywords:** High Resolution Computed Tomography Imaging, Round Window, Cochlear Implantation Surgery

## 1. Introduction

The posterior tympanotomy approach is the main technique for cochlear implantation [(1)]. Successful cochlear implantation by this approach depends on conclusive identification of the round window niche (RWN), which may be difficult in patients with limited RWN visibility. Facial nerve canal in the facial recess may be obscuring the round window [(2)].

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 some patients may need a conventional bony cochleostomy [3].

The round window is usually partially hidden by the bony round window niche and this familiar landmark must be identified before the bony niche can be drilled away to fully expose the round window membrane. Once the round window membrane is fully exposed, then it can be opened to enter the perilymphatic space of the scala tympani before the electrode can be carefully and slowly inserted [4].

## 2. Patients and Methods

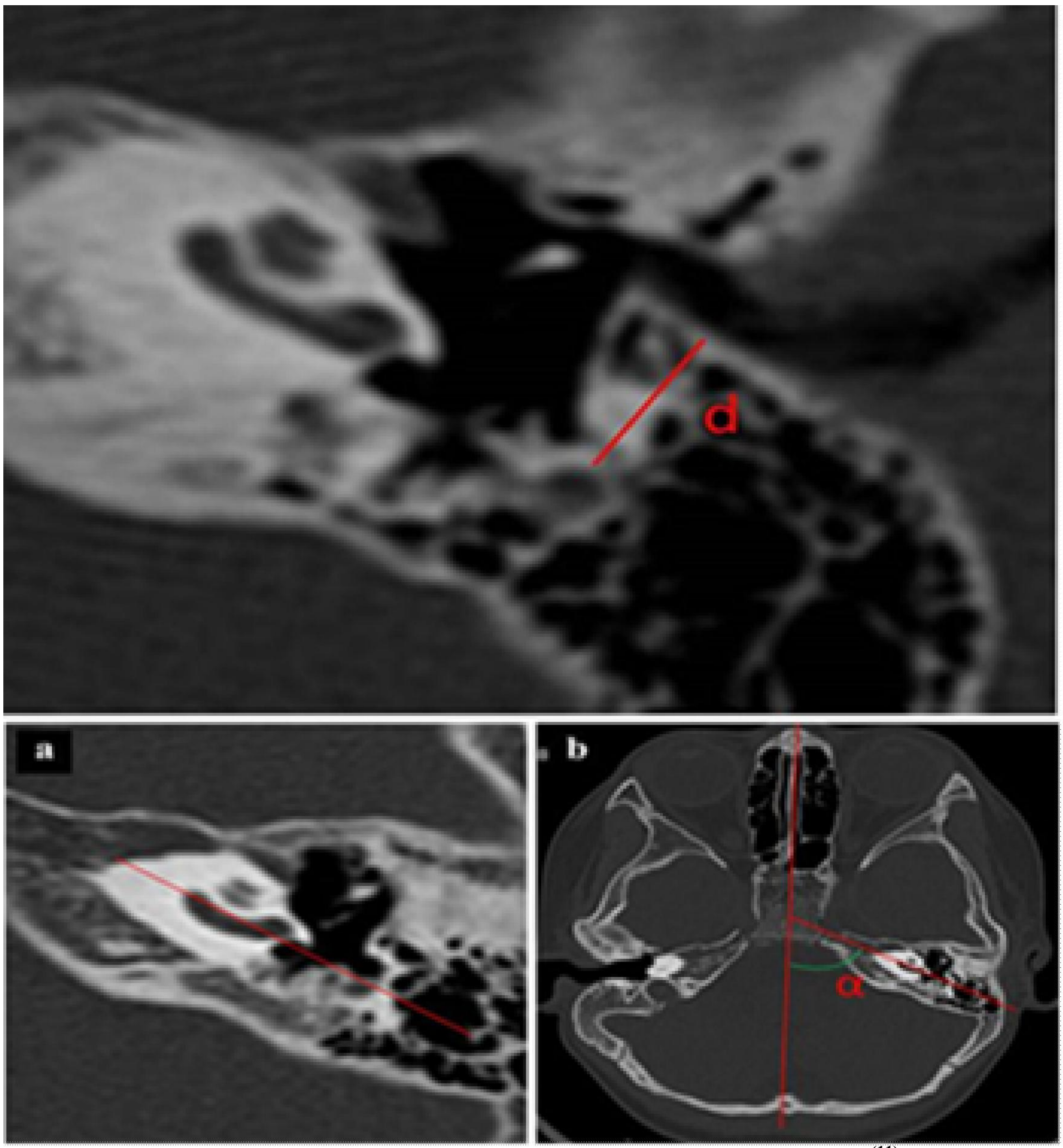


**Figure 1:** Shows the vertical distance d (line a). The angle α (line b). [11]

In this work the possibility of preoperative assessment of round window visibility in relation to the facial recess this was done in order to anticipate the type of round window exposure before surgery by using High-resolution computed tomography (HRCT) scan, was studied.

A total of 50 consecutive patients fulfilling the inclusion criteria were included in the present study. Clinical details including history, physical examination, speech and language, psychological evaluation were collected. Audiological evaluation was done including otoacoustic emissions, auditory brainstem responses, speech discrimination tests and tympanometery.

**Study tools and procedure**

Pre-operative temporal bone CT scans were analyzed by the primary author, who was blinded to the intraoperative scoring of surgical difficulties. The CT scan contained high-resolution images that are 0.625 mm thick, inter slice gap is 1 mm. 120 kV and 200 mA with a matrix size of 512 is used. With reconstructing coronal and sagittal images. The images were viewed in the standard bone window setting.

The patient was placed in a supine position. Axial scanning was performed from the mastoid to the leading edge of the petrous bone. The vertical distance between the leading edge of the vertical section of the facial nerve and the posterior wall of the external auditory canal (*d* value) is measured on the round window membrane plane of the preoperative temporal bone CT images. The *α* value of the angle between two lines [the line from the leading edge of the facial nerve on the plane to the midpoint of the round window membrane and the line from the nasal septum or the perpendicular plate of the ethmoid bone to the occipital protuberance (the median sagittal line) was measured. The two measures were taken in axial cut at the level of round window.

A correlation was done between the intraoperative degree of round window membrane exposure and the measured values. The visibility of round window niche based on surgical view (i.e. through posterior tympanotomy) during surgery was graded according to ST Thomas Hospital classification.

**Statistical analysis**

The collected data was revised, coded, tabulated and introduced to a PC using IBM© SPSS© Statistics version 23 (IBM© Corp., Armonk, NY) and JMP® version 13.2.1 (SAS© Institute Inc., Cary, NC). Mann Whitney Test (U test) was used to assess the statistical significance of the difference of a non-parametric variable between two study groups where P value less than 0.05 was considered statistically significant. Box plot test was used to illustrating the distribution of distance d and α angle in the study population. Receiver-operating characteristic (ROC) curve test was used to examine the value of distance (d) or angle (α) for prediction of difficult exposure of the round window. P-values <0.05 were considered statistically significant.

## 3. Results

This study included 50 children; their ages ranged from 3 to 5 years, with a mean of 4±1 years. That underwent unilateral cochlear implant with posterior tympanotomy round window approach. The population' demographic characteristics are shown in **Table 1.**

**Table (1):** Demographic characteristics of the study participants.

| Variable | Mean ± SD (range) / Number (%) |
|---|---|
| Age (years) | 4 ± 1 (3 to 6) |
| Gender | |
| *M* | 23 (46.0%) |
| *F* | 27 (54.0%) |
| Distance d (mm) | 6 ± 1 (5 to 8) |
| Angle α (mm) | 55 ± 10 (0 to 70) |
| Thompson classification | |
| *Class I* | 28 (56.0%) |
| *Class IIa* | 8 (16.0%) |
| *Class IIb* | 11 (22.0%) |
| *Class III* | 3 (6.0%) |
| Round window exposure | |
| *Easy* | 36 (72.0%) |
| *Difficult* | 14 (28.0%) |

Two parameters were measured α and d values by using pre-operative high-resolution temporal bone CT scan. Regarding prediction of difficult round window exposure using distance d and angle α parameters for all the cases, results were analyzed by

Receiver-operating characteristic (ROC) curve test as follows:

A) Best cutoff in d value is a distance of ≥5.2 mm (sensitivity = 79%, specificity = 36%). Area under the ROC curve = 0.526 (95% CI = 0.380 to 0.669, P-value = 0.774). Distance d proved to have poor predictive value. As shown in figure1.

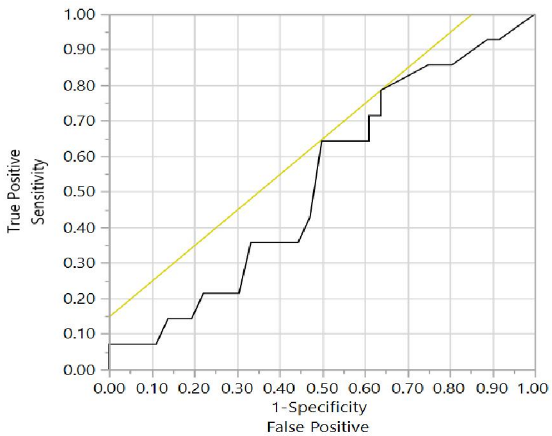


**Figure 2.** Receiver-operating characteristic (ROC) curve analysis for prediction of difficult round window exposure using distance d.

B) Best cutoff in α value is an angle α of ≤56° (sensitivity = 71%, specificity = 53%). Area under the ROC curve = 0.555 (95% CI = 0.407 to 0.695, P-value = 0.055). Angle α proved to have good predictive value. As shown in Figure2.

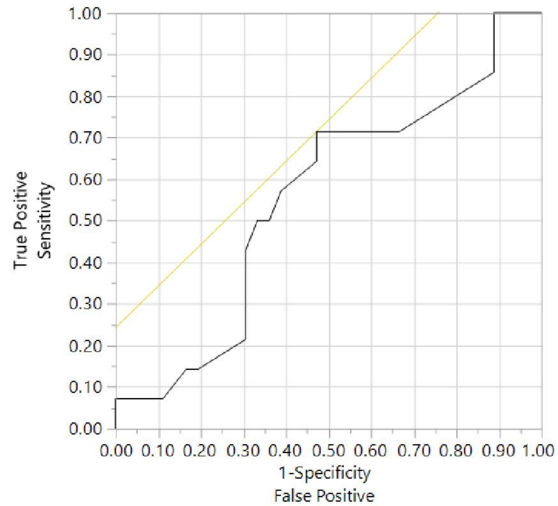


**Figure 3**. Receiver-operating characteristic (ROC) curve analysis for prediction of difficult round window exposure using angle α.

**Intraoperative round window membrane exposure conditions for all cases:**

According to the recorded intraoperative round window membrane exposure conditions, the round window membrane was completely exposed in 28out of 50 cases (class I), which accounted for the majority (56%). In 19 cases, the round window membrane was partially exposed (class IIa and IIb) (16%, 22%). Only 3 cases (6%) had unexposed round window membranes (class III) as shown in Figure5.

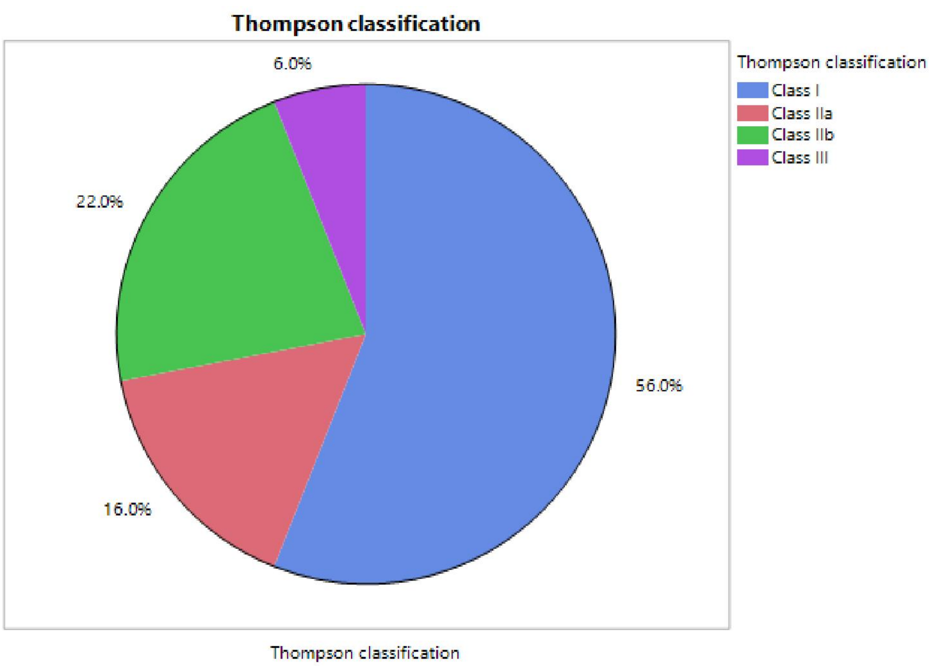


**Figure 4.** Pie chart illustrating the Thompson classification for round window exposure among our patients.

In our study, two comparison were done, a comparison of distance d and angle α in patients with Thomas classification type I/IIa/IIb and Thomas classification III. And another comparison of distance d and angle α in patients with Thomas classification type I and Thomas classification IIa/IIb.

**A)** Comparison of distance d and angle α in patients with Thompson class I/IIa/IIb (group A) and Thompson class III (Group B) as shown in (Table 2): **The angles** of the two groups were measured and statistically analyzed. Among the 50 cases, the angle of the complete to partial round window membrane exposure group (group A) was 54.9 ± 9.8, and the angle of the unexposed round window membrane group (group B) was 53.7 ± 2.1. Best cutoff is an angle α of ≤56° (sensitivity = 100%, specificity = 49%). Angle α proved to have good predictive value. As shown in (Table 2 & Figure6)

**Table 2. Comparison of distance d and angle α in patients with Thompson class I/IIa/IIb and Thompson class III**

| Variable | Thompson class I/IIa/IIb (n=47) | Thompson class III (n=3) | Difference | 95% CI | P-value* |
|---|---|---|---|---|---|
| Distance d (mm) | 5.7 ± 0.9 | 5.8 ± 0.7 | 0.1 | -1.0 to 1.2 | 0.895 |
| Angle α (mm) | 54.9 ± 9.8 | 53.7 ± 2.1 | -1.2 | -12.8 to 10.3 | 0.053 |

Data are mean ± SD. 95% CI = 95% confidence interval. *Unpaired t-test.

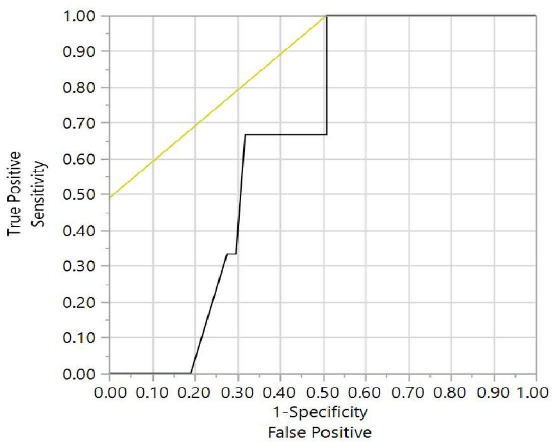


**Figure 5.** Receiver-operating characteristic (ROC) curve analysis for prediction of Thompson class III using angle α.

**The distances** of the two groups were measured and statistically analyzed. The distances are presented as the mean ± standard deviation. Among the 50 cases, the distance of the complete to partial round window membrane exposure group (Group A) was 5.7 ± 0.9, and the distance of the unexposed round window membrane group (group B) was 5.8 ± 0.7. Best cutoff is a Distance d of ≥5.2 mm (sensitivity = 100%, specificity = 34%). Distance d proved to have poor predictive value between group A (completely and partially exposed) and group B (unexposed pound window). As shown in (Figure7).

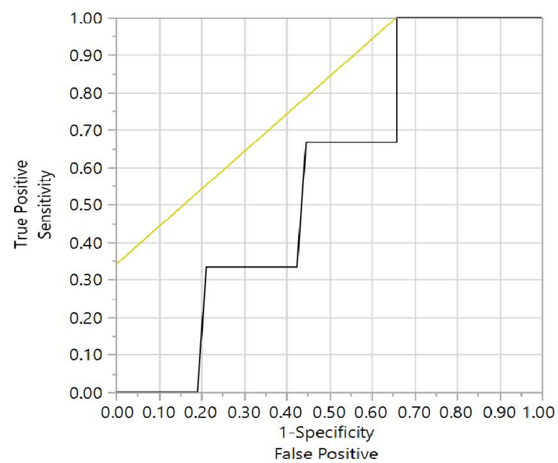


**Figure 6.** Receiver-operating characteristic (ROC) curve for prediction of Thompson class III using distance d.

**Table 3. Comparison of distance d and angle α in patients with Thompson class I and Thompson class IIa/IIb**

| Variable | Thompson class I (n=28) | Thompson class IIa/IIb (n=19) | Difference | 95% CI | P-value* |
|---|---|---|---|---|---|
| Distance d (mm) | 5.7 ± 0.8 | 5.7 ± 1.1 | 0.0 | -0.5 to 0.6 | 0.931 |
| Angle α (mm) | 56.0 ± 6.3 | 53.3 ± 13.6 | -2.7 | -8.6 to 3.2 | 0.035 |

Data are mean ± SD. 95% CI = 95% confidence interval. *Unpaired t-test.

**B)** Comparison of distance d and angle α in patients with Thompson class I and Thompson class IIa/IIb as shown in (Table 3): **The angles** of the two groups were measured and statistically analyzed. The angles are presented as the mean ± standard deviation. Among the 50 cases, the angle of the complete round window membrane exposure group ST Thomas classification I (group A) was 56.0 ± 6.3, and the angle of the partial round window membrane group ST Thomas classification IIa /IIb (group B) was 53.3 ± 13.6. Best cutoff is an angle α of ≤57° (sensitivity = 63%, specificity = 50%). Angle α proved to have good predictive value to full (group A) and partial round window exposure (group B). As shown in (Table 3 & Figure8).

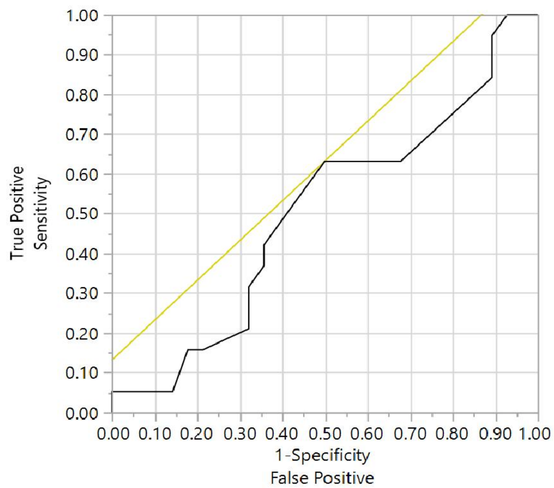


**Figure 7.** Receiver-operating characteristic (ROC) curve for discrimination between patients with Thompson class IIa/IIb and Thompson class I using angle α.

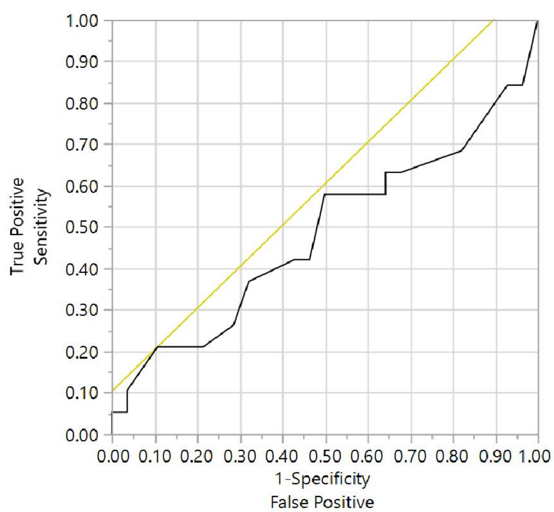


**Figure 8.** Receiver-operating characteristic (ROC) curve for discrimination between patients with Thompson class IIa/IIb and Thompson class I using distanced.

**The distances** of the two groups were measured and statistically analyzed. The distances are presented as the mean ± standard deviation. Among the 50 cases, the distance of the complete round window membrane exposure group ST Thomas classification I (group A) was 5.7 ± 0.8, and the distance of the partial round window membrane group ST Thomas classification IIa /IIb (group B) was 5.7 ± 1.1. Best cutoff is a distance d of ≤6.8 mm (sensitivity = 21%, specificity = 89%). Distance d proved to have poor predictive value. As shown in (Figure 9).

## 4. Discussion

In the present study, an attempt has been made to determine if there are potential predictors of difficulties associated with the key surgical steps during cochlear implantation based on an analysis of the pre-operative temporal bone CT scan. These well-established an important step include round window exposure.

The study showed that the *α* value (the angle between the line connecting the leading edge of the facial nerve to the midpoint of the round window and the line from the nasal septum or the perpendicular plate of the ethmoid bone to the occipital protuberance (the median sagittal line)) measured in the preoperative CT scans can predict intra operatively the exposure of the round window membrane. This concurs with ***Lee et al.*** [(5)] found that angle between the cortex of the EAC and the FN, and FN location relative to the basal turn are correlated with maximum visibility of the stapes area in the posterior tympanotomy approach. However, they did not study actual RWN visibility through the facial recess but focused on a location anterior to the RWN.

***Bettman et al.*** [(6)] reported in their study that preoperative CT measurements, such as facial recess width and the angle between facial recess and basal turn of the cochlear, were not useful in predicting the visibility of round window.

The results in this study are consistent with other studies that can utilize radiology to predict Rw visibility such as ***Kashio et al.*** [(7)] noted that RWN visibility is highly correlated with the EAC angle and the FN location but not with the facial recess width. Also, noted that intraoperative RWN visibility is poorer and the EAC angle is significantly smaller in children than in adults.

***McRackan et al.*** [(8)] suggested that the change in the angle between the FR and the basal turn is related to age and the EAC angle is significantly wider in adults.

***Fouad et al.*** [(9)] explained that a line (prediction line) was drawn parallel to the EAC line along the anterolateral part of the FN prescribed by ***Kashio et al.*** [(7)] was not significantly correlated with the RW visibility. Due to the difference between results may be due to the difficulty of drawing the EAC line in children due to the incomplete development of the EAC before 6 years old making any measurement based on EAC line seems inaccurate in children.

In the present study, we also measured the *d* value which is the distance between the vertical segment of the facial nerve and the posterior wall of the external auditory canal which was not significant in predicating exposure of round window as P-values <0.05.

This contradicts ***Pendem et al.*** **[10]** who stated that the location of the vertical section of the facial nerve, the chorda tympani nerve, and the angle of the facial nerve and chorda tympani nerve are Factors affecting the size of the facial recess.

Also ***Park et al.*** **[4]** agreed with ***Pendem et al.*** **[10]** in that the exposure of the round window niche and round window membrane are associated the location of the vertical section of the facial nerve, for example, if the location of the vertical segment of the facial nerve is shallow, the facial recess shows a "deep well" shape, and the round window niche becomes difficult to access; this also affects the exposure of the round window membrane and may cause failure of electrode insertion or lead to facial paralysis.

On the other hand ***Lee et al.*** **[5]** agreed with our study in that the line connecting the leading edge of the facial nerve and the midpoint of the round window membrane can more intuitively determine the difficulty of exposure of the round window membrane through the facial recess approach.

Also, ***Pendem et al.*** **[10]** have reported that the distance between the short process of incus and RWN and also the distance between oval window and RWN have positive correlation with RWN visibility.

***Park et al.*** **[4]** have assessed RWN bony overhang radiologically by assessing four consecutive axial cuts of the preoperative CT scan. However, they did not find a significant correlation with RWN visibility; a thicker RWN bony overhang was not associated with greater difficulty in accessing round window. Similarly**,** ***Kashio et al.*** **[7]** have applied a prediction method without radiologic measurements; the RWM was traced in the antero-posterior direction, and a line "prediction line" was drawn parallel to the EAC line along the anterolateral part of the FN. The intersection of prediction line with RWM tracing line was classified as anterior, middle or posterior. They found strong correlation between anterior intersection and invisible RWM. However, RWM tracing line with subsequent divisions into anterior, middle and posterior sections may be relatively difficult to apply and may be also subjected to interobserver variability.

In our opinion, the failure of the d distance to predict the visibility of the round window is explained by its ability to detect only the facial recess width. The facial recess width doesn't necessarily concise with round window visibility.

On the other hand, the α angle, which showed significant predictive value for round window visibility, can detect the degree of rotation of the cochlea and / or the anterior location of the facial nerve which concise more with round window visibility in our opinion.

Cochlear implant surgery remains a challenging surgery. The round window exposure is a critical step in success of this surgery. Preoperative radiological predication of RW visibility helps the surgeon to anticipate the degree of difficulty in cochlear implant.

**Conclusion**

From this study, we conclude that the *α* value of the angle between two lines [the line from the leading edge of the facial nerve on the plane to the midpoint of the round window membrane and the line from the nasal septum or the perpendicular plate of the ethmoid bone to the occipital protuberance (the median sagittal line) can help in determining the extent of visibility of the round window seen during posterior tympanotomy round window insertion approach when the *α* value is less than55degree, correlates to easier round window visibility 78% efficacy, however if the angle greater than 55 degree this correlate to difficult round window visibility 45% efficacy. In such cases, the surgeon should fully expose the round window membrane, which could decrease the risk of complications.

While d value of the vertical distance between the leading edge of the vertical section of the facial nerve and the posterior wall of the external auditory canal was not significant in predicating exposure of round window.

**References**

1. Clark GM (2003): Surgical anatomy: Cochlear implants: Fundamentals and applications. Springer-Verlag New York; 2: 58-100.
2. Goycoolea MV, Exploratory tympanotomy. In: Goycoolea M, Paparella MM, Nissen R, eds: (1989): Atlas of otologic surgery. Philadelphia, PA: W. B. Saunders Co.
3. Leong AC, Dan Jiang D, Agger A, O'Connor AF (2013): Evaluation of round window accessibility to cochlear implant insertion. Eur Arch Otorhinolaryngology; 270:1237–42.
4. Park E, Amoodi H, Kuthubutheen J, Chen JM, Nedzelski JM, Lin VY (2015): Predictors of round window accessibility for adult cochlear implantation based on pre-operative CT scan: a prospective observational study. J Otolaryngol Head Neck Surg; 44(1):20.

5. Lee DH, Kim JK, Seo JH, Lee BJ (2012): Anatomic limitations of posterior tympanotomy: What is the major radiologic determinant for the view field through posterior tympanotomy? J Craniofac Surg; 23: 817Y20.
6. Bettman RH, Appelman AM, van Olphen AF, Zonneveld FW, Huizing EH (2003): Cochlear orientation and dimensions of the facial recess in cochlear implantation. ORL J Otorhinolaryngol Relat Spec; 65:353-8.
7. Kashio A, Sakamoto T, Karino S, Kakigi A, Iwasaki S, Yamasoba T (2015): Predicting round window niche visibility via the facial recess using high-resolution computed tomography. Otol Neurotol; 1:e18–23.
8. McRackan TR, Reda FA, Rivas A, Noble JH, Dietrich MS, Dawant BM, et al. (2012): Comparison of cochlear implant relevant anatomy in children versus adults. Otol Neurotol; 33:328-34.
9. Fouad YA, ElAassar AS, El-Anwar MW, Sabir E, Abdelhamid A, Ghonimy M (2017): Role of Multislice CT Imaging in Predicting the Visibility of the Round Window in Pediatric Cochlear Implantation Int Arch Otorhinolaryngol; 20:180–4.
10. Pendem S, Rangasami R, Arunachalam R, Pulivadulu Mohanarangam V, Natarajan P (2014): HRCT Correlation with Round Window Identification during Cochlear Implantation in Children, journal of clinical imaging science; 4.
11. Xie LH, Tang J, Miao WJ (2018): Preoperative evaluation of cochlear implantation through the round window membrane in the facial recess using high resolution computed tomography, Surg Radiol Anat 40: 705.

9/11/2019