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Original Article

Round Window Accessibility Prediction in Cochlear Implant Surgery

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BACKGROUND: Clear identification of the round window (RW) through the facial recess is a key surgical step for successful cochlear implantation (CI) surgery, which may be very challenging in some cases. Objective is to predict round window (RW) accessibility during CI surgery using high-resolution computed tomography (HRCT).

METHODS: We retrospectively reviewed preoperative HRCT scans of 142 patients who underwent CI surgery via the standard posterior tympanotomy approach at our ENT Head and Neck Surgery department. Surgical accessibility of the RW was assessed according to 2 methods, similar to the ones introduced by Mandour et al and Elzayat et al. Pre-operative imaging findings were then compared to the actual surgical accessibility of the RW by reviewing surgical notes and video recordings.

RESULTS: Difficult surgical access to the RW was correctly predicted in our series by Mandour's method in 81.8% of the cases, with a sensitivity and specificity of 56.3% and 96.4%, respectively, and by Elzayat's method in 72.2% of the cases, with a sensitivity and specificity of 50% and 94.5%, respectively. Combining both methods showed an increase in sensitivity levels (Se = 71.9%). When the 2 methods both predicted difficult RW access, there was a strong probability that drilling a cochleostomy would be necessary for safe electrode insertion along the scala tympani of the basal turn of the cochlea ($P < .001$).

CONCLUSION: These 2 methods are both simple and reliable tools that can help the surgeon anticipate difficult surgical access and prepare for the potential use of alternative techniques.

KEYWORDS: Cochlear implantation, round window, correlation

INTRODUCTION

Cochlear implantation (CI) is a well-established treatment option widely used for the rehabilitation of patients with severe to profound sensorineural hearing loss, who receive little to no benefit from conventional hearing aids.

Posterior tympanotomy (PT) is the main surgical approach used in CI surgery to gain access to the middle ear without violating the tympanic membrane. It is achieved by opening the facial recess (FR), a triangular intra-temporal area bordered by the fossa incudis superiorly, the mastoid portion of the facial nerve (FN) medially, and the chorda tympani laterally.[1]

Clear identification of the round window (RW) through the FR is a fundamental and key surgical step for successful CI surgery, which may be very challenging in some cases. Therefore, surgeons should be able to predict RW accessibility pre-operatively.

The aim of this study is to determine if there are potential pre-operative imaging markers that could help predict the surgical accessibility of the RW via the facial recess during CI surgery, using high-resolution computed tomography (HRCT).

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METHODS

Ethical Considerations

This study was approved by the Ethics Committee of The Faculty of Medicine and Pharmacy of Marrakech, Cadi Ayyad University, Marrakech, Morocco (224/23).

Informed consent was obtained from all participants.

Study Design

This was a retrospective observational study on a series of CI surgeries performed at our ENT Head and Neck Surgery department during the period from January 2017 to January 2022.

Subjects

A total of 142 patients with severe to profound sensorineural hearing loss, who underwent CI surgery via the standard posterior tympanotomy approach, were included. Patients with inner ear anomalies, previous mastoid surgery, re-implantation, revision surgery, and those who were implanted via alternative techniques were excluded from the study.

Pre-operative Imaging Data

All cases were reviewed by a senior ENT surgeon who was blinded to the surgical findings.

Surgical accessibility of the RW was assessed on pre-operative axial HRCT scans according to 2 methods: (1) Using slices with maximum RW niche visibility, a line was drawn along the posterior wall of the bony external auditory canal (EAC line), and another line was drawn from the posterior margin of the RW niche along the anterior margin of the mastoid portion of the facial nerve (prediction line). If the 2 lines were parallel or nearly parallel, the RW was classified as "clearly visible." On the other hand, if both lines intersected with each other, the RW was classified as "barely visible/non-visible" (Figure 1). (2) The shape of the RW niche was analyzed using the same axial images. If the bony overhang that shields the RW membrane appeared as a completely closed circular structure "O-shaped," the RW was classified as "barely visible/non-visible." However, if the bony overhang appeared incomplete "C-shaped," the RW was classified as "clearly visible" (Figure 2).

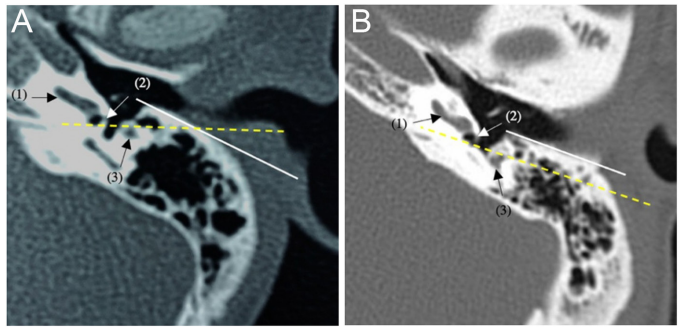

Figure 1. Axial HRCT scan of the left temporal bone. (1) basal turn of the cochlea, (2) RW niche, (3) mastoid portion of the facial nerve. The EAC line (solid white) is drawn along the posterior wall of the bony EAC. The prediction line (dashed yellow) is drawn from the posterior margin of the RW niche along the anterior margin of the mastoid portion of the facial nerve. (A) EAC line and prediction line are intersected; RW is classified as "barely visible/non-visible." (B) EAC line and prediction line are parallel; RW is classified "clearly visible."

These 2 methods are similar to the ones reported by Mandour et al[2] and Elzayat et al[3], respectively.

Intra-operative Findings

We used the St Thomas' Hospital (STH) classification to assess RW accessibility during surgery[4] (Table 1).

Intra-operative scoring was obtained by reviewing surgical notes and video recordings.

A second senior ENT surgeon who was blinded to HRCT findings reviewed all the cases. The RW was considered either "Clearly visible" (Type I or IIa) or "Barely visible/non-visible" (Type IIb or III).

Imaging findings were then compared to the actual accessibility of the RW during surgery.

Statistical Analysis

Statistical analysis was done using Statistical Package for Social Sciences (IBM® SPSS® Statistics, Chicago, IL, USA) version 26. Sensitivity (Se), Specificity (Sp), positive predictive value (PPV), and negative predictive value (NPV) of these 2 methods in the prediction of difficult RW access were calculated. A Chi-square test of

MAIN POINTS

- In this paper, we present 2 simple and practical radiological methods based on well-established anatomical landmarks in CI surgery that can help the surgeon anticipate difficult surgical access to the round window and prepare for the potential use of alternative techniques.
- The first method includes 3 important parameters that are crucial for adequate exposure of the round window through the facial recess: 1—posterior wall of the bony external auditory canal (EAC), 2—mastoid portion of the facial nerve, 3—location of the round window niche.
- The second method includes the orientation of the round window niche opening as another variable that can have a significant impact on the surgical approach.
- Imaging findings correlated well with intra-operative scoring of round window accessibility and also had a significant impact on the surgical approach: when both methods predicted difficult surgical access, there was a strong probability that drilling a promontory cochleostomy would be necessary for safe electrode insertion along the scala tympani of the basal turn of the cochlea ($P < .001$).

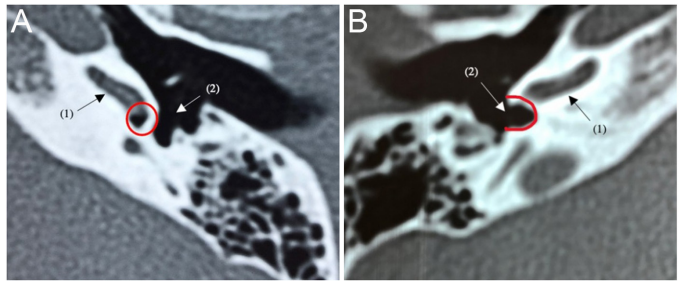

Figure 2. A, B. Axial HRCT scan of the left temporal bone. (1) basal turn of the cochlea, (2) RW niche. (A) O-shaped RW niche classified as "barely visible/non-visible." (B) C-shaped RW niche classified as "clearly visible."

Table 1. St Thomas' Hospital Classification

Type **I**	Full exposure of the RW is achieved (100%)
Type **IIa**	>50%
Type **IIb**	<50%
Type **III**	Non-visible RW (0%)

RW, round window.

independence was used to evaluate the impact of these imaging findings on the surgical approach. A *P*-value <.05 was considered statistically significant.

RESULTS

A total of 142 patients were included in the current study. There were 67 males (47.2%) and 75 females (52.8%), 134 children (mean age 4.9 years, ranging from 1.2 to 17 years), and 8 adults (mean age 27.4 years, ranging from 18.3 to 52.5 years). All patients had severe to profound sensorineural hearing loss and were implanted via the standard posterior tympanotomy approach. One hundred fourteen patients were implanted on the right side and 28 on the left side.

Following Mandour's method (EAC line /prediction line), the RW was classified as "Clearly visible" in 120 cases, of which 106 were confirmed intra-operatively, and "Barely visible/non-visible" in 22 cases, of which 18 were confirmed intra-operatively.

Sensitivity and Sp of Mandour's method in the prediction of RW accessibility in our series were 56.3% and 96.4%, respectively. Positive predictive value and NPV were 81.8% and 88.3%, respectively (Tables 2 and 3).

Following Elzayat's method (RW shape), the RW was classified as "Clearly visible" (C-shaped) in 120 cases, of which 104 were confirmed intra-operatively, and "Barely visible/non-visible" (O-shaped) in 22 cases, of which 16 were confirmed intra-operatively.

Sensitivity (Se) and Specificity (Sp) of Elzayat's method in the prediction of RW accessibility in our series were 50% and 94.5%, respectively. Positive predictive value and NPV were 72.2% and 86.6%, respectively (Tables 4 and 5).

Table 2. Correlation Between Imaging Findings (Mandour's Method) and Intra-operative Scoring of Round Window Accessibility

	Clearly Visible RW (Type I or IIa)	Barely Visible/ Non-Visible RW (Type IIb or III)	Total
Parallel EAC/prediction lines	106	14	120
Intersected EAC/prediction lines	4	18	22
Total	110	32	142

EAC, external auditory canal; RW, round window.

Table 3. Diagnostic Value of Mandour's Method in the Prediction of Round Window Accessibility

Se	Sp	PPV	NPV
56.3%	96.4%	81.8%	88.3%

NPV, negative predictive value; PPV, positive predictive value; Se, sensitivity; Sp, specificity.

Table 4. Correlation between Imaging Findings (Elzayat's Method) and Intra-operative Scoring of RW Accessibility

	Clearly Visible RW (Type I or IIa)	Barely Visible/ non visible RW (Type IIb or III)	Total
C-shaped RW	104	16	120
O-shaped RW	6	16	22
Total	110	32	142

RW, round window.

Table 5. Diagnostic Value of Elzayat's Method in the Prediction of Round Window Accessibility

Se	Sp	PPV	NPV
50%	94.5%	72.2%	86.6%

NPV, negative predictive value; PPV, positive predictive value; Se, sensitivity; Sp, specificity.

Also, the RW was considered 'barely visible/non-visible' intra-operatively in 32 cases, of which 23

correlated with imaging findings of either "O-shaped RW" or "intersected EAC/prediction lines."

Therefore, combining both Elzayat's and Mandour's methods showed an increase in sensitivity levels (Se = 71.9%), and hence better correlation with surgical findings.

Moreover, there was an agreement between the 2 radiological methods in the prediction of difficult RW access in 12 cases (both intersected EAC/prediction lines and O-shaped RW niche). Nine of them (75%) correlated with intra-operative findings of "Type III" RW and required drilling a promontory cochleostomy for electrode insertion (Figure 3). A Chi-square test of independence showed that when the 2 methods both predicted difficult RW access, there was a strong probability that drilling a cochleostomy would be necessary for safe electrode insertion along the scala tympani of the basal turn of the cochlea ($P < .001$).

DISCUSSION

Successful cochlear implantation surgery via the posterior tympanotomy approach depends on the conclusive identification of

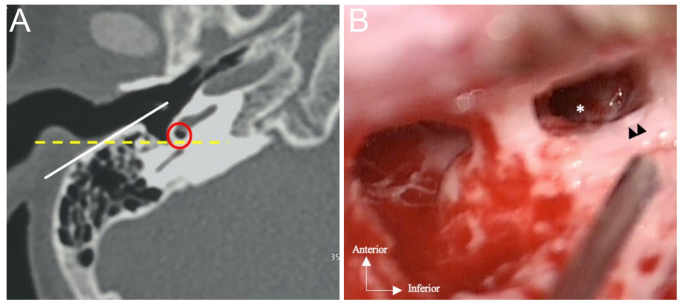

Figure 3. A, B. (A) axial HRCT scan of the right temporal bone. Mandour's and Elzayat's methods both indicate potential difficult RW access (intersected EAC/prediction lines and O-shaped RW niche), which is confirmed during surgery. (B) Intra-operative view showing a non-visible RW (Type III) despite maximum surgical effort to optimize the view through the FR. Note the anterior displacement of the mastoid portion of the facial nerve (double arrowhead), which is immediately exposed upon drilling the posterior tympanotomy (*).

the round window, which may be very challenging in some cases.[5] Therefore, surgeons should be able to predict round window accessibility prior to surgery. Pre-operative imaging of the temporal bone provides valuable information that could help the surgeon anticipate difficult surgical access and prepare for the potential use of alternative techniques.

The aim of this study was to determine if there are potential pre-operative imaging markers that could help predict the surgical accessibility of the RW during cochlear implantation surgery.

The first method used in the current study includes 3 important parameters that are crucial for adequate exposure of the RW through the FR: 1—posterior wall of the bony EAC, 2—mastoid portion of the facial nerve, and 3—location of the RW niche. Intersected EAC/prediction lines indicate that surgical access to the RW via posterior tympanotomy might be hindered by either posterior inclination of the posterior wall of the bony EAC, anterior displacement of the mastoid portion of the facial nerve, or posteriorly located RW niche.

The second method includes the orientation of the RW niche opening as a variable that can impact on RW visibility during surgery. A "C-shaped" RW niche on axial HRCT images indicates that its opening is oriented laterally and posteriorly and lies in an oblique vertical plane, facing directly at the surgeon when viewed through posterior tympanotomy.[3] On the other hand, an "O-shaped" RW niche indicates that its opening is oriented inferiorly and lies in a nearly horizontal plane, facing downward and therefore difficult to visualize through posterior tympanotomy.[3]

Our results show that there is a strong, statistically significant correlation between imaging findings and intra-operative scoring of RW accessibility. Difficult surgical access to the RW was correctly predicted in our series by Mandour's method in 81.8% of the cases, with a sensitivity and specificity of 56.3% and 96.4%, respectively, and by Elzayat's method in 72.2% of the cases, with a sensitivity and specificity of 50% and 94.5%, respectively.

The relatively low sensitivity reported in our study compared to Mandour et al[2] and Elzayat et al[3] can be due to the fact that key parameters, which can compromise surgical accessibility of the RW, were analyzed separately by these 2 methods.

For example, a "C-shaped" RW niche on axial HRCT images could be associated with surgical difficulties regarding RW identification due to anterior displacement of the facial nerve, which would correlate with HRCT findings of "intersected EAC/prediction lines." In other words, depending on which method you are using, a barely/non-visible type IIb or III RW intraoperatively could correlate with completely different imaging findings, accounting for the relatively low sensitivity reported in the current study. Subsequently, combining both methods in our study allowed us to include more variables and resulted in higher sensitivity levels, hence better correlation with surgical findings.

When analyzing accessibility on a CT scan, surgeons should be aware of the complexity of the surgical anatomy of the RW and take into account all potential anatomical factors that can hinder access before making any decision.

Multiple studies have attempted to predict RW accessibility prior to surgery using HRCT of the temporal bone.

Kashio et al[5] applied a prediction method similar to Mandour's, which consists of drawing a line parallel to the posterior wall of the bony EAC and passing through the anterior margin of the mastoid portion of the facial nerve (prediction line). They found that a posteriorly located RW membrane, in relation to the proposed prediction line, was significantly correlated to difficult RW visualization during surgery.

In a different study, Elzayat et al[6] measured the membrano-facial angle (MFA) on oblique sagittal HRCT reconstructions, which is the angle between the RW membrane and the longitudinal axis of the mastoid portion of the facial nerve. They found that a higher MFA was correlated with difficult access, as it reflects downward angulation of the RW, which can significantly impact the surgical approach.

Rajati et al[7] and Fouad et al[8] reported that intra-operative RW visibility was highly correlated with pre-operative HRCT measurements.

Our study presents 2 simple and practical methods based on well-established anatomical landmarks and key parameters that are fundamental for adequate RW exposure, using standard axial HRCT images, in contrast to the above-mentioned studies that mostly rely on special reconstructions and complex measurements, which can be subject to inter-observer and intra-observer variability.

Moreover, according to our analysis, imaging findings not only correlated with intra-operative scoring of RW accessibility but also had a significant impact on the surgical approach. When the 2 methods both predicted difficult RW access, there was a strong probability that drilling a cochleostomy would be necessary for safe electrode insertion along the scala tympani of the basal turn of the cochlea.

This is particularly important for preoperative patient counseling about outcome expectations, especially when the goal is the preservation of residual hearing. In fact, CI with preservation of residual hearing requires an exclusive round approach for electrode insertion since drilling the promontory for a cochleostomy is associated with a greater risk of acoustic trauma and the entry of bone dust into the scala tympani, which is unwarranted in this type of surgery.

This can have a significant impact on preoperative decision-making regarding the side of implantation, type of electrode, and surgical approach.

CONCLUSION

The current study presents 2 simple and reliable tools that can help the surgeon anticipate difficult surgical access and prepare for the potential use of alternative techniques.

Ethics Committee Approval: This study was approved by the Ethics Committee of The Faculty of Medicine and Pharmacy of Marrakech, Cadi Ayyad University, Marrakech, Morocco University (Approval No: 224, Date: 2023).

Informed Consent: Informed consent was obtained from all participants.

Peer-review: Externally peer reviewed.

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Declaration of Interests: The authors have no conflicts of interest to declare.

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