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Difficult round window access during cochlear implantation: a simple prediction method utilising pre-operative CT imaging

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Main Article

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Abstract

Objective. Difficulty visualising the round window is occasionally encountered during cochlear implant surgery. This paper presents a novel method for predicting difficult round window accessibility using pre-operative computed tomography (CT) imaging.

Methods. This is a retrospective multicentre study of all cochlear implantation surgical procedures conducted in two Singaporean tertiary hospitals between 2018 and 2021. Pre-operative CT temporal bone scans were reviewed and two lines were drawn on a single axial cut. Where both lines intersect medially, difficult round window visualisation is predicted. Computed tomography predictions were compared with intra-operative findings, and statistical analysis was performed.

Results. In 9 of 89 cases (10.1 per cent) difficult round window access was noted intra-operatively and 8 cases (88.9 per cent) were correctly predicted by the novel method ($p < 0.001$; sensitivity, 89 per cent; specificity, 100 per cent).

Conclusion. This study describes a simple, effective method to predict difficult round window access on axial CT temporal bone images, without reconstructed images or complex calculations.

Introduction

Cochlear implantation surgery is commonly performed for patients with hearing loss who are not sufficiently benefitting from hearing aids.[1] An occasional challenge faced by surgeons is difficult visualisation of the round window membrane through the facial recess opening. Clear visualisation of the round window membrane is vital to allow for atraumatic insertion of the cochlear implant electrodes into the cochlea.[2] Inability to visualise the round window may necessitate additional intra-operative manoeuvres such as an extended round window approach, cochleostomy, sacrifice of the chorda tympani nerve or even a canal wall-down mastoidectomy with blind sac closure. Being able to predict such challenging cases in the pre-operative setting is invaluable for patient counselling and surgical planning, and can improve surgical outcomes.

Computed tomography (CT) of the temporal bone is commonly performed prior to cochlear implant surgery. Multiple previous studies have been published describing various methods of predicting difficult round window access on pre-operative CT, but there has been no consensus on the best method of prediction. Some of these methods are complex to use in clinical practice because of the need to measure multiple angles and lines on different CT cuts,[3] while others involve the use of reconstructed images, which are not always easily available to the clinician.[4,5] The aim of this study was to assess a novel CT prediction method, which is simple and based on axial CT temporal bone cuts, for the prediction of difficult intra-operative round window visualisation.

Materials and methods

This was a retrospective, multicentre study of all patients who underwent cochlear implantation surgery between January 2018 and December 2021 in the otolaryngology departments of two tertiary healthcare institutions in Singapore, Singapore General Hospital and Changi General Hospital.

Exclusion criteria included: (1) patients with no available pre-operative CT scans of the temporal bone; (2) patients with underlying anatomical anomalies such as aural atresia or

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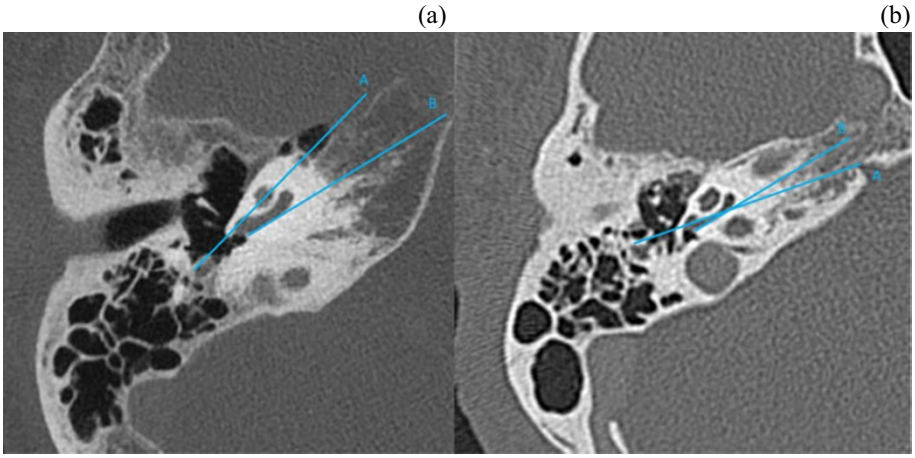


Figure 1. Prediction lines drawn on selected cuts. (a) Diverging lines seen when prediction lines are traced in the medial direction, predicting for good round window visualisation. (b) Prediction lines converging as they are traced lateral to medial, predicting for difficult round window visualisation.

bony obliteration of the round window membrane; and (3) patients who underwent cochlear implantation without the use of a facial recess approach.

The study received ethics approval from the Institutional Review Board.

Computed tomography protocol

Pre-operative high-resolution temporal bone CT images were acquired using a Toshiba Aquilion (Otawara, Tochigi Prefecture, Japan), Siemens Somatom Definition Flash (Forchheim, Germany) or Siemens Somatom Force CT machine. The CT was performed at 120 kV and 240 mA on the Toshiba CT machine and at 120 kV and 140 mAs on the Siemens CT machines, with a slice thickness of 0.6 mm.

Computed tomography measurements

Pre-operative CT temporal bone scans were reviewed on the Vue Picture Archiving and Communication System (Carestream, Rochester, NY, USA) platform. The novel predictive method was utilised to predict for intra-operative difficulty of visualisation of the round window membrane. The predictive method involved drawing two prediction lines on selected axial cuts for all patients by a single reviewer blinded to intra-operative findings. This process was repeated during a separate session to assess for intra-rater reliability. Axial sections of the CT temporal bone were screened and a single axial cut was selected when the mastoid segment of the facial nerve, the round window membrane and the basal turn of the cochlea were all clearly identifiable on that cut. Two prediction lines were then drawn on the selected axial cut.

The first line (line A on Figure 1) was drawn from the anterior aspect of the round window membrane to the anterior aspect of the mastoid segment of the facial nerve. This acts as a surrogate for the position of the round window with respect to the mastoid segment of the facial nerve. It was hypothesised that the more posterior the round window with respect to the mastoid segment of the facial nerve, the more difficult the visualisation.

The second line (line B on Figure 1) was drawn from the posterior margin of the round window membrane, parallel to the basal turn of cochlea, utilising the basilar membrane as a reference for the axis of the basal turn of the cochlear. This acts as a surrogate for cochlear rotation, and it was hypothesised that a more rotated cochlea (basal turn aligned more vertical than horizontal on axial CT cuts) would result in a harder to visualise round window membrane intra-operatively.

By tracing both lines from the lateral to the medial aspect, they can be classified as diverging or converging, depending on whether they intersect medially. The converging lines, where the two lines intersect medial to the round window, would represent a combination of a more posteriorly positioned round window with respect to the facial nerve and a more rotated cochlea. This was hypothesised by the study team to predict difficult round window visualisation. In contrast, diverging lines, where the two lines diverge medial to the round window, would represent a combination of a more anteriorly positioned round window with respect to the facial nerve and a less rotated cochlea. This was hypothesised by the study team to predict easier round window visualisation (Figure 1).

In cases where there was more than one axial cut, with clear visualisation of the mastoid segment of the facial nerve, round window membrane and cochlear basal turn, prediction lines were drawn on all suitable axial cuts. If at least one of the axial cuts showed diverging prediction lines, the case was classified to predict easier round window visualisation. On the other hand, if all suitable axial cuts predicted poor round window visualisation, the case was then classified as such.

Intra-operative results

Operative notes were reviewed to determine the ease of round window visualisation intra-operatively. Difficult visualisation was determined if there was reported poor visualisation of the round window through the facial recess, sometimes warranting additional surgical manoeuvres such as a cochleostomy or an extended round window approach. Intra-operative findings were then compared with CT prediction to assess the efficacy of the proposed prediction method in identifying cases of difficult round window visualisation.

Statistical analysis

Statistical analysis was performed to look for concordance between intra-operative round window visualisation and CT prediction of round window visualisation. Variables such as patient age, sex and side of implant were also analysed for association with difficulty

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of intra-operative round window visualisation. The chi-square test was used for categorical variables and the Mann–Whitney U test was used for continuous variables. The sensitivity and specificity of the proposed CT prediction method were calculated. SPSS version 29 (IBM, Chicago, IL, USA) was used for all statistical analyses in this study.

Results and analysis

Of the 100 cases initially selected, 89 (84 patients) were included in the final study population. Eight cases were excluded because they did not have pre-operative CT temporal bone scans available, two cases were excluded because of underlying aural atresia or bony obliteration of the round window and one case was excluded because cochlear implantation was performed with a subtotal petrosectomy and blind-sac closure.

The mean age of the studied population was 44.9 years (range, 1.0–88.0 years), 50.6 per cent of the cases were male and 57.3 per cent were right-sided cochlear implantations (Table 1).

Of the 89 included cases, 9 were found intra-operatively to have difficult visualisation of the round window. Of the 9 cases, 8 (88.9 per cent) were correctly predicted to have difficult visualisation of the round window membrane using the novel CT prediction method ($p < 0.001$).

The remaining 80 cases were found intra-operatively to have easier visualisation of the round window. All 80 cases (100 per cent) were correctly predicted by the novel CT method to have easier round window visualisation. This is detailed in Table 2.

The CT prediction method was able to identify cases of difficult intra-operative round window visualisation with a sensitivity of 89 per cent, specificity of 100 per cent, positive predictive value of 100 per cent and negative predictive value of 99 per cent. There was no intra-rater difference in the CT prediction of round window visualisation when the prediction lines were redrawn in a separate sitting.

There was no association between the difficulty of intra-operative visualisation of the round window with age, sex or side of ear ($p = 0.215$, 0.308 and 0.549, respectively).

Table 1. Demographic information of the included study population

Characteristic	Value
Age (mean (range); years)	44.9 (1.0–88.0)
Sex (*n* (%))	
– Male	45 (50.6)
– Female	44 (49.4)
Side (*n* (%))	
– Right	51 (57.3)
– Left	38 (42.7)
Implant brand (*n* (%))	
– Advanced Bionics	16 (18.0)
– Cochlear	44 (49.4)
– Med-El	29 (32.6)

Table 2. Correlation between predicted difficulty of round window membrane visualisation using novel CT prediction method and intra-operative findings

	Intra-operatively difficult (*n*)	Intra-operatively not difficult (*n*)	Total (*n*)
Predicted difficult	8	0	8
Predicted not difficult	1	80	81
Total	9	80	89

Discussion

Difficult round window visualisation via the facial recess approach is an occasionally encountered challenge in cochlear implantation surgery. This study presents a CT prediction method that can be easily used in clinical practice because it utilises a single axial cut on high-resolution CT. Only two lines need to be drawn for prediction, one line being a surrogate marker for round window position relative to the facial nerve and the other line being a surrogate marker for the degree of cochlear rotation. The results of this study suggest that our CT prediction method is efficacious, with a positive predictive value of 100.0 per cent and a negative predictive value of 98.7 per cent.

The use of pre-operative imaging to predict intra-operative difficult round window access has also been explored by multiple other studies in the literature, a handful of which introduce prediction methods with high positive and negative predictive values, comparable with our novel method. These predictive methods vary widely, utilising various parameters such as prediction lines,[3,6,7] angular relations between structures,[4,5,8] distance measurements[7,9] and even round window niche morphology.[10] There is a far larger number of studies which only looked at variables associated with difficult round window visualisation, without specifying a method of prediction, for instance in the form of formulas or cut-off values. Hence a direct comparison of the results of these studies and our own was not possible.

A few studies in the literature have similarly explored the use of prediction lines. Kashio *et al.*[6] utilised a prediction line drawn parallel to the external auditory canal along the anterolateral facial nerve, and assessed the point of intersection on the round window membrane. Non-posterior-intersecting lines predicted difficult round window membrane visualisation (positive predictive value, 94.44 per cent; negative predictive value, 88.24 per cent). This method was replicated by Ghoneim *et al.*[9] in a separate cohort of patients, with poorer results (positive predictive value, 40 per cent; negative predictive value, 91.4 per cent).

Jwair *et al.*[7] proposed a method utilising a prediction line drawn from the anterior aspect of the mastoid facial nerve to the posterior border of the basal turn of the cochlea in the axial sections. Intersection of the prediction line with the round window membrane anterolateral to the midpoint was used to predict difficult round window visualisation (positive predictive value, 75.0 per cent; negative predictive value, 60.71 per cent). Mandour *et al.*[3] utilised a method requiring two prediction lines, one from the bony-cartilaginous junction of the posterior external auditory canal wall to the tympanic annulus and another from the posterior margin of the round window membrane along the anterolateral facial nerve (positive predictive value, 100 per cent; negative predictive value, 97.14 per cent). Of these studies, those utilising two lines for prediction, Mandour *et al.*[3] and this study, appear to yield the best positive and negative predictive values, possibly as a result of the improved ability to evaluate the position of the round window relative to other structural landmarks. However, the method proposed by Mandour *et al.*[3] requires the use of more than one CT

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cut where both lines could not be drawn on the same cut, which may be more tedious to use in clinical practice.

Other studies explored the use of angles between structures as predictors. Elzayat *et al.*[4] utilised the angle between the mastoid portion of the facial nerve and the chorda tympani nerve on a reconstructed parasagittal section. More than 25.5° was predictive for good round window membrane visualisation (positive predictive value, 99.36 per cent; negative predictive value, 95.06 per cent). In separate study, Elzayet *et al.*[5] utilised the angle between the round window membrane in the oblique sagittal view and the longitudinal axis of the vertical segment of the facial nerve, where 15.1° or greater predicted difficult round window access (positive predictive value, 100 per cent; negative predictive value, 76.6 per cent).

Shim *et al.*[8] utilised the anterior angle between the anteroposterior axis transecting the clivus perpendicularly and a line parallel to the round window in the superior most axial cut of the basal turn of the cochlea. An angle equal to or greater than 90° was predicted for difficult round window visualisation (positive predictive value, 38.46 per cent; negative predictive value, 100 per cent). The two methods described by Elzayat *et al.*[4,5] yielded high positive and negative predictive values, but they require the use of reconstructed CT sections, which are not always readily available to the clinician. Shim *et al.*[8] described a simpler method requiring only a single axial cut, but unfortunately the method yielded significantly poorer positive predictive value.

The first angle focused on the relation of the facial nerve and the chorda tympani, which correlates to the size of the facial recess, impacting round window visualisation. The second angle evaluates the angulation of the round window membrane, which if rotated more postero-inferiorly from the facial nerve would lead to difficult round window visualisation. Creating an oblique sagittal view of the round window membrane allows the three-dimensional orientation of the round window membrane to be assessed accurately when compared with the vertical segment of the facial nerve. While these two prediction methods demonstrate high positive and negative predictive values, the clinical application of these methods may prove challenging and tedious because it requires reconstructed CT sections to obtain measurements, and the process of reconstructing these necessitates using multiple different views. The method introduced by Shim *et al.*, on the other hand, also assesses the angulation of the round window, but with a simpler direct method. However, the results showed a far lower positive predictive value and would not be as reliable in clinical application.

Another group of prediction methods utilises measured distances between structures, most commonly facial recess width. Ghoneim *et al.*[9] utilised the perpendicular distance from the anterolateral facial nerve to the axis of the external auditory canal as a surrogate measure for facial recess width, where 4.75 mm or less predicted difficult round window visualisation (positive predictive value, 33.3 per cent; negative predictive value, 100 per cent). Jwair *et al.*[7] measured the distance between the facial nerve and the chorda tympani nerve at the second-last axial CT section of the mastoid segment of the chorda tympani nerve, and found that a distance equal to 1.5 mm or less predicted difficult round window visualisation (positive predictive value, 65.4 per cent; negative predictive value, 93.5 per cent).

Predictions methods utilising measurements of facial recess width appear to yield poorer positive predictive value, while negative predictive value remains high. This is likely as a narrower facial recess alone may not translate to difficult round window access if the round window is more anteriorly positioned relative to the facial recess, while a wider facial recess may compensate for a more posteriorly positioned round window, still allowing visualisation. Considering facial recess width alone may represent oversimplification when it comes to predicting difficult round window visualisation. This is concordant with some other studies in the literature[6,11–13] that have found that facial recess width has no significant association with difficult round window visualisation.

In this study, the utilisation of two lines that can be simply drawn on a single axial CT cut yielded good positive and negative predictive values compared with other studies in the literature, while remaining quick and simple to use. The described method accounts for both round window position relative to the facial nerve, as well as the degree of cochlear rotation. A dichotomous outcome of either converging or diverging prediction lines to predict for difficult round window visualisation was adopted to avoid the use of arbitrary cut-off values because slight variations in the way lines are drawn around minute anatomical structures may result in large and meaningless differences in obtained values.

The limitations of this study include its retrospective nature, which may create a degree of observer bias. To mitigate this, the reviewer was blinded to intra-operative findings when reviewing CT images and a standardised way of selecting CT cuts for analysis was used. Future prospective studies should be conducted to further validate this CT prediction method.

- Difficulty with visualising the round window is occasionally encountered during cochlear implant surgery
- This paper presents a novel method for assessing round window accessibility by drawing two lines on a single axial cut on pre-operative computed tomography temporal bone scans
- When both lines intersect medially, this represents a posteriorly positioned round window and a rotated cochlea, which predicts difficult round window visualisation
- In a retrospective study of 84 patients (89 ears), the novel method yielded a sensitivity of 89 per cent and specificity of 100 per cent of predicting difficult round window access

Conclusions

We present a simple-to-use and effective pre-operative CT prediction method that is able to aid clinicians in identifying cases of difficult round window access before cochlear implant surgery.

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