SYSTEMATIC REVIEW

Preoperative Predictors of round window visibility on High resolution CT-scan temporal bone in patients undergoing cochlear implant surgery: A Systematic Review

Syed Akbar Abbas[1], Muhammad Wasif[2], Abdul Basit Shah Vardag[3], Haissan Iftikhar[4], Huzaifa Moiz[5], Syed Shabbir Afzal[6]

Abstract

Objective: To evaluate the correlation of high-resolution computed tomography-based radiological predictors with the surgical ease of access to the round window membrane in cochlear implant surgery.

Method: The systematic review was conducted from April 2020 to May 2020 at the Aga Khan University Hospital, Karachi, and comprised literature search on PubMed, Cumulative Index of Nursing and Allied Health Literature-Plus, Wiley Cochrane Library and Web of Science databases for studies published in the English language between January 2000 and January 2020 that followed the population-intervention-comparison-outcome model. The search was done using key words, such as high-resolution computed tomography, temporal bone, round window and cochleostomy. Studies dealing with paediatric and adult cochlear implantations were included. The included studies were subjected to risk-of-bias assessment using the National Institute of Health study quality assessment tool for case series. The review was duly registered with PROSPERO..

Results: Of the 292 studies initially identified, 6(2%) were included for systematic review. Overall patient age ranged between 1-85 years. No significant use of facial recess width for defining intraoperative visibility could be found. The use of the distance between the round window and the facial nerve, the alpha angle, the angle beta and the prediction line were of significance.

Conclusion: Radiological facial recess width had no significant use in determining the ease of access to the round window membrane.

Keywords: Cochlear implants, Temporal bone, Round window, Middle ear, CT scan temporal bone.

PROSPERO ID registration link: https://www.crd.york.ac.uk/PROSPERO/view/CRD420261302451.

DOI: https://doi.org/10.47391/JPMA.AKU-10Surg-17

[1-5]Aga Khan University Hospital, [6]Ziauddin University Hospital, Karachi, Pakistan

Correspondence: Abdul Basit Shah Vardag.

Email: abdulb8998@gmail.com

ORCID ID: 0000-0001-8257-219X

Introduction

According to a survey done in 1996 by the National Institute on Deafness and Other Communications Disorders, approximately 28 million Americans were deaf or hearing-impaired. The number, it was feared, could reach 44 million by the year 2020 and 73.5 million by 2060.[1] An epidemiological survey on deafness in the United States showed the prevalence to be as high as 1.1 per 1,000 children, with 23% of this subset attributed to congenital causes. Over the years, both round window (RW) and cochleostomy approaches have been described in the literature, but the RW approach is used more often by cochlear implant surgeons as it limits damage to inner ear structures.[2,3] The RW approach also makes the approach to scala tympani adequate with better outcomes in implantation. The RW approach also remains the most reliable avenue to access scala tympani.[4,5] The surgical ease of access has been defined with specific reference points in different studies along with subsequent measurements.[6] The difference in temporal bone and cranial measurements among different populations and age groups have been well documented .[7] St. Thomas Hospital's classification of round window membrane (RWM intraoperative visibility is perhaps the most widely used system.[8] This system divides the intraoperative RW visibility into three categories; fully visible, partially visible, and not visible. Further refinements in temporal bone radiological techniques hold promise for middle ear surgery.[9]

With the advent of high-resolution computed tomography (HRCT), preoperative measurements can be taken to evaluate for intraoperative ease of access to the round window niche (RWN). CT maintains its place as an important tool to evaluate middle ear anatomy and its variations are important for successful implantation, especially in pre-lingual deaf children.[10]

Kashio et al. in 2014 highlighted facial recess (FR) width for the assessment of the ease of access to RW. Since then, different authors have devised different radiological models for preoperative assessment.[11-14]

The current systematic review was planned to present an overview of different RW predictive models available.

Materials and Methods

The systematic review was conducted from April 2020 to May 2020 at the Aga Khan University Hospital, Karachi and comprised literature search on PubMed, Cumulative Index of Nursing and Allied Health Literature-Plus (CINAHL-Plus), Wiley Cochrane Library and Web of Science databases for studies published in the English language between January 2000 and January 2020 that followed the population-intervention-comparison-outcome model (PICO) model, where the population group was the patients undergoing cochlear implant surgery, the intervention was CT scan of the temporal bone, there was no comparison group, and intraoperative RW visualisation was the outcome. The key search terms were CT scan, computed tomography, HRCT, CT temporal bone, HRCT temporal bone, facial recess, posterior tympanotomy, round window, round window niche, cochlear implant, and cochlear implant surgery.

The review was registered with PROSPERO (https://www.crd.york.ac.uk/PROSPERO/view/CRD420261302451).

The studies were screened by two independent reviewers. In case of disagreement, input from a third reviewer was sought. Data was collected on a predesigned data extraction sheet.

Studies dealing with both paediatric and adult cochlear implantations were included. All the studies with preoperative HRCT scans and patients undergoing cochlear implant surgery were included. The studies included comprised candidates with normal temporal bone anatomy. All studies with measurements done on CT scans in an axial plane were included.

Studies on anatomic models and cadavers were excluded, and so were case reports, non-English manuscripts, and letters to editors/correspondence.

The risk of bias of the studies was evaluated using the 9-item National Institute of Health (NIH) quality assessment tool for case series, which is used to assess bias in observational studies. For the purpose of the current review, a score of 7 or above indicated a low risk of bias, a score of 4-6 indicated a moderate risk, and a score of 3 or less indicated high risk.

Results

Of the 471 studies initially identified, 212(45%) were from PubMed, 172(36.5%) from Web of Science, 79(16.8%) from CINAHL-Plus, and 4(0.8%) from Cochrane Library, while 4(0.8%) studies were identified through manual search. On screening, 292(62%) studies were left after the removal of duplicates, and, of them, 6(2%) were selected for full-text review[11-14,16,17] (Figure 1). Overall, 4(66.7%) studies showed a low risk of bias, and 2(33.3%) had a moderate risk (Table). Patients age across the studies ranged 1-85 years.

FR width was measured as the vertical distance between the external auditory canal (EAC) and the leading edge of the facial nerve (FN) (Figure 2). It was analysed by 4(66.7%) of the studies.[11-14] The initial concept was that the greater the width of the facial recess, the greater will be the RW visibility. Before the widespread use of the RW approach, the relationship of FR in relation to the basal

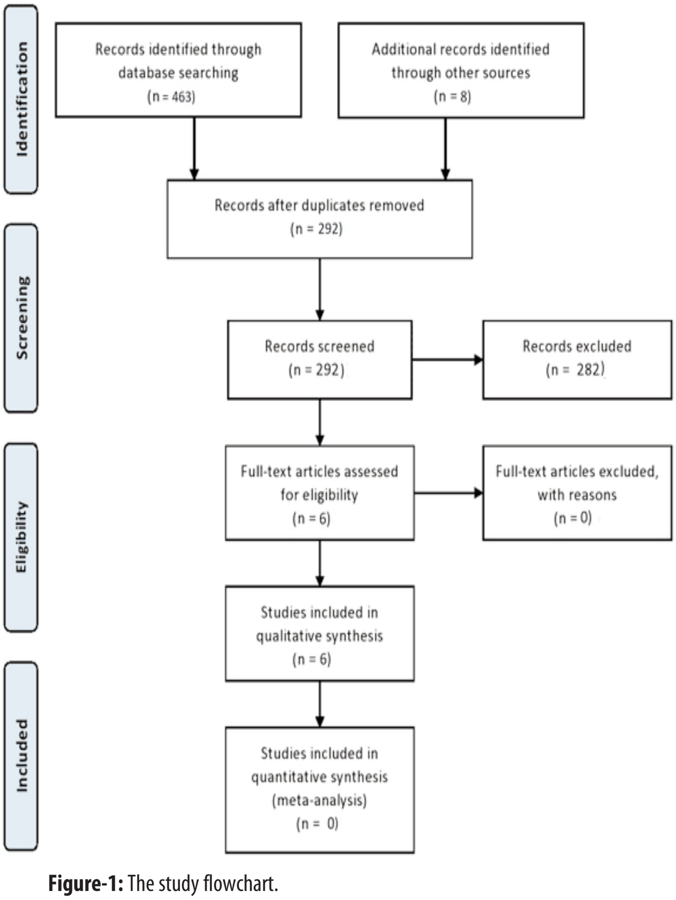

Figure-1: The study flowchart.

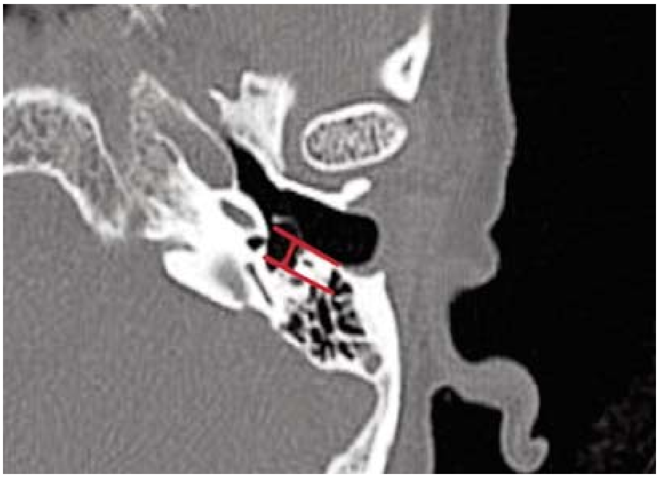

Figure-2: Facial nerve (FN) width.

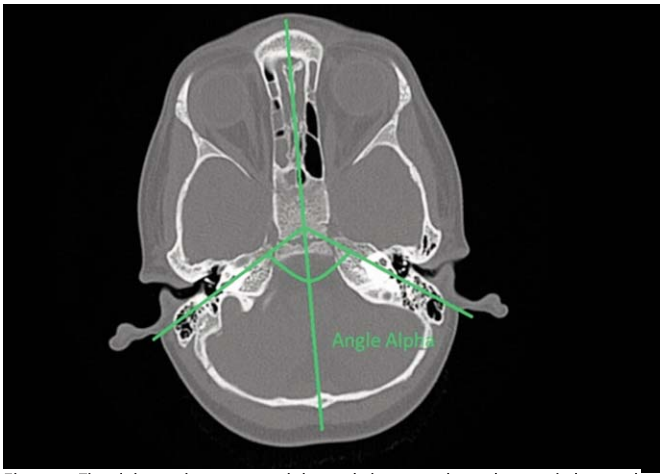

Figure-3: The alpha angle represented the angle between the mid-sagittal plane and the line passing through the cochlear basal turn.

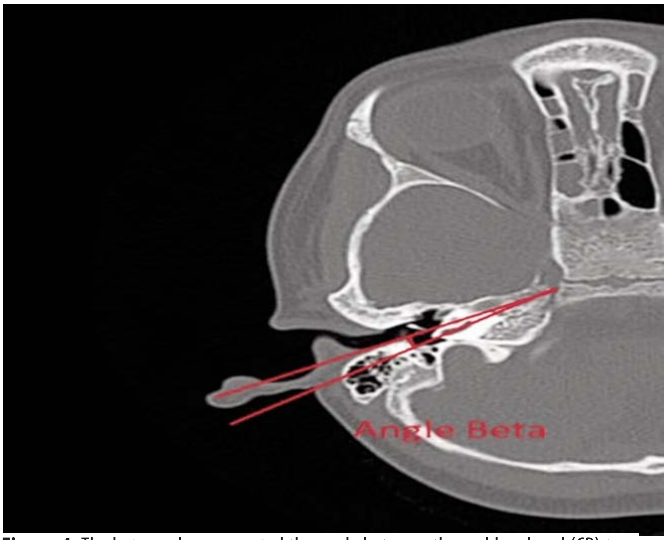

Figure-4: The beta angle represented the angle between the cochlear basal (CB) turn and the external auditory canal (EAC) line.

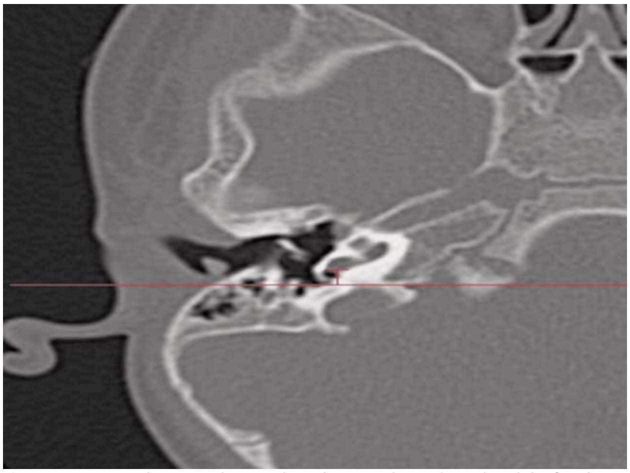

Figure-5: Distance between the round window membrane (RWM) and the facial nerve (FN).

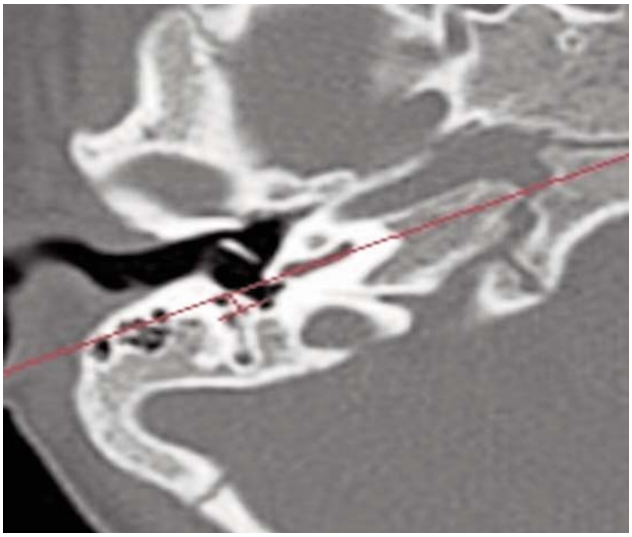

Figure-6: Distance between the basal turn and the facial nerve.

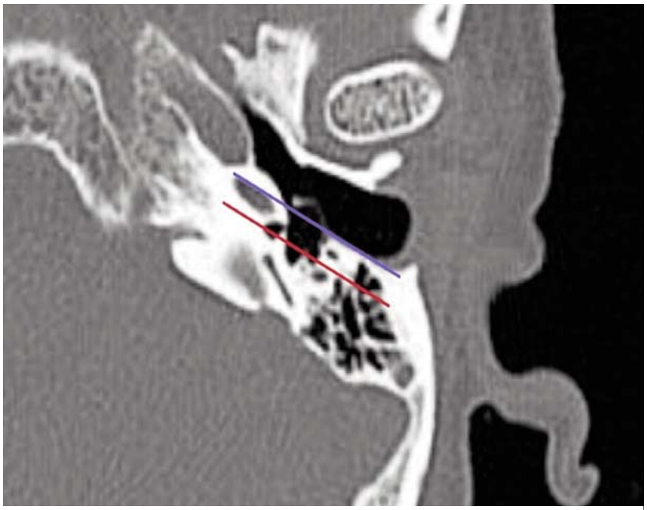

Figure-7: The prediction line.

Table: Assessment of the risk of bias in the studies analysed.

Study	Was the study question or objective clearly stated?	Was the study population clearly and fully described, including a case definition?	Were the cases conse-cutive?	Were the subjects compar-able?	Was the interven-tion clearly described?	Were the outcome measures clearly defined, valid, reliable, and implemented consistently across all study participants?	Was the length of follow-up adequate?	Were the statistical methods well-described ?	Were the results well-described?
Chen et al -2019 [11]	Yes	yes	N/A	Yes	Yes	Yes	NA	Yes	Yes
fouad et al. [12]	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes	No
kang et al.[13]	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes	Yes
Kashio et al.[14]	Yes	Yes	N/A	No	Yes	Yes	N/A	Yes	Yes
sharma et al.[16]	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes	No
Xie et al. [17]	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes	Yes

turn of the cochlea was studied for ease of cochleostomy.[15]

Kashio et al. retrospectively studied 70 ears undergoing cochlear implantation in adult and paediatric age groups.[14] The FR width was measured perpendicular from the EAC to the anterolateral part of FN. A line was drawn from the centre of the RW, and another line was drawn from the junction of the bony-cartilaginous junction on the posterior wall and tympanic annulus. The angle was determined between these two lines as angle 'a'. To predict RW visibility, a line was drawn from the EAC along the anterior aspect of FN and divided into anterior 20% visibility, middle 60% visibility, and posterior 20% visibility. The RW visibility was categorised as fully visible, partially visible, and completely invisible based on this categorisation. There were 15 ears with the anterior intersection of the prediction line that had an invisible, nearly invisible RWN. The FR width was 4.7 ± 0.9mm in invisible ears, 4.4 ± 0.8mm in partially visible ears, and 4.9 ± 1.44mm in fully visible RWNs. FR width was not a predictor of RMN visibility.[14]

Kang et al.[13] did a retrospective review of 84 paediatric and adult ears for RW visibility through FR. They were successful in 70(83.3%) cases in the RW group compared to 14(16.7%) in promontory cochleostomy (PC) group. The median FR width in RW and PC groups was 3.17mm (interquartile range [IQR]: 2.46-4.85mm) and 3.24mm (IQR: 1.32-4.83mm), respectively. FR width was not a predictor of RWN visibility.[13]

Fouad et al. studied 60 paediatric ears for RW visibility during cochlear implantation.[12] The RW visibility was based on the St. Thomas Hospital classification system.[8] The mean FR width was 5.07 ± 0.85mm. FR width was not a predictor of RW visibility.[12]

The alpha angle was measured between the mid-sagittal plane and the mid-cochlear basal turn joining with the leading edge of the FN (Figure 3) Sharma et al. and Xie et al. showed significant but contrasting results related to the alpha angle.[16,17] In an interesting study by Jeffery et al,, a significant change in cochlear orientation related to sagittal orientation was found during foetal life, but this did not change much in later years of life.[18] Sharma et al. studied 19 adult and paediatric patients for RW visibility using the St Thomas Hospital classification of RW visibility[8]. The mean angle measurement for type I fully visible RWM intraoperatively was 64.06. In contrast, the mean angle for type IIa and IIb, a partially visible or invisible RWM, was 63.81 and 56.48, respectively. The RW visibility decreased as the angle became more acute, and it was shown to be statistically significant.[16] In contrast, Xie et al. studied 176 patients with cochlear implantation [17], and reported the mean angle for the fully visible RWM group to be 60.7 ± 5.63°, and the mean angle for partially visible and invisible groups to be 63.42 ± 7.04° and 66.56 ± 9.05°, respectively. As the angles became more obtuse, the intraoperative RW visibility decreased.[17]

The angle between cochlear basal (CB) turn and the EAC line was named the beta angle for ease of description (Figure 4). The angle has been defined as the intersection of EAC and a line passing through the middle of the basal turn. This angle was evaluated in three studies.[12-14] Kashio et al/ drew a significant result with this radiological parameter. EAC angles were -0.5 ± 3.2°, 5.5 ± 4.7° and 13.4 ± 7.8° in ears with invisible/nearly invisible, partially visible, and fully visible RWN, respectively. As the angle increased the visibility of RWM increased.[14] Kang et al. reported the median angle to be 1300° (IQR: 2.90-32.80°) in the RW visualised group whereas it was 7.4° (IQR: 6.1-13.3°) for the PC group.[13] The wider beta angle was a statistically significant predictor of RW insertion. Lastly, Fouad et al. studied 60 paediatric ears.[12] The mean angle measurement was 17.83 ± 12°. The finding did not draw any significant association between the beta angle and RW visibility.

The RF distance has been described by Kang et al.[13] and Fouad et al.[12], and it is defined as the vertical distance between the anterior margin of FN and the RW (Figure 5). Both the studies reported a significant correlation between RW visibility and the distance on CT temporal bone preoperatively. The median distance reported by Kang et al. in the RW group was 2.78mm (IQR: 1.98-4.65mm), whereas in the PC group it was 2.11mm (IQR: 1.66-2.32mm). Fouad et al.[12] reported that whenever RF was >4mm, the RW was visible (types 1 and 2), and when this distance was up to 4mm, the RW was invisible (type 3).

A significant correlation was found between the distance between the basal turn and facial nerve (BF) and the intraoperative RWM visibility by Kashio et al.[14] and Fouad et al.[12] (Figure 6). Kashio et al. observed a distance of 0.0 ± 0.8, 0.7 ± 0.9 and 1.1 ± 07 mm for groups I, II and III, respectively[14]. Fouad et al.[12] reported the mean distance to be 0.84 +/- 0.75mm (p=0.000419) in patients undergoing implantation in the paediatric age group. On the contrary, Kang et al[13] failed to draw a positive correlation between the BF distance and RW visibility (p=0.981).

A line parallel to the EAC line was drawn passing through the anterolateral edge of FN, and the relationship with RWM was assessed (Figure 7). This parameter has been discussed by Fouad et al.[12] and Kashio et al.[14] The former study did not find a significant association with this radiological predictor (p=0.25), and the prediction line passed posterior to RW in 92% of the cases. However, the latter concluded that the relationship of the intersection with RWM was categorised as an anterior, middle and posterior intersection where the extremes represented invisible and visible RWM, respectively.

Discussion

To our knowledge, the current review is the first comprehensive review of CT scan predictors of RW visibility for cochlear implantation, and identifies the commonly used predictors of RW on preoperative CT scan.

The FR width is the commonest studied parameter, and the review identified three retrospective reviews addressing this measurement through HRCT of the temporal bone. Kashio et al. and Kang et al. reported on both adult and paediatric cochlear implant candidates[13.14], while Fouad et al. studied this parameter on the paediatric population alone.[12] FR was defined differently in all the three studies. Kashio et al. defined it as the perpendicular distance between the EAC line and the anterolateral part of the FN[14], while Kang et al. defined it as the distance between FN and the chorda tympani[13], and Fouad et al. described it as the distance between the tympanic annulus and the anterolateral part of the FN.[12] Lack of uniform description of the FR may contribute to minor differences in calculation. The reviewers are not sure how much difference this lack of uniformity may contribute to the results. In another review on 29 cochlear implant insertions, Bettman et al. could not establish a link between FR width and ease of insertion through RW.[12-15]

The cochlear orientation to the sagittal plane has been studied in paediatric and adult patients. There has been a significant change in the orientation of basal turn with a sagittal plane in foetal life.[18] This change has also been documented in later years of life.[19] This increase in angulation possibly makes adult cochlear implantation easier than paediatric.[8] The alpha angle was studied by Xie et al[17] and Sharma et al.[16] The former reviewed 176 children and teenage implant recipients, while the latter studied 19 adult and paediatric patients. Both came up with a contrasting conclusion on EAC angle and ease of RW visualisation. The difference in results could be attributable to the use of oto-endoscope and the much smaller sample size in the study by Sharma et al.[16,17]

The EAC angle measurements done by McRackan et al. were 20.55 degrees in children and 24.48 degrees in adults.[20] In the current review, Kashio et al. and Kang et al. [13,14] had significant results with better round visibility with wider EAC, and, hence, easy RW insertion. Both authors were working with a study population consisting of paediatric and adult implant recipients. On the other hand, Fouad et al. could not demonstrate a difference in EAC angle and RW insertion, which could possibly be because of a homogenous sample of paediatric ears only.[12]

Distance between the RW and FN has been considered an important predictor of RW visualisation in both adult and paediatric groups in studies by Fouad et al.[12] and Kang et al.[13] A difference in RW-FN measurement in the two studies can be explained by the way the distance was measured. In Fouad et al.[12], the distance was taken from the centre point of RW and through FN. In Kang et al[13], the measurements were taken from the posterior edge of the FN and the RW.

The distance between the cochlear basal turn and FN was evaluated by Fouad et al. and Kashio et al.[12,14], and both the studies rated the intraoperative ease of visibility as per the St. Thomas Hospital classification[8] into four groups, while Kang et al.[13] simply divided the intraoperative visibility into RW and PC groups. Fouad et al. and Kashio et al. concluded it was a statistically significant predictor of RW visibility.[12.14] Kang et al.[13] did not come up with BF as a possible predictor of RW visibility. This is possible in part owing to the measurement method. Kang et al. took an oblique distance between the CBT and FN, while Fouad et al. and Kashio et al. obtained a vertical BF measurement.[12-14]

The prediction line was studied by Fouad et al. and Kashio et al. with contrasting results. Fouad et al. did not conclude any statistical significance of the prediction line with RWM visibility. Kashio et al. concluded that the relationship of the intersection with RWM was categorised as an anterior, middle and posterior intersection, where the extremes represented invisible and visible RWM, respectively. The more anterior the prediction line, the higher the chances of having an invisible RW, while the chances of RW visibility increased as the prediction line passed through the middle and posterior aspect of RW.[12,14]

Even in extended RW approach, the level of hearing preservation has been reported to be moderate.[21] Hence, whether a pre-curved slim modiolar or straight electrode is chosen, the RW approach is the desired choice for insertion. A preoperative assessment of the anatomical landmarks can help in decision-making and appropriate expectations in hearing preservation cochlear implants.[21,22]

The current review comprehensively covers all the predictors that have been studied. However, there were certain limitations including the lack of segregation based on RWM versus niche visibility. The data reported by various authors differed, therefore, increasing the heterogeneity. Intraoperative visibility of RWM was not reported uniformly according to any one classification system. In addition, the majority of the studies under consideration evaluated the paediatric age group, and only a few studies also considered the adult population.[11-14,16,17] The current review could not identify any predictors for age groups due to limited data.

Due to heterogeneity of the different predictors studied on preoperative CT scans and a variety of classifications of intraoperative RW visualisation, meta-analysis was not possible in the current review. Data heterogeneity also compromised the level of evidence in the studies included, and differences in defining the terminology. Some of the studies also differed in terms of design.

The review is intended to streamline the existing literature and to guide prospective studies to make a direct comparison between existing variables in order to help the CI surgeons in nascence to better approach their patients. The review can also form the basis of improved preoperative counselling by surgeons to appropriately explain risks, and to eventually improve the process of informed consent.

Conclusion

FR width had no significant use in defining intraoperative visibility. Furthermore, the use of the distance between RW facial nerve (RF), the alpha angle, the beta angle, and the prediction line were found to be of significance. These parameters can add to the quality of preoperative surgical planning, can help in preoperative counselling, direct future studies, and improve intraoperative anticipation of landmarks.

Acknowledgement: We are grateful to Mr Khwaja Mustafa, the university librarian, for facilitating literature search.

Disclaimer: None.

Conflict of Interest: None.

Source of Funding: None.

References

1. Goman AM, Reed NS, Lin FR. Addressing estimated hearing loss in adults in 2060. JAMA Otolaryngol Head Neck Surg 2017;143:733-4. doi: 10.1001/jamaoto.2016.4642
2. Avasarala VS, Jinka SK, Jeyakumar A, Avasarala VS. Complications of cochleostomy versus round window surgical approaches: a systematic review and meta-analysis. Cureus 2022;14:e25454. doi: 10.7759/cureus.25454
3. Jangra A, Das KN, Sharma V, Timmaraju S, Khera P, Tiwari S, et al. Comparison of depth of electrode insertion between cochleostomy and round window approach: a cadaveric study. Eur Arch Otorhinolaryngol 2024;281:3547-55. doi: 10.1007/s00405-024-08549-3
4. Aljazeeri I, Alturaiki S, Abdelsamad Y, Alzhrani F, Hagr A. Various approaches to the round window for cochlear implantation: a systematic review. J Laryngol Otol 2023;137:1064-82. doi: 10.1017/S0022215123001593
5. Sharma V, Mohan V, Soni K, Goyal A. Comparison of long-term speech and impedance outcome of cochlear implantation in prelingual deaf paediatric patients between cochleostomy and round window insertion. J Laryngol Otol 2024;138:1-8. doi: 10.1017/S0022215124000301
6. Stuermer K, Winter T, Nachtsheim L, Schubert AD, Lenarz T, Maier H. Round window accessibility during cochlear implantation. Eur Arch Otorhinolaryngol 2021;278:363-70. doi: 10.1007/s00405-020-06095-4
7. Jwair S, van Eijden JJ, Blijleven EE, Dankbaar JW, Thomeer HG. Radiological and surgical aspects of round window visibility during cochlear implantation: a retrospective analysis. Eur Arch

Otorhinolaryngol 2022;279:67-74. doi: 10.1007/s00405-021-06783-5
8. Leong AC, Jiang D, Agger A, Fitzgerald-O'Connor A. Evaluation of round window accessibility to cochlear implant insertion. Eur Arch Otorhinolaryngol 2013;270:1237-42. doi: 10.1007/s00405-012-2106-4
9. Teszler CB, Ruimi D, Bar-Meir E, Eviatar E, Gavriel H, Halperin D. Width of the extended facial recess: a numerical study of ultrahigh-resolution computed tomography and its implications in minimally invasive otologic surgery. Otol Neurotol 2005;26:782-9. doi: 10.1097/01.mao.0000178141.04601.dc
10. Radomska K, Mielnik M, Gostyński M, Dzięciołowska-Baran E. Objective evaluation using computed tomography of round window access for cochlear implantation. Eur Arch Otorhinolaryngol 2024;281:6367-76. doi: 10.1007/s00405-024-08672-1
11. Chen J, Wu Y, Shi J, Zhang L, Wang Y, Liu H. Predictors of round window membrane visibility in pediatric cochlear implant surgery using temporal bone HRCT: a retrospective study. Int J Pediatr Otorhinolaryngol 2019;121:150-3. doi: 10.1016/j.ijporl.2019.03.017
12. Fouad YA, Elaassar AS, El-Anwar MW, Yacout YM, Khazbak AO. Role of multislice CT imaging in predicting the visibility of the round window in pediatric cochlear implantation. Otol Neurotol 2017;38:1097-103. doi: 10.1097/MAO.0000000000001493
13. Kang JY, Chung JH, Park HS, Lee SH, Park CW, Kim SJ. Radiological parameters related to success of the round window approach in cochlear implantation: a retrospective study. Clin Otolaryngol 2018;43:1535-40. doi: 10.1111/coa.13207
14. Kashio A, Sakamoto T, Karino S, Kakigi A, Yamasoba T. Predicting round window niche visibility via the facial recess using high-resolution computed tomography. Otol Neurotol 2015;36:18-23. doi: 10.1097/MAO.0000000000000644
15. Bettman RH, Appelman AM, van Olphen AF, Graamans K. Cochlear orientation and dimensions of the facial recess in cochlear implantation. ORL J Otorhinolaryngol Relat Spec 2003;65:353-8. doi: 10.1159/000076054
16. Sharma R, Meher R, Passey JC, Bansal A, Sood S. Comparative evaluation of round window niche accessibility pre-operatively on high-resolution computed tomography of the temporal bone with intra-operative findings. J Laryngol Otol 2019;133:575-9. doi: 10.1017/S0022215119001269
17. Xie LH, Tang J, Miao WJ, Zhang Y, Chen Y, Li Y. Preoperative evaluation of cochlear implantation through the round window membrane in the facial recess using high-resolution computed tomography. Surg Radiol Anat 2018;40:705-11. doi: 10.1007/s00276-018-1972-x
18. Jeffery N, Spoor F. Prenatal growth and development of the modern human labyrinth. J Anat 2004;204:71-92. doi: 10.1111/j.1469-7580.2004.00250.x
19. Lloyd SK, Kasbekar AV, Kenway B, Moffat DA, Irving RM. Developmental changes in cochlear orientation—implications for cochlear implantation. Otol Neurotol 2010;31:902-7. doi: 10.1097/MAO.0b013e3181db7146
20. McRackan TR, Reda FA, Rivas A, Wanna GB, Haynes DS. Comparison of cochlear implant relevant anatomy in children versus adults. Otol Neurotol 2012;33:328-34. doi: 10.1097/MAO.0b013e318245cc9f
21. Klabbers TM, Heutink F, Huinck WJ, van der Woude WJ, Verbist BM, Mylanus EAM. Intracochlear electrode array position and cochlear implant outcomes using the nucleus slim modiolar electrode and the extended round window approach: a follow-up study. Eur Arch Otorhinolaryngol 2022;279:4735-43. doi: 10.1007/s00405-022-07376-4