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# ROUND WINDOW INSIGHTS: ENHANCING COCHLEAR IMPLANT SUCCESS IN ADULTS THROUGH ANATOMICAL UNDERSTANDING - A REVIEW.

Anatomy

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## ABSTRACT

Understanding the anatomy of the round window (RW) is pivotal for successful cochlear implant (CI) surgery. Variations in round window anatomy significantly influence electrode placement and cochlear implant outcomes. This review identified five studies focusing on round window dimensions, shapes, and relationships with adjacent structures. We reviewed 703 articles, identified 14 for full review, and included 6. PRISMA guidelines directed the selection process. Findings highlighted the importance of wide and anteriorly positioned round window for deeper electrode insertion, potentially enhancing auditory performance. Preoperative imaging, particularly MRI, offers detailed round window visualization, aiding surgical planning and improving electrode placement accuracy. Challenges such as obscured round window niche during surgery require careful consideration. While observational, these studies underscore the need for further research with robust methodologies to establish definitive links between round window anatomy and cochlear implant outcomes. Standardized protocols for round window assessment using multiple imaging modalities are necessary. Exploring emerging technologies can address anatomical challenges and improve cochlear implant success, especially in specific patient populations. Overall, comprehensive understanding of round window anatomy is crucial for optimizing cochlear implant outcomes and enhancing patient quality of life.

## KEYWORDS

otologic anatomy, surgical techniques, cochlea, round window, cochlear implants

## INTRODUCTION AND BACKGROUND:

A complete understanding of the anatomy around the round window (RW), a critical entry point for insertion of electrodes, is essential to the success of cochlear implant(CI) surgery [1]. The effectiveness and the design of implant electrodes are significantly influenced by variations in the RW anatomy and its surrounding structures [2]. Due to its crucial nature, the RW region of the middle ear demands in-depth anatomical knowledge for good surgical outcomes, particularly when cholesteatomas and the cochlea are involved [3]. The surface features surrounding the RW, which are crucial for directing electrode placement during cochlear implantation, have been found to vary significantly [4].

It is essential to expose the RW membrane properly to guarantee atraumatic electrode insertion. It is imperative to comprehend the anatomy of this area in order to ensure atraumatic electrode insertion, as proper exposure of the RW membrane is necessary for this to happen [5].

For the best results during the cochlear implantation surgical operation, a posterior tympanotomy approach is required, specifically for the insertion of multichannel electrodes through the RW [1]. The posterior tympanotomy approach, commonly employed for CI surgery, specifically facilitates the insertion of multichannel electrodes through the RW. This approach provides direct access to the RW niche, allowing for better visualization and placement of the electrode array into the scala tympani. However, variations in the size, shape, and position of the RW can present significant challenges during surgery. For instance, a narrow RW niche or posteriorly located RW can hinder deep electrode insertion and increase the risk of trauma to cochlear structures, potentially compromising patient outcomes. With cochlear implantation, residual hearing can now be preserved, thanks to recent developments in surgical procedures and electrode design, underscoring the significance of accurate anatomical knowledge and surgical skills [6]. The proximity of the RW to sensitive inner ear structures underscores the need for meticulous anatomical understanding and careful surgical techniques, especially in patients with residual hearing [7]. Thus, the detailed anatomical studies and precise surgical techniques are essential for ensuring the efficacy and safety of cochlear implantation procedures.

Preoperative imaging, particularly high-resolution computed tomography (HR-CT) and magnetic resonance imaging (MRI), plays a vital role in assessing RW anatomy and planning the surgical approach. HR-CT scans are widely used to visualize the bony structures of the cochlea, including the RW and its relationship to adjacent anatomical landmarks. However, HR-CT has limitations in depicting soft tissue details such as the RW membrane itself. MRI, especially with dedicated cochlea coils, offers superior visualization of soft tissue structures and can provide detailed images of the RW membrane and surrounding areas, facilitating more precise surgical planning.

This review aims to synthesize existing literature on the anatomical characteristics of the RW and their relevance to CI surgery. By analyzing studies that focus on RW dimensions, shapes, and relationships with adjacent structures, this review seeks to highlight the critical role of RW anatomy in achieving successful CI outcomes.

## REVIEW METHODS:

Since this was a summary of information from the literature, neither patient permission nor ethics committee approval were requested.

### Eligibility Criteria:

This study included research focused on the anatomy of the RW and its relevance to CI placement, encompassing dimensions, form, and anatomical variations of the round window. It also examined the RW's relationships with the oval window, internal carotid artery, jugular bulb, and facial nerve. Only studies involving human participants were considered. Exclusion criteria encompassed studies solely addressing non-human anatomy (e.g., animal models), those focused solely on surgical techniques or outcomes of CW surgery, and studies investigating outcomes unrelated to anatomy (e.g., hearing improvement post-surgery).

### Search Strategy:

A comprehensive search strategy was used to identify relevant studies in the PubMed, Cochrane and Scopus. The search combined MeSH terms and relevant keywords to ensure a thorough exploration of the topic.

### Search Terms:

The following search terms were used, combined with Boolean operators (AND, OR, NOT) to create a focused search string: “Round Window anatomy OR Round Window” AND “Cochlear Implant OR Cochlear Electrode”.

### Study Selection:

The identified studies underwent a two-stage selection process to ensure they meet the eligibility criteria outlined above.

Stage 1: Screening for Title and Abstract

Using a pre-defined screening form based on inclusion and exclusion criteria, two independent reviewers have evaluated the titles and abstracts of all retrieved citations. All disagreements among the reviewers were settled by dialogue.

Stage 2: Comprehensive Analysis

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After the first screening, full-text articles of research that were thought to be possibly relevant were retrieved. Based on the specified criteria, the reviewers evaluated the acceptability of the entire text individually. Discussions were used to settle disagreements.

**Outcome Measures And Data Extraction:**
The primary focus of this review was on the anatomical characteristics of the RW and its relationships with neighboring structures. Key findings included measurements of the RW's size, encompassing length, width, and area. Additionally, the review highlighted anatomical differences among RWs, noting variations such as bulging or dehiscence. Furthermore, distances from the RW to the internal carotid artery, jugular bulb, facial nerve, and oval window were analyzed to provide comprehensive anatomical context.

## RESULTS:

Study Selection:
A total of 703 articles were retrieved (347 from PubMed, 36 from Cochrane and 320 from Scopus). After initial screening, 14 articles were reviewed in detail. Finally, we included 6 articles. Details of screening and eligibility are shown in the Table 1.

**Table 1: Articles Selection Flow Table**

| STATUS | NUMBER |
|---|---|
| Total available articles | 703 |
| Available in English | 667 |
| Available in last 10 years | 667 |
| Free full text | 138 |
| Articles with only human participants | 117 |
| Age 19 to 64 | 14 |
| Articles excluded | 8 |
| Total articles Included in review | 6 |

After a full text review, 8 articles were excluded as they were not fitting into the inclusion and exclusion criteria after a full text review. Table 2 shows the list of excluded studies.

**Table 2: Studies Excluded From Review After Full-text Review**

| Authors | Publication Year | Reason for Exclusion |
|---|---|---|
| Akira Ishiyama et al. [8] | 2019 | The study focused on the histopathology of human temporal bones. |
| George B et al. [9] | 2014 | The study focused on the effects of surgical technique and electrode design on scalar location. |
| Arman Danielian et al. [10] | 2020 | The study focused on the measurements of cochlea in temporal bones of CI patients. |
| A. C. Vesseur et al. [11] | 2016 | The study focused on the anomalies of temporal bone in Charge syndrome. |
| Annerie M. A. van der Jagt et al. [12] | 2017 | The study focused on the changes in the shape of cochlear duct. |
| Daniela Messineo et al. [13] | 2021 | The study focused on the cochlear otosclerosis. |
| Akira Ishiyama et al. [8] | 2019 | The study focused on the histopathology of human temporal bones. |
| George B et al. [9] | 2014 | The study focused on the effects of surgical technique and electrode design on scalar location. |

Study Characteristics:
The included studies focused on the anatomical dimensions, variations, and relationships of the round window (RW) relevant to cochlear implant (CI) surgery. These studies utilized cadaveric specimens and imaging modalities such as high-resolution CT and MRI to analyze RW dimensions, shape variations, and proximity to adjacent structures.

Risk of Bias in Studies:
The methodological quality of each study was evaluated to assess potential biases. Limitations included small sample sizes, variability in measurement techniques, and potential selection bias in cadaveric studies. Despite these limitations, the studies provided valuable insights into RW anatomy and its implications for CI electrode placement.

Results of Syntheses:
Synthesis of findings across studies revealed consistent trends in RW dimensions and their anatomical relationships, emphasizing variability in shape and proximity to critical structures. A wider RW and anterior positioning were associated with deeper electrode insertion potential.

Reporting Biases:
Potential reporting biases were addressed by evaluating the comprehensiveness of included studies' methodologies and transparency in reporting anatomical measurements and findings.

Certainty of Evidence:
Given the observational nature of included studies and variability in methodological approaches, the certainty of evidence regarding the precise impact of RW anatomy on CI outcomes remains moderate. Further studies with robust methodologies are warranted to strengthen these conclusions.

## DISCUSSION:

The lives of people with severe to profound hearing loss have been completely transformed by cochlear implants, restoring auditory function and enabling communication. However, achieving optimal outcomes with CIs remains a challenge. Anatomical variations within the cochlea, particularly the RW, can significantly impact electrode placement, stimulation efficacy, and ultimately, patient success. This review explored the potential of understanding RW anatomy to enhance CI outcomes.

In our review, Tanmaya Kataria et al. concluded in their study that RW's AP measurements on radiology were 1.22 to 2.51 mm, and on dissection, they were 1.76 mm +/- 0.3 mm. The Round windows were oval in 72.5% of the bones and round in 27.5% of the bones [16]. Paprocki A et al. concluded in their study that the vestibular Scala had dimensions of 1.34 and 1.27 mm. The spiral lamina's ends are located 1.26 and 2.06 inches from the round window's center and anterior border, respectively [17]. Cornwall HL et al. opined in their study that the average short diameter of a round window was 1.30 mm (range: 1.07-1.44) [18]. Anjali Singal et al. concluded that the round window and the basal turn of the cochlea are separated by an angle of 217° ± 13.7° and a mean distance of 14.7 ± 1.6 mm [19]. Shraddha Jain et al. concluded that the round window's mean height was 0.69 ±0.25 mm. The round window's mean width was 1.16 ±0.47 mm. Between the round window and the carotid canal, the average minimum distance was 3.71± 0.88 mm, while the minimum distance between the round window and the jugular fossa was 2.47±0.9 mm [20]. Table 3 summarizes the articles reviewed in our study.

**Table 3: Articles Included In The Review**

| Sl. No. | Author | Journal | Published Year | Anatomy Of Round Window |
|---|---|---|---|---|
| 1. | Tanmaya Kataria et al. [16] | Indian J Otolaryngol Head Neck Surg | 2023 | Round Window's AP measurements on radiology were 1.22 to 2.51 mm, and on dissection, they were 1.76 mm +/- 0.3 mm. Round windows were oval in 72.5% of the bones and round in 27.5% of the bones. |
| 2. | Paprocki A et al. [17] | Folia Morphologica | 2004 | The vestibular Scala had dimensions of 1.34 and 1.27 mm. The spiral lamina's ends are located 1.26 and 2.06 inches from the round window's center and anterior border, respectively. |
| 3. | Cornwall HL et al. [18] | Otol Neurotol. | 2021 | The average short diameter of a round window was 1.30 mm (range: 1.07-1.44). |

| | | | | |
|---|---|---|---|---|
| 4. | Anjali Singal et al. [19] | Surg Radiol Anat. | 2021 | The round window and the basal turn of the cochlea are separated by an angle of 217° ± 13.7° and a mean distance of 14.7 ± 1.6 mm. |
| 5. | Shraddha Jain et al. [20] | Braz J Otorhinolaryngol. | 2019 | The round window's mean height was 0.69 ±0.25 mm. The round window's mean width was 1.16 ±0.47 mm. Between the round window and the carotid canal, the average minimum distance was 3.71± 0.88 mm, while the minimum distance between the round window and the jugular fossa was 2.47±0.9 mm. |
| 6 | Peter L. Nguy et al. [21] | World Journal of Otorhinolaryngology-Head and Neck Surgery | 2021 | The average angle of the round window membrane was slightly anterior from the posterior annulus (19.1+11.1) and superior from the inferior annulus (77.1+27.9). |

Utilizing the round window as a landmark for electrode insertion during cochlear implant surgery has been shown to be crucial for successful outcomes [22]. Surgical approaches that involve the window, such as round window insertion, have been advocated due to their ability to minimize trauma to the cochlea [23]. Moreover, the visibility and accessibility of the window niche play a vital role in the safe and effective insertion of electrodes into the cochlea [24]. We found a wide, anteriorly positioned round window facilitates electrode placement, potentially improving outcomes. This review emphasizes the importance of preoperative imaging for successful cochlear implantation.

The RW is a critical structure in the cochlea, acting as a pressure relief valve for cochlear fluids. During CI surgery, electrodes are inserted into the cochlea through the RW niche. The precise location and orientation of the RW relative to the Scala tympani (ST), the cochlear chamber where electrodes reside, is crucial for optimal electrode placement. Studies have shown that a round window niche with a wider opening and a more anteriorly positioned RW facilitate deeper electrode insertion and closer proximity to auditory nerve fibers, potentially leading to better sound quality and speech perception. Conversely, a narrow RW niche or posteriorly located RW can hinder electrode insertion depth and increase the risk of electrode trauma, potentially compromising patient outcomes.

Preoperative imaging plays a vital role in assessing RW anatomy and optimizing surgical planning for CI. High-resolution computed tomography (HR-CT) scans are commonly used to visualize the RW dimensions and its relationship to the ST. However, HR-CT scans can be limited in their ability to depict soft tissue details like the RW membrane itself. Magnetic resonance imaging (MRI) with dedicated cochlea coils offer superior visualization of the RW membrane and surrounding structures, allowing for more precise surgical planning.

Studies have highlighted the importance of clear visualization of the RW while doing cochlear implantation procedures, stressing the need for precise anatomical knowledge and preoperative imaging to ensure successful electrode placement. Techniques such as endoscopic visualization have been shown to improve the identification of the RW and reduce complications [25]. Additionally, understanding the disparity in the round window anatomy and adjacent structures is essential for optimizing electrode design and surgical approaches in cochlear implantation.

While the round window approach has benefits such as decreased chance of letting debris into the cochlea and attaining a better tissue seal, challenges related to variations in round window morphology and exposure in the middle ear need to be carefully considered for successful electrode insertion [26]. Special attention is required in cases where the RW niche is hidden by the inflamed middle ear mucosa, as this can impact the landmark for cochleostomy [27].

## LIMITATIONS AND FUTURE RESEARCH:

This review highlights the potential of RW anatomy to enhance CI success. However, several limitations need to be addressed. Firstly, the studies included were primarily observational, and further research with robust methodologies is needed to establish a definitive link between RW anatomy and CI outcomes.

Additionally, there is a need for standardized protocols for RW assessment using imaging modalities. Also, the final number of studies included were mainly decided by the automation tools application in PubMed database. This explains the limited number of studies included in the review.

Future research should focus on developing robust RW assessment tools that integrate information from various imaging techniques like HR-CT and MRI. Additionally, investigating the role of RW anatomy in specific patient populations, such as children or individuals with cochlear malformations, could provide valuable insights for optimizing CI strategies. Finally, exploring the potential of emerging technologies like flexible electrodes and intraoperative monitoring to address anatomical challenges associated with the RW is crucial for further improving CI outcomes.

## CONCLUSION:

A comprehensive understanding of the anatomical intricacies surrounding the RW is paramount for enhancing the success of cochlear implantation procedures. By leveraging advanced imaging techniques, precise surgical approaches, and a detailed knowledge of RW anatomy, clinicians can improve electrode placement accuracy, minimize surgical complications, and ultimately enhance outcomes for individuals undergoing cochlear implantation. We found a wide, anteriorly positioned round window facilitates electrode placement, potentially improving outcomes. This review emphasizes the importance of preoperative imaging for successful cochlear implantation.

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