Access to Round Window Niche via Posterior Tympanotomy and Impact of Drilling Its Overhangs: A Cadaveric Descriptive Study

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Abstract We intended to study the morphological parameters of round window region and assess the gain in exposure achieved by drilling the round window niche overhang. The Exposure of the round window membrane (RWM) is of prime importance to carry out atraumatic electrode insertion for cochlear implantation. The anatomy of round window has been a subject of considerable debate in literature. Fifty-one Formalin preserved adult cadaveric temporal bones were micro-dissected to carry out an ‘optimal’ posterior tympanotomy to expose the round window region. The bony overhangs of round window niche (RWN) were next drilled to achieve maximal possible exposure the RWM without violating the annulus of the same. The exposure was classified as per St Thomas’ Hospital classification. The round window could not be visualized in 3 bones (5.9%). The commonest morphology of RWN was dome shaped, found in 18 (37.5%) and that of the RWM was oval shaped, found in 14 (29.2%) bones. Pre drilling 41 bones had a > 50% exposure of RWM while post drilling > 50% exposure could be achieved in all the bones except the 3 bones in which RWN could not be visualized to begin with. The drilling of the RWN overhangs exposed RWM in entirety in 91.7% of bones with a visible morphology of RWN pre drilling. RWN and RWM exhibit varied morphology. Drilling of the round window

niche overhangs can considerably enhance the exposure of RWM.

Keywords Round window niche · Posterior tympanotomy · Cochlear implantation · Crista semilunaris

Introduction

Anatomy of Round window niche (RWN) and Round window membrane (RWM) shows numerous variations and has been described in details in the literature. There has been extensive debate regarding the true shape of RWM. The round window was thoroughly described by Antonio Scarpa in 1772, who named it as the secondary tympanic membrane in view of its conical shape [1]. There have been multiple studies since then debating over the shape and configuration of RWN/RWM. The RWM acts as semipermeable membrane at the entrance to the inner ear and may be affected by various pathological conditions involving middle ear [2]. This very nature of the RWM helps with the transtympanic delivery of drugs to the inner ear in cases of Meniere’s disease, Sudden Sensorineural hearing loss and in patients with tinnitus.

The round window was used as the natural portal for insertion of the cochlear implants in the initial days of development and establishment of the technique. However, the anatomical difficulties and problems of variable exposure of membrane and restriction imposed by crista situated anteroinferiorly, to the entry into scala tympani led to development of alternate more straightforward and accommodative approach of drilling a cochleostomy in the basal turn for intracochlear electrode insertion. However, with the current emphasis on residual hearing preservation

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and Electroacoustic stimulation (EAS), the round window has been revived as a doorway to electrode insertion [3].

A thorough knowledge of anatomical intricacies and variations pertaining the RWN/RWM and surrounding structures is a must to obtain desirable excellency in the surgical results. There are many studies elaborating the anatomical intricacies of the Round Window region [4–7]. The current study highlights the variable anatomy of RWN/RWM region as seen from the standard posterior tympanotomy approach and the effects of drilling the RWN overhangs on exposure of the RWM.

Materials and Methods

Study Design

The study was a cadaveric human temporal bone study.

Ethical Consideration

With the permission of Institutional Review Board (IRB), temporal bones were harvested from de-identified adult human cadavers.

Study Sample

Fresh cadaveric temporal bones were obtained from the department of Forensic Medicine and Toxicology, and dissected systematically at temporal bone dissection lab using standard otologic instruments and drill under microscopic view with Leica M320 F12 microscope. The age and gender of the cadavers were unknown.

Dissection Steps and Data Collection

After positioning the bones in House—Urban temporal bone holder, under microscope, a complete mastoidectomy was done and an optimal posterior tympanotomy was carried out preserving a thin bone shell over facial nerve and chorda tympani till the chordo-facial angle. Superiorly an incus bar was preserved. Through this wide posterior tympanotomy, the round window niche (RWN) was visualized and the view affording maximal visualization of round window membrane was photographed at 10 × magnification. Next, the posterosuperior overhang, and when needed anteroinferior overhang of RWN was drilled, preserving the annulus of RWM and without violating the perilymphatic space, to achieve maximum exposure of round window membrane (RWM). Another snapshot was taken at same field of view, orientation and magnification in view as was done before drilling. If despite this drilling, complete exposure of RWM could not

be achieved; further bony drilling was done till RWM was visualized in entirety, violating perilymphatic space, if needed. The pre/post drilling views were compared and improvement in exposure post drilling was recorded keeping fully exposed RWM as reference. Following parameters were noted:

1. Shape of RWN.
2. Shape of RWM.
3. RWM area visible *before* drilling the overhangs (compared to fully exposed RWM).
4. RWM area visible *after* drilling the overhangs (compared to fully exposed RWM).
5. Presence of Crista Semilunaris.

Pre drilling exposure of RWM was classified as Grade 0 (RWN/RWM not visible), Grade 1 (< 50% of RWM visible), Grade 2 (50–75% of RWM visible) and Grade 3 (> 75% of RWM visible), while post drilling classified as per the St Thomas' Hospital (STH) classification detailed in Table 1. It classifies the exposure of RWM after adequate drilling of RWN overhang via an optimal posterior tympanotomy. Type 1 refers to complete exposure of RWM while type 2 refers to a subtotal exposure. In type 2a, RWM is exposed $\geq 50\%$, while in type 2b, the round window exposure is < 50%. When the RWM cannot be seen despite adequate drilling, its classified as a type 3 exposure. The effect of drilling the overhangs over the area of RWM exposed is shown in Fig. 1.

The data was analyzed using Microsoft Excel 2016 for Mac (version 15.12.3).

Results

A total of Fifty-one cadaveric temporal bones were dissected. Twenty-six were right sided and twenty-five were left sided. When carrying out posterior tympanotomy, a 'herald cell' was identified in twenty-two bones (43.1%). The RWN and RWM could be identified in forty-eight bones (94.1%), and were unidentifiable in three bones

Table 1 Round window Membrane Visibility via posterior tympanotomy (% of area exposed compared to fully exposed RWM)

Before drilling overhang (n = 51)	After drilling overhang (n = 51)
Grade 0 (not visible)—3 (5.9%)	STH type 1 (100%)—44 (86.3%)
Grade 1 (< 50%)—7 (13.7%)	STH type 2a ($\geq 50\%$)—4 (7.8%)
Grade 2 (50–75%)—24 (47%)	STH type 2b (< 50%)—0
Grade 3 (> 75%)—17 (33.3%)	STH type 3 (not visible)—3 (5.9%)

STH St Thomas' Hospital, RWM round window membrane

Fig. 1 Illustrative images of Round Window exposure pre drilling (left) and post drilling (right). The round window areas have been encircled in the magnifier

Table 2 Shape of the RWN

Shape of RWN	Number (n = 48)
Dome shaped	18 (37.5%)
Triangular	12 (25%)
Pear shaped	7 (14.6%)
Bean shaped	4 (8.3%)
Oval	4 (8.3%)
Round	2 (4.2%)
Keyhole shaped	1 (2%)

RWM round window membrane

(5.9%) despite a wide and optimal posterior tympanotomy. Table 2 lists the shapes of RWN identified in the forty-eight bones. The commonest shape encountered was dome shape, observed in 37.5% of bones. Various shapes of RWN are depicted in Fig. 2.

The area of round window membrane visible before and after drilling the overhang was compared with the fully exposed round window membrane. Out of fifty-one bones, only one bone had a pre-drilling fully exposed RWM, while forty-one bones had an exposure of > 50%. Barring the three bones, in which the RWN/RWM could not be visualized to begin with, in all of our specimen, > 50% exposure of RWM could be achieved and a 100% exposure could be achieved in forty-four bones. After drilling down all the bony overhangs, the RWM shape was noted down. The various shapes are tabulated in Table 3 and shown in Fig. 3. The commonest observed shape was an oval shaped membrane (29.2%), while a pear shape was seen in 2 (4.2%) cases.

After exposure of the RWM, an observation was made regarding the presence of crista semilunaris. It was found to

be present in thirty-nine out of forty-eight cases (79.2%) and was located in an anteroinferior location immediately juxtaluminal to the RWM.

Discussion

Interest in round window as a portal to insertion of cochlear implant has been revived with the advent of electroacoustic stimulation. Insertion of electrode via round window is considered to be less traumatic compared to bony cochleostomy. Also electrodes cover around 2 mm area of the basal neural elements which would be otherwise spared with the cochleostomy technique [8]. The anatomy of RWN/RWM bears a direct impact on the success of implant electrode insertion and resulting acoustic/speech rehabilitation of the implantees.

Traditionally the implantation has been done via a mastoidectomy and posterior tympanotomy approach. The view of RWM via a posterior tympanotomy affords considerable variability and despite an optimally done posterior tympanotomy, may not give adequate exposure as a result of narrow facial recess or a posteriorly placed morphology of RWN. In our study, we found three cases of a hidden RWN situated posteriorly with respect to the view afforded by a posterior tympanotomy in unselected adult cadaveric population, constituting ~ 6% of the total temporal bones. This situation creates a practical surgical dilemma and unanticipated change of surgical approach intraoperatively (for example transcanal approach or drillout of medial EAC with cartilage reconstruction).

We found the commonest shape of RWN to be Dome shaped (37.5%). Other shapes encountered included

Fig. 2 Various shapes of Round Window Niche

Table 3 Shape of RWM

Shape	Number (n = 48)
Oval	14 (29.2%)
Bean shaped	12 (25%)
Round	11 (22.9%)
Quadrangular	6 (12.5%)
Semi-colon shape	3 (6.3%)
Pear shaped	2 (4.2%)

RWM round window membrane

triangular, pear shaped, oval, round and keyhole-shaped. The most common shape of the RWM was oval (29.2%), followed by bean shaped (25%), round (22.9%),

quadrangular (12.5%), semicolon (6.3%) shaped and pear shaped (4.2%). The Keyhole-shaped RWN and Semicolon and pear shaped RWM have been described rarely in literature [9]. Well-documented in literature, the human RWN/RWM shapes demonstrate significant inter individual variability [4–6, 9]. The round window membrane has been described to be saddle like and likened to a chair in view of its non-planar, orthogonal and skewed configuration [5]. Bonaldi et al. [6] reported the most common shape of RWM to be triangular in shape while in the study by Singla et al. [9], the most common shape of RWM was oval. The round window niche has often been described to be triangular or prismatic in shape [7, 10].

The anterior/posterior pillars and roof of RWN results in partially hidden view of RWM such that when seen from a

Fig. 3 Various shapes of Round Window Membrane. **a** Round, **b** Oval, **c** Bean shaped, **d** Quadrangular

posterior tympanotomy, usually only the anterior part of RWM is visible. The implications are twofold. First, a narrow niche results in difficulty in negotiating the electrode during implantation and secondly, the posterosuperior bony overhang poses difficulty in passing the electrode along the axis of the cochlear basal turn and directs it towards the modiolus. Drilling of posterosuperior bony overhang results in wider exposure of RWM, however, care needs to be taken to avoid drilling too far posterosuperiorly to avoid damaging the spiral ligament and auditory neural elements. If further exposure is needed for safe and successful implant insertion, an ‘extended membranous cochleostomy’ can be done by anteroinferior drilling to extend the bony round window aperture.

In our study, if the RWN/RWM was partially visible pre drilling, a 100% exposure of RWM could be achieved in 91.7% of cases. Drilling the niche has been shown to typically increase the RWM visibility by a factor of 1.5–3 times [11]. Leong et al. [12] found that in 89% of adults and 78% of pediatric patients < 4 years’ age, > 50% exposure of RWM (STH type 1 and 2a) could be achieved. Cases with unfavorable exposure (< 50%, STH type 2b and 3) were twice as common in children as compared to adults. Its noteworthy that the maximal drilling of RWN overhangs is usually less than that required for a conventional cochleostomy [13].

Another “doorstep” to the entry of electrode into the cochlea, beyond the bony overhangs of RWN, is formed by the Crista semilunaris which is a bony prominence arising from the floor or anteroinferior part of the scala tympani, immediately medial (juxtaluminal) to the attachment of RWM. This bony prominence can cause deflection of the electrode towards basilar membrane and modiolus causing damage to the vital auditory neural elements and mix up of endolymph and perilymph resulting in immediate loss of any prospects of preservation of residual hearing. In our study, the Crista could be identified in thirty-nine out of forty-eight bones (81.3%) with identifiable RWN/RWM. The implication lies in the need to drill the Crista if prominent and causing deflection of the electrode away from intended trajectory. Drilling of the crista should be done with caution keeping in mind the close proximity (often < 0.5 mm) of canal for the cochlear aqueduct and vein of cochlear aqueduct (continuation of common modiolar vein), the damage to which could jeopardize the cochlear function and residual hearing [11].

Conclusion

Round Window anatomy is highly variable. Cases in which RWN cannot be identified may need an alternate approach for the cochlear implantation. Drilling the posterosuperior

overhang of RWN significantly improves RWM visibility and helps in complete insertion of the electrode array. Additional anteroinferior drilling may be needed for STH type 2b RWM exposure for adequate access.

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Compliance with Ethical Standards

Conflict of interest None declared.

Ethical Approval Ethical approval was obtained from the Institutional Ethical Committee.

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