Standardized Computed Tomographic Imaging and Dimensions of the Round-Window Niche

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Abstract: Both the increasing usage of intratympanic medication to the inner ear through the round window and the popularity of cochlear implantation have raised interest in the anatomy of the round-window niche (RWN). The objectives of this study were to measure the RWN and to standardize a computed tomographic projection for measuring it. We included patients of all ages who underwent computed tomography for various reasons. We measured computed tomographic images acquired from 214 patients aged 4–85 years and included 414 ears and excluded 14 inflamed "wet" ears. We measured depth, width, and shape of the RWN and skull width. The RWN dimensions did not change with age, whereas the skull width increased with age in both genders throughout the patients' entire life. Folds and soft tissue could not be demonstrated in computed tomographic imaging. In conclusion, a special oblique projection that clearly demonstrates the RWN was reconstructed, and this reconstruction allows for standardized measuring.

Key Words: computed tomography; operculum; round-window membrane; round-window niche; skull dimensions

The fine anatomy of the round-window niche (RWN) has been addressed recently in several publications [1–5]. Two recent developments—cochlear implantation [2–6] and intratympanic medication of the inner ear through the round-window (RW) membrane [7–11]—have increased interest in this anatomy and in the imaging of the RWN. Stewart and Belal [3] described the anatomy of the RW and mentioned the presence of membranes in the RWN but did not study them. In 1986, Proctor et al. [1] gave a thorough anatomical description of the RWN. Takahashi et al. [12] studied five temporal bones under computed tomography (CT) scan and calculated the dimensions and the volume of the RWN. Silverstein et al. [7] introduced the intratympanic treatment for Ménière's syndrome and sudden hearing loss. Alzamil and Linthicum [5] described in detail the presence of membranes and soft tissue inside the RWN in 32% of 202 temporal bones. Their findings question the efficacy and mechanism of intratympanic medication in obstructed RWNs. The variations in RWN dimensions found in the aforementioned articles and in others [13–17] initiated the need for an accurate imaging evaluation of the RWN anatomy. Evaluation of inner-ear anomalies is another aspect of the importance of the detailed study of the RWN. Standardizing a method of examination affords better correlation of the findings in various subjects. It is important also for comparison of data for research purposes. Studies based on CT evaluation have been published [12,18,19], but no standard method exists for evaluation. In this study, we assessed the RWN dimensions and analyzed whether and how they correlated to age.

STUDY DESIGN

We undertook a prospective study of CT scans of 214 patients referred for imaging as a part of their medical investigation. In the study, we included only CT scans of normal middle ears, with no evidence of inflammatory middle-ear disease in the patients' history and on the CT findings (such as effusion). Using imaging data acquired from routine basic CT acquisitions and without additional radiation or positions, we processed special

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Figure 1. Oblique reconstruction of the internal ear showing the oval and round windows in the same plane. The operculum is seen between the two windows.

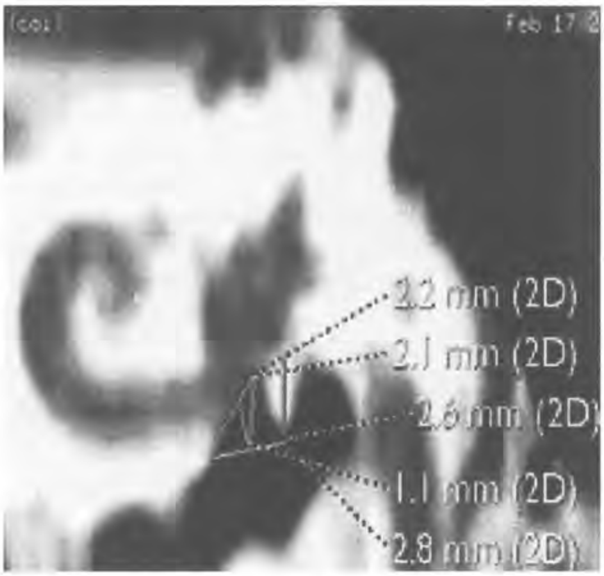

Figure 2. Oblique reconstruction centered to the round window, with measurements.

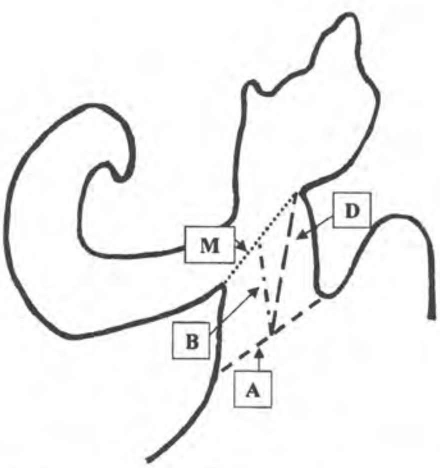

Figure 3. Parameters measured. (*A* = distance between promontory and operculum; *B* = length; *D* = air depth; *M* = round-window membrane.)

enlarged views of the RWN for evaluation. We carried out a correlation between the RWN size and skull width in all age groups and analyzed several parameters.

TERMINOLOGY

A clear anatomical description of the RWN is described in an article by Proctor et al. [1]. The structure overhanging the niche from its lateral aspect was referred to only as *anteroinferior overhang* in that article and was not named in another by Frantz et al. [2]. This overhang is a prominent structure in the presented CT view that we used for the RWN. We called this structure the *operculum* (Figs. 1–3).

TECHNIQUE

We performed all CT studies with a fast (four-slice) helical CT scanner (Lightspeed Plus, GE Medical Systems, Milwaukee, USA). The examination parameters included 1.2 mm collimation, 120 kV, 120 mA at 0.8 seconds, gantry rotation, pitch of 0.75, and a high-detail reconstruction algorithm (Bone Plus, GE). We conducted image postprocessing after transferring all images to a workstation (Advantage Windows adw4.0, GE). For each ear, we performed oblique multiplanar reconstruction (MPR) in the plane parallel to the posterior semicircular canal and centered to the RW. We then used the produced MPR images for orthogonal two-dimensional measurements of the RW and adjacent recess (Fig. 4; see also Figs. 1–3).

Figure 4. Creating an oblique reconstruction in a plane parallel to the posterior semicircular canal–basal turn of the cochlea.

DATA AND MEASUREMENTS

We collected measurements of width, length, angle, and shape (conical or cylindrical; see Figs. 2,3). The measurements were obtained as follows:

- RW membrane: the distance between the bony edges of the RW opening.
- Operculum width: the distance between the maximal convexity on the promontory and the end of the operculum. The point of maximal convexity, as opposed to an arbitrary point on the bony wall opposite the end of the operculum, was easy to define (see Fig. 3). Many variations were found in this opposite wall that made it difficult in some cases to locate an exact point. The maximal convexity point, therefore, was found to be useful.
- RWN length: the distance between the middle of the operculum width and the deepest part of the RWN.
- RWN air depth: the distance between the middle of the operculum width and the middle of the RW membrane.
- Operculum width: measurement of the larger biparietal diameter of the skull in each patient's axial projection.

The measurements presented are arbitrary, although they could represent some typical parameters of the RWN dimensions as demonstrated in the CT scan. The points from which the measurements were taken were those that could be easily identified in the CT image.

RESULTS

We collected data from 214 patients (428 ears) and excluded ears with an inflammatory condition (n = 14) to avoid false results. In patients who had a unilateral middle-ear disease, we included the contralateral normal ears. A total of 414 ears were included in the study and were analyzed.

The male-female ratio was 52% to 48%. The patients' age distribution was 47.7 ± 21 years (range, 4–85 years). We observed no difference between right and left sides. The shape was conical in 92% of the ears and cylindrical in 8%. The referral diagnoses were ver-

Table 1. Subjects' Age, Skull Width, and Dimensions of the Round-Window Niche, According to Gender

	Mean	SD	Minimum	Maximum	*p* Value
Age (yr)					
All	47.7	21.0	4	85	—
Male	43.1	21.2	4	83	—
Female	52.2	19.9	5	85	< .0001
Skull width					
All	132.76	8.266	107.0	153.0	—
Male	135.067	8.29	110	153	—
Female	130.308	7.52	107	145	< .0001
Membrane width[a]					
All	1.583	0.276	0.90	2.70	—
Male	1.619	0.295	0.90	2.70	—
Female	1.545	0.250	0.90	2.30	< .05
Operculum width[b]					
All	2.221	0.421	0.90	3.40	—
Male	2.284	0.435	0.90	3.40	—
Female	2.153	0.395	1.00	3.00	< .005
RWN length[c]					
All	1.665	0.258	1.00	2.70	—
Male	1.696	0.266	1.10	2.70	—
Female	1.632	0.246	1.00	2.20	< .05
RWN air depth[d]					
All	1.665	0.260	1.00	2.70	—
Male	1.695	0.269	1.10	2.70	—
Female	1.633	0.274	1.00	2.20	< .05

RWN = round-window niche; SD = standard deviation.
[a] *M* in Figure 3.
[b] *A* in Figure 3.
[c] *B* in Figure 3.
[d] *D* in Figure 3.
Note: Measurements in millimeters.

Table 2. Skull Width of 209 Skulls According to Age and Gender

	Female Subjects			Male Subjects		
Age Decade	**Number**	**Mean**	**SD**	**Number**	**Mean**	**SD**
1	5	113.8	4.8	5	124.7	5.1
2	3	125.3	5.5	13	126.6	7.7
3	10	127.3	5.4	17	135.4	6.1
4	10	131.3	6.7	14	139.1	8.1
5	12	129.8	6.6	16	137.7	6.7
6	22	130.3	5.4	11	134.4	5.4
7	22	131.5	6.4	17	137.4	7.1
8	15	134.8	5.9	13	138.4	7.9
9	3	140.0	8.7	1	130.0	0.0
Total	102			107		

SD = standard deviation.
Note: Measurements demonstrate continuous growth of skull.

tigo, 50%; sensorineural hearing loss, 13%; tinnitus, 11%; and headache, 6%. We diagnosed various other common problems in the remaining 20%.

Our measurements are presented in the Tables 1 and 2 and in Figure 5. The size of the RWN in all age groups was similar, indicating that it reached its final size in early life. It did not grow with age, in contrast to skull width, which grew especially in the first two decades of life and continued throughout the entire life in both genders. We found the RWN to be bigger in male subjects than in female subjects.

DISCUSSION

In this study, we evaluated the bony outlines of the RWN in a large number of ears. Soft-tissue structures (and membranes) could not be identified by CT. Therefore, we could not contribute to the demonstration of membranous folds in the RWN, which are so important for the diffusion mechanism of intratympanic medications. Conversely, the RW membrane clearly is always located at the very end of the RWN.

Consequently, membranes frequently seen in middle-ear surgeries at the RWN opening are mucosal folds external to the RW membrane and are not the RW membrane. In keeping with a report by Alzamil and Linthicum [5], 32% of ears in our patients (133) should have folds. As no collection of fluid was demonstrated in any of those patients, we can presume that the RWN is not completely obstructed by those folds.

To demonstrate the bony configurations of the RWN, we suggest the technique just presented, which reveals them most clearly. When scanned in this way, RWNs can be compared to one another. This coincides with the aim of Purcell et al. [20], who suggested the use of standardized CT temporal bone studies to permit

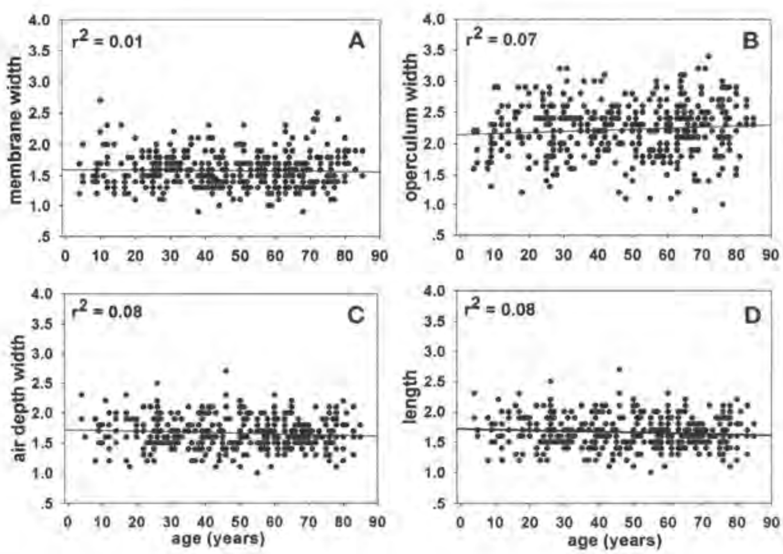

Figure 5. (A) Round-window membrane width according to age. (B) Operculum width according to age. (C) Round-window niche depth according to age. (D) Round-window niche length according to age.

comparisons for inner-ear evaluation in cases of malformations. The measurements we obtained were accurate and close to one another, verifying that this demonstration of the RWN can be used as a standard view of this anatomy.

CONCLUSIONS

We presented several findings in this study. The shape of the RWN is usually conical, becoming narrower toward its fundus. Its size does not change with age; this finding bears out the fact that the ear reaches its final size at birth. All the dimensions of the RWN were bigger in male subjects than in female subjects. In contrast to the RWN, which reaches its final size in early life, skull dimensions demonstrated a slow and continuous growth throughout a subject's entire life [21]. Skull width was greater in men than in women in all age groups.

In summary, as endoscopies of the middle ear still have limited value [22,23], imaging is important and is less invasive for evaluation of the RWN. Our study contributes to the demonstration of the RWN in two ways: a technical imaging method that can be used as a standard view of the RWN (as well as for some other structures of the ear) and the assessment of the RWN's dimensions. Current CT technology does not yet allow study of delicate folds in the RWN.

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