Original Paper

Audiology & Neurotology

Audiol Neurotol 2017;22:50–55
DOI: 10.1159/000471840

Received: November 2, 2016
Accepted: March 20, 2017
Published online: June 23, 2017

The Crista Fenestra and Its Impact on the Surgical Approach to the Scala Tympani during Cochlear Implantation

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Keywords
Round window · Cochlear implant · Crista fenestra

Abstract
Objective: The aim of this work was to describe the dimensions of the crista fenestra and determine its presence by means of high-resolution computed tomography (CT) for the purpose of cochlear implantation via the round window approach. ***Methods:*** A series of 10 adult human temporal bones underwent high-resolution CT scanning and were further dissected for microscopic study of the round window niche. ***Results:*** In all of the specimens, the round window membrane was fully visualized after the complete removal of bony overhangs. The crista fenestra was identified as a sharp bony crest located in the anterior and inferior borders of the niche; its area ranged from 0.28 to 0.80 mm^2 (mean 0.51 ± 0.18). The proportion of the area occupied by the crista fenestra in the whole circumference of the round window ranged from 23 to 50% (mean 36%). We found a moderate positive correlation between the area of the niche and the dimensions of the crista fenestra (Spearman rho: 0.491). In every case, high-resolution CT scanning was unable to determine the presence of the crista fenestra. ***Conclusion:*** The crista fenestra occupies a variable but expressive area within the bony round window niche. Narrower round window niches tended to house smaller crests. The presence of the crista fenestra is an important obstacle to adequate access to the scala tympani. Nevertheless, a high-resolution CT scan provides no additional preoperative information with regard to its presence for the purpose of surgical access to the scala tympani via the round window niche.

Introduction

Surgical access to the scala tympani through the round window niche for cochlear implantation has gained recent popularity after decades of widespread preference for the traditional cochleostomy [Roland et al., 2007; Erixon et al., 2012; Atturo et al., 2014; Mom et al., 2016]. Contemporary studies comparing these 2 approaches have demonstrated equivalent outcomes [Briggs et al., 2006; Hamerschmidt et al., 2012; Havenith et al., 2013; Kang and Kim, 2013; Adunka et al., 2014].

The main criticism of the round window approach concerns its uncertain pattern [Leong et al., 2013; Singla et al., 2013] in opposition to the stable morphology observed in the bony promontory. The superior border of

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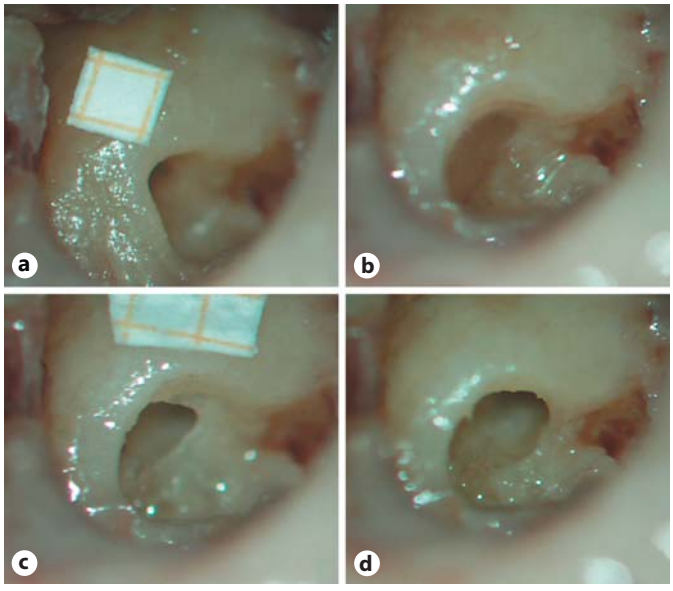

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Fig. 1. Right temporal bone. **a** Exposure of the round window niche. **b** Exposure of the round window membrane after removal of bony overhangs. **c** The round window after removal of its membrane. **d** The round window after removal of the crista fenestra.

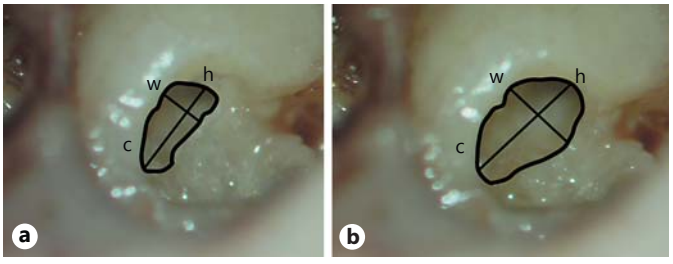

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Fig. 2. Method for determination of the width (w), height (h), and circumference (c) of the round window niche before (**a**) and after (**b**) removal of the crista fenestra.

the niche – the tegmen – and the postis posterior (posterior pillar) are important anatomical obstacles to proper visualization of the round window membrane through the posterior tympanotomy [Proctor et al., 1986; Roland et al., 2007].

Once these bony overhangs have been removed and the round window membrane is fully exposed, a sharp bony crest, the crista fenestra, is identified in the anteroinferior border of the niche [Franz et al., 1987; Atturo et al., 2014]. The membrane of the round window arises from the free edge of the crest. The few studies that have properly analyzed the crista fenestra reveal that this structure occupies an important portion of the circumference of the round window and, therefore, of the entrance to the scala tympani. Nevertheless, the area occupied by the crista and its impact on surgical access to the scala tympani have been neglected.

The main objective of the current study was to describe the morphology of the crista fenestra and analyze its impact on the approach to the scala tympani of the basal turn of the cochlea for cochlear implantation. As a secondary objective, we focused on the radiological presence of the crista as determined by high-resolution computed tomography (CT). Because the crista fenestra has not been described radiologically, we assume that this analysis can contribute to more accurate preoperative planning in cases in which the round window approach is the proposed protocol for cochlear implantation.

Methods

The study sample consisted of 10 adult human temporal bones fixed in 10% formalin and conserved under refrigeration. Specimens were donated by the Department of Morphological Sciences of the Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil. The project was approved by the Research Ethics Committee of the Hospital de Clínicas, Porto Alegre, Brazil.

All specimens initially underwent high-resolution CT scanning. All scans were performed on a 128-slice dual-source CT scanner (Discovery HD 750, General Electric Healthcare) and images were analyzed using the AW 4.2 Workstation (General Electric Healthcare). The modified Stenvers view was used to investigate the round window niche. An independent radiologist reviewed all of the scans.

The specimens were dissected in the Department of Experimental Surgery at the Research Center of the Hospital de Clínicas de Porto Alegre. A wide mastoidectomy and identification of the tympanic tegmen, sigmoid sinus, and the mastoid portion of the facial nerve preceded the analysis of the round window niche. The posterior external auditory canal and the tympanic membrane were removed. The oval and round windows were fully exposed, and the ossicular chain was kept intact.

Once the round window niche was identified (Fig. 1a), its bony overhangs were drilled out until the round window membrane was completely visualized (Fig. 1b). The membrane was then carefully removed (Fig. 1c). The crista fenestra was identified and then completely removed using a small 0.5-mm-diameter cutting bur (Fig. 1d). All steps were digitally documented using a GoPro Hero 1080 camera, and the images were analyzed using ImageJ, an image processing and analysis software developed by the US National Institutes of Health (http://www.imagej.gov/nih/ij).

Linear and square measurements of the round window were obtained with millimeter graph paper placed close to the niche (Fig. 1a). The images were measured and scaled for pixel-to-millimeter conversion. This scale was used for round window assessment before and after removal of the crista fenestra.

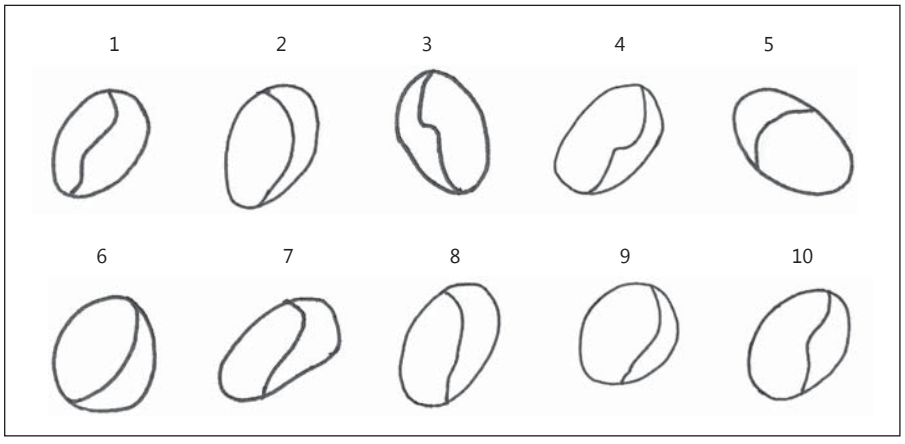

Fig. 3. Morphology of the round window niche and the crista fenestra.

The variables were correlated by the Spearman rank correlation coefficient or the Spearman rho. In order to label the strength of the association between the variables, for absolute values of rho, 0–0.29 was regarded as weak, 0.3–0.69 as moderate, and 0.7–1 as strong.

The width of the round window niche was first defined as the largest anteroposterior distance, while the highest superoinferior distance determined its height. We defined the height as absolutely perpendicular to the width's tracing. The circumference of the niche was used for determination of its area (Fig. 2).

Results

The round window niche was positively identified in all specimens. In 3 cases, however, the round window membrane could not be visualized due to the presence of bony overhangs. In the 7 remaining temporal bones, the visible area of the membrane ranged from 0.09 to 0.46 mm^2.

After drilling out the bony overhangs, the round window membrane was completely visualized in all specimens. Its height ranged from 0.60 to 1.04 mm (mean 0.77), while its width ranged from 1.19 to 1.71 mm (mean 1.41). The area of the round window ranged from 0.54 to 1.29 mm^2 (mean 0.91). After removal of the crista fenestra, the area of the round window ranged from 0.83 to 2.02 mm^2 (mean 1.42). The proportion of the area occupied by the crista in the whole circumference of the round window ranged from 23 to 50% (mean 36%). Individualized data on the area of the round window and the crista fenestra and the proportional relationship between these variables are summarized in Table 1.

Height and width values were compared using the Spearman correlation coefficient. A value of 0.468 was obtained before removal of the crista, indicating a moderated, positive correlation between these variables. After removal of the crista, the correlation dropped to 0.127. These results indicate that height and width are positively correlated, especially when the crista fenestra is kept intact.

The area of the round window and the area of the crista fenestra were also examined using the Spearman correlation coefficient. The final value of 0.491 indicates a moderate positive correlation. This result suggests that wider round window niches tend to have larger crests, while narrower niches tend to have smaller crests. The morphology and position of the crista fenestra are shown individually in Figure 3.

Table 1. Area of the round window before and after removal of the crista fenestra, area of the crista fenestra, and proportion of the area occupied by the crista in the whole circumference of the round window

Specimen No.	Round window, mm^2		Crista fenestra, mm^2	Proportion, %
	before	after		
1	0.78	1.58	0.80	50.6
2	0.80	1.29	0.49	38.0
3	0.54	0.83	0.28	34.1
4	0.97	1.61	0.64	39.5
5	1.02	1.43	0.41	29.1
6	0.99	1.36	0.37	27.2
7	0.93	1.32	0.39	29.6
8	0.58	1.11	0.53	47.9
9	1.29	1.68	0.39	23.2
10	1.21	2.02	0.80	39.8
Mean	0.91	1.42	0.51	35.9
SD	0.24	0.32	0.18	8.93

SD, standard deviation.

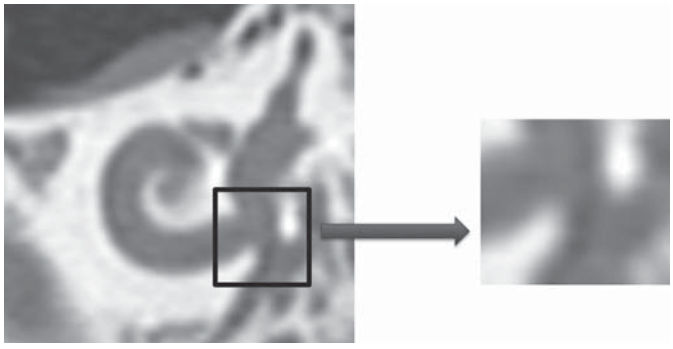

Fig. 4. CT scan (modified Stenvers view) focusing on the round window niche.

CT scans positively identified the round window niche in all 10 specimens. However, the crista fenestra was not individualized in any of the cases. The method used for identification of the crista fenestra is shown in Figure 4.

Discussion

The approach to the scala tympani through the bony niche of the round window for cochlear implantation was first described in the 1980s [Franz et al., 1987]. However, a widespread preference for basal turn cochleostomy has been observed. The main reason for this choice may relate to the variable morphology of the niche in opposition to the stable, constant access observed during cochleostomy.

The surgical protocol that has been used at the Department of Otolaryngology of the Hospital de Clínicas de Porto Alegre since 1995 is based on the original posterior tympanotomy technique described by House [1976]. Some modifications have been made to the original protocol, called the combined approach technique, or CAT [Lavinsky et al., 2010; Lavinsky-Wolff et al., 2012]. In this new protocol, to gain access to the middle ear cleft, the skin of the external auditory canal is dissected out until the tympanic annulus is reached, providing a wide exposure of the middle ear, which remains isolated from the cutaneous surface. The posterior tympanotomy is smaller than that in the original protocol, but wide enough for electrode insertion toward the middle ear cleft. The main benefit of the CAT is the wide exposure of the promontory, providing a favorable angle to safely perform a cochleostomy with minimal risk to the facial nerve.

In recent years, however, some studies have demonstrated a renewed interest in round window insertions. Roland et al. [2007] pointed out some benefits, such as a reduced amount of drilling, thereby reducing the risk of acoustic trauma and minimizing the loss of perilymph and entry of bone dust into the scala tympani, the possibility of sealing the tissues immediately, and stimulation of more basal neural elements. Further studies that compared the approaches have reported similar audiological outcomes, both in the preservation of residual hearing [Briggs et al., 2006; Erixon et al., 2012; Havenith et al., 2013] and speech perception scores [Hamerschmidt et al., 2012; Kang and Kim, 2013]. However, Kang and Kim [2013] stated that the round window should be used as a portal for electrode insertion only in cases with a favorable anatomy.

Leong et al. [2013] proposed a classification based on the visibility of the round window membrane. In cases with wide visibility, the electrodes could be inserted directly through the round window (membrane cochleostomy). In cases in which visibility is hardly achieved, or even impossible, access through the round window is impracticable and the traditional cochleostomy (bony cochleostomy) should be performed. Intermediate cases could be managed either by cochleostomy or by removal of the bony overhangs (extended round window approach). The results indicate that, in some of the cases, the bony overhangs of the round window niche must be drilled out for proper visualization of the membrane. Those authors did not mention the presence of the crista fenestra.

In the present study, the different morphology of the osseous niche was evident. Moreover, removal of the bony overhangs was required to obtain an adequate view of the membrane, even with the possibility of some degree of acoustic trauma.

The crista fenestra is always identified in the inferior or anterior border of the round window, or in both borders simultaneously. Because of this variability, we decided to study the area of the crista fenestra, which might emerge as a more reliable predictor of scala tympani accessibility in comparison with linear measurements, thus adding new information to the relevant literature.

In the present study, the difference between the largest (0.80 mm^2) and the smallest crista (0.28 mm^2) is evidence of its variable development. The moderate, positive Spearman correlation coefficient observed between the area of the round window and the area of the crista fenestra suggests that wide, well-developed round window niches have larger crests. Conversely, narrow, constricted niches usually have smaller crests. This finding is surgically relevant because, when facing narrow round window nich-

es, the possibility of obtaining space by removing the crista fenestra is unlikely and the surgeon should expand the surgical field by removing the bony overhangs.

Because the crista fenestra occupies a significant portion of the circumference of the round window, it limits access to the scala tympani. Due to its location in the inferior and anterior borders of the window, the crista could push the electrodes toward the modiolus, increasing resistance to their insertion. Atturo et al. [2014] defined the crista fenestra as a "doorstep" at the entrance of the basal turn of the cochlea.

According to Franz et al. [1987], removing the crista fenestra is absolutely necessary to properly visualize the scala tympani through the posterior tympanotomy. However, they did not describe their surgical protocol. The observations in the present study suggest that the use of cutting burs results in an increased risk of bone dust entering into the scala tympani. This could lead to an inflammatory process in the cochlea, fibrosis, and further ossification [Waltzman and Roland, 2014]. When using a delicate hook, the fracture of the crest may allow small bone fragments to enter the scala tympani. If the crest is not fully removed, its small spicules may damage the electrode array during insertion.

Based on these statements, it is possible to affirm, in contrast to what some authors have pointed out [Roland et al., 2007; Franz et al., 1987], that removal of the crista fenestra should be avoided – particularly in patients with residual hearing. In these cases, surgeons should enlarge the access route to the round window at the expense of the bony overhangs of the round window niche. Once intraoperative judgment identifies poor access, a traditional cochleostomy must be considered.

A high-resolution CT scan is considered the gold standard for assessment of the morphology of the temporal bone [Cohen et al., 2005]. All preoperative protocols recognize CT as an indispensable tool for preoperative evaluation before cochlear implantation. In a recent study, however, Park et al. [2015] concluded that radiological assessment of the bony niche could not predict the difficulties that surgeons might encounter during this approach. Radiological identification of the crista fenestra and its dimensions would provide surgeons with valuable data and the possibility of predicting potential intraoperative scenarios.

In the present study, the crista fenestra was not radiologically identified in any of the cases. Possible reasons for this may be the small size of the crista and the fact that it could not be properly individualized from the membrane arising from its free edge.

Conclusions

The crista fenestra is a sharp bony crest, which occupies an expressive area within the round window niche. It can be considered the most important barrier to the scala tympani.

Narrower bony niches tend to house small crests. In this situation, removal of the crista fenestra could not provide additional room in the circumference of the niche.

The impossibility of predicting its presence by CT scan blinds the surgeon to intraoperative circumstances. To overcome this situation, it is imperative that the otological surgeon be familiar with both techniques, since the choice of approach may ultimately depend on intraoperative decision making.

Disclosure Statement

The authors have no competing interests or funding to declare.

References

Adunka OF, Dillon MT, Adunka MC, King ER, Pillsbury HC, Buchman CA: Cochleostomy versus round window insertions: influence on functional outcomes in electric-acoustic stimulation of the auditory system. Otol Neurotol 2014;35:613–618.

Atturo F, Barbara M, Rask-Andersen H: Is the human round window really round? An anatomic study with surgical implications. Otol Neurotol 2014;35:1354–1360.

Briggs RJ, Tykocinski M, Xu J, Risi F, Svehla M, Cowan R, Stover T, Erfurt P, Lenarz T: Comparison of round window and cochleostomy approaches with a prototype hearing preservation electrode. Audiol Neurotol 2006; 11(suppl 1):42–48.

Cohen D, Blinder G, Perez R, Raveh D: Standardized computed tomographic imaging and dimensions of the round window niche. Int Tinnitus J 2005;11:158–162.

Erixon E, Köbler S, Rask-Andersen H: Cochlear implantation and hearing preservation: results in 21 consecutively operated patients using the round window approach. Acta Otolatyngol 2012;132:923–931.

Franz BKH, Clark GM, Bloom DM: Surgical anatomy of the round window with special reference to cochlear implantation. J Laryngol Otol 1987;101:97–102.

Hamerschmidt R, Schuch LH, Rezende RK, Wiemes GR, Oliveira AK, Mocellin M: A comparison between neural response telemetry via cochleostomy or the round window approach in cochlear implantation. Braz J Otorhinolaryngol 2012;78:71–75.

Havenith S, Lammers MJ, Tange RA, Trabalzini F, della Volpe A, van der Heijden GJJ, Grolman W: Hearing preservation surgery: cochleostomy or round window approach? A systematic review. Otol Neurotol 2013;34:667–674.

House WF: Cochlear implants. Ann Otol Rhinol Laryngol 1976;85(suppl 27):1–93.

Kang BJ, Kim AH: Comparison of cochlear implant performance after round window electrode insertion compared with traditional cochleostomy. Otolaryngol Head Neck Surg 2013;148:822–826.

Lavinsky L, Lavinsky-Wolff M, Lavinsky J: Transcanal cochleostomy in cochlear implantation: experience with 50 cases. Cochlear Implants Int 2010;11:228–232.

Lavinsky-Wolff M, Lavinsky L, Dall'Igna C, Lavinsky L, Setogutti E, Viletti MC: Transcanal cochleostomy in cochlear implant surgery: long-term results of a cohort study. Braz J Otorhinolaryngol 2012;78:118–123.

Leong AC, Jiang D, Agger A, Fitzgerald-O'Connor A: Evaluation of round window accessibility to cochlear implant insertion. Eur Arch Otorhinolaryngol 2013;270:1237–1242.

Mom T, Bachy A, Houette A, Pavier Y, Pastourel R, Gabrillargues J, Saroul N, Gilain L, Avan P: Cochlear implantation through the round window with a straight slotted electrode array: optimizing the surgical procedure. Eur Arch Otorhinolaryngol 2016;273:853–858.

Park E, Amoodi H, Kuthubutheen J, Chen JM, Nedzelski JM, Lin VY: Predictors of round window accessibility for adult cochlear implantation based on pre-operative CT scan: a prospective observational study. J Otolaryngol Head Neck Surg 2015;44:20–26.

Proctor B, Bollobas B, Niparko JK: Anatomy of the round window niche. Ann Otol Rhinol Laryngol 1986;95:444–446.

Roland PS, Wright CG, Isaacson B: Cochlear implant electrode insertion: the round window revisited. Laryngoscope 2007;117:397–402.

Singla A, Sahni D, Gupta AK, Loukas M, Aggarwal A: Surgical anatomy of round window and its implications for cochlear implication. Clin Anat 2013;27:331–336.

Waltzman SB, Roland JT Jr: Cochlear Implants, ed 3. New York, Thieme, 2014.