OBJECTIVES: Since there is great confusion in the literature about the anatomy and terms of the crista fenestra (CF) and the crista semilunaris, this paper is confined to the anatomy of the inferior margin of the round window (RW).

METHODS: This study was carried out on 20 cadaveric temporal bones. We measured the maximal height of the RW and the maximum height of the inferior bony edge of the RW, (termed CF type A), in this study. The ratio of the maximum height of CF type A to the maximum height of the RW was calculated. After drilling the CF type A, the scala tympani was visualized using a sialendoscope, and any bony projection in the inferior wall of the scala tympani just behind the round window membrane (RWM) was assessed and reported (termed CF B in this study).

RESULTS: We identified CF type A in 19/20 of cases (95%), and it was absent in only 1 case (5%). Its height ranged from 0.228 to 1.329 mm with an average of 0.604±0.347 mm. The percentage of CF type A to RW ranged from 19 to 75%, with an average of 42%. CF type B was present in only 2 specimens (10%).

CONCLUSION: CF type A occupied a significant part of the RW in most specimens, and therefore its drilling was essential in a large percentage of cases. CF type B (inside the scala tympani) was present in 10% of the temporal bone samples, and curettage had to be done in these cases.

KEYWORDS: Round window, crista fenestra, cochlear implant, cochlea
It should be noted that the term “crista fenestrae cochleae” was used in earlier descriptions of temporal bone anatomy to designate the entire extent of the bony ridge to which the vertical part of the RWM is attached, and the inferior portion of that ridge was termed the crista semilunaris. In the more recent literature, these terms have been used in different ways by different authors. To avoid confusion in terminology, Roland et al. have preferred to refer to the part of the bony annulus of the RW that may require drilling simply as the anteroinferior area of the annulus.

Since the literature shows great confusion about the anatomy and terms of crista fenestra (CF) and crista semilunaris, this paper is confined to the anatomy of the inferior margin of the RW using cadaveric dissection of temporal bones.

MATERIALS AND METHODS

This study was carried out on 20 cadaveric temporal bones with no signs of ear pathology. This was approved by the Ethics Committee of our institution. Cortical mastoidectomy was performed in all the temporal bone specimens, and we then gained access to the RWM by lowering the posterior canal wall to the level of the vertical portion of the facial nerve. The RWM was exposed after drilling the superior and the posterior bony overhangs of the RW. The RWM was then carefully removed and the inferior margin (the CF) was visualized and photographed. It was completely removed using a small cutting burr, 0.5 mm in diameter. The RW area was then photographed. The entrance of scala tympani was visualized using a microscope and a 0.9 mm sialendoscope (Karl-Storz, Tuttlingen, Germany), and any bony prominence in its inferior wall just behind the RWM was documented and reported.

Measurement Procedure

The dissection was digitally captured. We used a small ruler graded into millimeters and placed near the RWM, as reference for measurement. The images were uploaded to the computer and analyzed. We used the Image J software created by the National Institutes of Health, the United States (http://www.imagej.nih.gov/ij), to process and analyze images. The images were scaled to convert pixels to millimeters.

For the purpose of describing the inferior bony margins of the RW, we have adopted the Baki-ElZayat classification. In this classification, 2 bony edges were identified and studied: the main inferior bony edge to which the RWM is attached, designated in this study as CF A. The maximal height of this bony projection as well as the height of the RW was measured (Figure 1). The percentage of the height of CF A to the height of the RW was obtained. The cases were subdivided into:

- **A1**: Crista height less than 33% RW height.
- **A2**: Crista height between 33% and 66% RW height.
- **A3**: Crista height more than 66% RW height.

After removal of the CF type A, any inferior bony prominence in the inferior wall of the scala tympani in its entrance just behind the RW membrane was designated as CF type B). The cases were subdivided into:

- **B0**: No bony projection in the inferior wall of scala tympani just behind the RWM.
- **B1**: Small bony projection in the inferior wall of scala tympani just behind the RW.
- **B2**: Large bony projection in the inferior wall of scala tympani just behind the RWM.

Data analysis was done using Microsoft Excel 365 for Windows.

RESULTS

This study was conducted on 20 cadaveric temporal bones (12 right and 8 left). The antero-inferior area of the RW was fully studied. For descriptive purposes, we adopted the Baki-ElZayat classification, where we designated the term CF type A to the inferior bony prominence of RW to which the RWM was attached. The term CF type B was designated to refer to any bony prominence in the inferior wall of the scala tympani just behind the RWM. In this study, we identified CF type A in 19/20 (95%) cases, and it was absent in only 1 (5%) case. Its height ranged from 0.228 to 1.329 mm, with an average of 0.604 ± 0.347 mm. The RW ranged in height from 0.707 to 2.155 mm, with an average of 1.500 ± 0.432 mm. The percentage of CF type A to RW ranged from 19 to 75%, with an average of 42% (Table 1, Figures 2 and 3).

In the present study, we found that in 8/19 specimens (42.1%), the height of crista was less than 33% of RW and thus included in category A1 (Figure 4); and in 9/19 (47.38) specimens, the height of crista was between 33 and 66% of RW and thus included in category A2 (Figure 4). Only 2/19 specimens (10.52) had large crista exceeding 66% and thus were included in category A3 (Figure 4).

As for the CF type B, in the present study, we found no bony prominence in the inferior wall of scala tympani (B0) in 18/20 (90%) specimens, small bony prominence (B1) in only 1/20 specimens (5%), and large bony prominence (B2) in another specimen (5%) (Figure 5).

DISCUSSION

Currently, cochlear implant insertion through RW is the most common approach to scala tympani. However, this approach carries many
challenges, including the presence of postero-superior bony overhangs, which may hide the RWM, and the existence of the bony crest at the anteroinferior border of the niche, which is called CF5,6,8,10 or crista semilunaris3,9,11 by different authors. As a result of its position in the inferior and anterior borders of the window, the crista could push the electrode toward the modiolus, increasing resistance to its insertion into scala tympani. Therefore, whenever the surgeon detects a notable crista, it may be appropriate to eliminate it with a fine curette to allow the proper and deep insertion of the electrode into the scala tympani. Otherwise, the electrode array may be displaced medially with subsequent injury to the spiral lamina and basilar membrane, resulting in poor hearing.13

In a study performed by Jain et al.,1 the maximum height of the RW varied from 0.51 to 1.27 mm with a mean of 0.69 ± 0.25 mm. In addition, they reported that the height of RW was ≤1 mm in 82.35% of temporal bone specimens. Singla et al.14 demonstrated in a study carried out on the Indian population that the average height of the RW was 1.62 ± 0.77, and the height of the RW was <1 mm in 12% of cases.

Angeli et al.8 demonstrated that the average height of RW varied from 0.60 to 1.04 mm, with an average of 0.77 mm. Atturo et al.7 reported that the mean longest diameter of RW was 1.90 mm while its smallest was 1.54 mm.

In our study, the RW height ranged from 0.707 to 2.155 mm with an average of 1.500 ± 0.432 mm.

In our opinion, the height of the RW itself is not the most important factor. We believe that the proportion of the height of the CF in relation to the height of the RW has more important implications than the absolute height of the RW.

Angeli et al.3 demonstrated that the area of the RW ranged from 0.54 to 1.29 mm² (mean 0.91) before drilling of CF, and from 0.83 to 2.02 mm after drilling of CF. The ratio of the CF to the RW area varied from 23 to 50%. Atturo et al.7 found that the average diameter of the CF was 1.31 mm. Roland et al.3 dissected 15 temporal bones and visualized the RW from inside the scala tympani. They preferred to refer to the anterior-inferior bony margin of the RW as CF, while they referred to the bony crest in the inferior wall of scala tympani that arises near the cochlear aqueduct as crista semilunaris.

Table 1. Maximum Height of the RW and Crista Fenestra A Area (n = 20)

| Specimen No. | Side | RW          | Crista Fenestra A | Proportion (%) |
|--------------|------|-------------|-------------------|----------------|
| 1            | RT   | 1.683       | 0.643             | 38%            |
| 2            | LT   | 1.088       | 0.243             | 22             |
| 3            | RT   | 1.189       | 0.289             | 2              |
| 4            | RT   | 1.180       | 0.852             | 72             |
| 5            | LT   | 1.748       | 0.460             | 26             |
| 6            | RT   | 1.988       | 0.390             | 19             |
| 7            | RT   | 0.707       | 0.228             | 32             |
| 8            | RT   | 0.747       | 0.329             | 44             |
| 9            | RT   | 1.371       | 0.000             | 0              |
| 10           | LT   | 1.242       | 0.937             | 75             |
| 11           | RT   | 1.013       | 0.413             | 40             |
| 12           | LT   | 2.155       | 1.329             | 61             |
| 13           | LT   | 1.846       | 1.132             | 62             |
| 14           | RT   | 1.935       | 1.237             | 64             |
| 15           | LT   | 1.902       | 0.957             | 50             |
| 16           | RT   | 1.867       | 0.600             | 32             |
| 17           | RT   | 1.872       | 0.363             | 19             |
| 18           | LT   | 1.795       | 0.795             | 44             |
| 19           | LT   | 1.246       | 0.428             | 34             |
| 20           | RT   | 1.432       | 0.464             | 32             |

Figure 2. Diagrammatic presentation of different shapes of Crista Fenestra A.
Since the literature shows great confusion about the anatomy and terms of CF and crista semilunaris, we have adopted the Baki-ElZayat classification\textsuperscript{12} in this paper, where we designated the term Crista Fenestra A to the inferior bony prominence of RW to which the RWM is attached. The term CF B referred to any bony prominence in the inferior wall of the scala tympani just behind RWM.

In this study, CF type A was detected in 19/20 (95\%) of the cases, and its height varied from 0.228 to 1.329 mm, with an average of 0.604 ± 0.347 mm. The percentage of CF type A to RW ranged from 19 to 75\%, with an average of 42\%. According to the same classification, CF type A formed less than one-third of RW (type A1) in 42.1\% of the specimens; it formed between one-third and two-thirds of RW (type A2) in 47.38\%, and more than two-thirds of RW (type A3) in only 10.52\% of temporal bones. Thus, the CF type A occupied a substantial part of the area of RW in 58\% of temporal bones. Therefore, we suggest that drilling of anteroinferior part of the RW (CF) may be

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{Different shapes and the ratio of Crista Fenestra A to RW. The dotted red line represents the boundary of Crista Fenestra A.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure4.png}
\caption{Different types of Crista Fenestra A. (A) Crista Fenestra A1, (B) Crista Fenestra A2, and (C) Crista Fenestra A3.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure5.png}
\caption{Crista Fenestra B (Black dots represent the boundary of CF).}
\end{figure}
required in at least 50% of cases for good exposure of RWM and scala tympani.

Concerning the bony crest in the inferior wall of scala tympani that arise near the cochlear aqueduct, Roland et al. have found it in 30% of 15 temporal bones dissected. They termed it as crista semilunaris. Kuma et al. showed a higher incidence of this crista semilunaris located immediately medial (juxta-luminal) to the RWM. It was present in 39 out of 48 cases (79.2%). However, Clifford and Gibson found that the length of crista semilunaris was 0.2 mm and of little impact on insertion of the cochlear implant electrode. In the present study, we have found this bony projection in 10% of cases. We have termed it as CF type B. Marchioni et al. in their study, have explained the presence of this bony projection in a small percentage of cases. They described the endoscopic anatomy of the RW, including the fustis. They have classified the fustis into type A, in which fustis leads to scala tympani but does not extend in the scala tympani; and type B, in which the anterosuperior end of the fustis is situated just below the scala tympani and represents the floor of the scala tympani. Additionally, they have found fustis A in 71.4% of cases and fustis B in 28.6% of cases. We can speculate that in our present study, the presence of the bony prominence inside the scala tympani in only 2 out of 20 cases (10%) can represent fustis B of Marchioni et al. We propose to suggest naming it the crista of scala tympani to avoid confusion with the CF in the inferior margin of RW.

As for the implications of the presence of these inferior bony projections in the inferior area of the RW, Franz et al. considered that a better and wider view of the scala tympani of the basal turn of the cochlea could be obtained by elimination of the CF, which provides the surgeon with adequate space for deep and proper electrode insertion. Atturo et al. emphasized the importance of the CF as a "doorstep" that could restrict the insertion of the electrode from the RW into the scala tympani. They showed that there was a great variation in the size and shape of CF that may be small and barely seen which, however, may be knife-sharp in some specimens.

Angeli et al. have recommended avoiding removal of the crista, especially in patients with a residual hearing, because using a burr may result in cochlear damage and impaction of bone spicule in the scala tympani. They suggested performing cochleostomy when the CF is large and obstructs easy access to the RW and scala tympani.

In the present study, we have preferred to refer to the anterior-inferior bony margin which was found in 95% of our cases as CF A, or simply as CF. While we have referred to the bony crest in the inferior wall of scala tympani which was found in 10% of our cases as CF B, we suggest the term crista of scala tympani, to avoid any possible confusion.

The present study emphasized drilling the anterior-inferior margin of the RW (CF type A) if it is prominent and crista forms more than one-third of the RW. It also recommends removing type B (crista of scala tympani), if present, by a small curette to allow proper insertion of the electrode without deflection toward the modiolus. Drilling and or curettage should be done cautiously to avoid surgical inner ear trauma and or injury to the cochlear aqueduct and its vein.

CONCLUSION
In the present study, we have identified 2 bony prominences in the inferior area of RW. The first one represented the anteroinferior overhang of RW. It was termed the CF type A and it was present in 95% of temporal bone specimens. It occupied a significant part of RW in 58% of specimens, and therefore, anteroinferior drilling of CF was essential in a large percentage of cases.

The second bony prominence was present inside the scala tympani. It was termed CF type B or crista of scala tympani. It was present in 10% of the temporal bones, and curettage had to be done in such cases.

Ethics Committee Approval: All procedures performed in this study were in accordance with the ethical standards of our institution (Approved by the ethical committee of the Faculty of Medicine, Alexandria University, and Ethical Number: 0105810).

Informed Consent: N/A.

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