Special Anatomic Considerations in Otosclerosis Surgery

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KEYWORDS

- Micro-CT • Human • Temporal bone • Otosclerosis • Otolith organ

KEY POINTS

- Micro–computed tomography and 3-dimensional rendering revealed the relationship between the otolith organs and the oval window.
- Besides saccule, awareness of the position of the utricle macula near the superior margin of the footplate is essential to avoid damage during stapes surgery.
- A step-by-step consideration of the anatomy in otosclerosis surgery is important.
- Calcification of the anterior malleolar ligament seems to be a normal finding. Fixation should therefore be substantiated by palpation at surgery.

INTRODUCTION

After primary stapes surgery, sensorineural hearing loss associated with vertigo is a rare complication today, with rates ranging from 0.2% to 3%.[1] The underlying causes of this complication include intravestibular protrusion of the prosthesis, damage to the membrane labyrinth, surgical manipulation of the floating footplate, perilymph fistula, immune system, or unexpected conditions such as a perilymph gusher. A gusher is often caused by modiolar defects and can likely be prevented by the use of preoperative computed tomography (CT). Damage to the saccule is a concern in stapes

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surgery, particularly in stapedectomy procedures.[2] A displaced, incorrectly sized, or unnecessarily long prosthesis can induce irritation or even disrupt the membrane labyrinth and cause hearing loss, and a reduced distance between the stapes and the membrane labyrinth may ensue. The prevalence of such anatomic variations is not well understood. Trauma to the utricle at the upper rim of the oval window (OW) is less often described. A surgical checklist presented by Linder and Fisch[3] highlighted the importance of visualizing the anterior malleolar process and ligament, the incudomalleolar joint, the exposure of the entire stapes, and the pyramidal process as well as identifying sclerosis of the round window (RW). With this checklist, the surgeon can identify those at risk of middle ear structure impairment.

The anatomy of the ear varies markedly. The size and shape of the inner ear, including those of the cochlea, OW, and RWs, can vary. Consequently, a hole drilled in the footplate could appear at different positions inside the vestibule. In “small” cochleae, the windows are smaller and are positioned closer to each other.[4,5] In addition, the distance from the OW to the sensory areas should be smaller in those with small cochleae. These areas include the base of the cochlea (high-frequency region), the saccule, the utricle, and the 2 ampullas of the superior and lateral semicircular canals. Therefore, surgery in a small ear is more challenging, and the surgeon needs to be acquainted with the anatomy behind the stapes footplate. However, it is difficult to conceptualize in 3 dimensions the projection of these inner ear structures in different planes. The membrane labyrinth is mostly studied in 2-dimensional (2D) temporal bone sections that provide limited information on spatial relationships. The present study was performed to provide more information on the 3-dimensional (3D) relationship between the vestibule and OW. For this purpose, the authors used micro-CT with a 3D rendering technique to study human temporal bones. 3D reconstructions and orthogonal sectioning, or a “cropping technique,” provided additional information on the projections of the vestibular organs on the medial wall of the middle ear.

Techniques Used in the Study

Temporal bone microdissections

A total of 113 archival specimens of macerated human temporal bones were analyzed. Fifty were from nonselected autopsy specimens (mean age of 56 years; 9 bilateral cases). The specimens were kindly provided by the Uppsala Medical Museum. The collection of temporal bones was established by the late Dr Herman Wilbrand and one of the present authors (H.R.-A.) during the 1970s and 1980s at the Department of Diagnostic Radiology and Otolaryngology at the Uppsala University Hospital. The results obtained from this collection were previously published.[6,7] Seventy-eight bones were dissected using a dental drill. The microdissected temporal bones were evaluated using a Zeiss V20 microscope (Germany). Sixty bones were not dissected and were observed using micro-CT without prior drilling. In addition, 3 cadaver temporal bones were investigated by soft tissue analyses. These bones were also obtained from the collection. Moreover, the authors analyzed 300 middle ear ossicles (triplets) for varying morphology (**Fig. 1**).

Micro–computed tomography

A total of 113 macerated temporal bones underwent micro-CT and 3D reconstruction. The bones were scanned with micro-CT (SkyScan 1176; Bruker, Belgium) using the following parameters: 65-kV source voltage, 385-μA current, 9-μm pixel size, 1-mm Al filter, 1-second exposure time, 2-frame averaging, and a 0.30° rotation step. The projection images were acquired over an angular range of 360°, with an angular step of 0.3°. In the resultant images, the image size was 4000 $\times$ 2672 pixels, and