Clinical Radiology 69 (2014) e146–e152

Contents lists available at ScienceDirect

Clinical Radiology

journal homepage: www.clinicalradiologyonline.net

Pictorial Review

The windows of the inner ear

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ARTICLE INFORMATION

Article history:
Received 13 April 2013
Received in revised form
22 October 2013
Accepted 30 October 2013

The oval and round windows of the inner ear are important structures for the transmission of sound and may be affected by a variety of disease entities. The anatomy of this small area is one that often causes the radiology trainee some difficulty, but there are certain disease states that can be easily diagnosed when knowing where and how to look. As this area is very important to the otologist in a variety of preoperative settings, accurate assessment of the windows and recognition of important and potentially complex intra-operative anomalies, will greatly aid our surgical colleagues.

Introduction

The oval window is an opening between the middle ear and the vestibule, which is covered by a membrane. It lies at the depth of a narrow recess. The tympanic facial canal travels on the roof of this recess. The stapes footplate occupies the window and is circumferentially attached by the annular ligament. Sound waves travel via the external auditory canal to the tympanic membrane where vibrations are transmitted through the ossicular chain to the stapes. This moves in and out against the oval window causing vibrations of the adjacent perilymph. The wave created by the movement of the oval window travels through the perilymph of the scala vestibuli and continues through the scala tympani to the round window.[1]

The round window is the opening of the scala tympani into the middle ear, covered by the secondary tympanic membrane. The round window is recessed in the round window niche. The niche is pouch-shaped, and the width of the opening of the niche varies from 0.5–3 mm.[2,3]

The window is covered by a membrane, which has a horizontal part posterosuperiorly and a slightly larger vertical portion antero-inferiorly. Movement of incompressible endolymphatic fluid in the cochlea, stimulated by movement of the oval window, transmits sound to the hair cells in the organ of Corti. This sound energy is dissipated at the round window.

High-resolution computed tomography (HRCT) is the best imaging option for evaluation of the middle ear, the bony labyrinth, and the windows between the middle and inner. Multiplanar reconstruction is essential for accurate assessment of the anatomy (Figs 1 and 2).

Cochlear implantation

Cochlear implantation is increasingly used to improve severe or profound sensorineural hearing loss that has not responded to other forms of augmentation. The absolute requirements are the presence of a cochlea and a cochlear nerve.[5] The vertical portion of the membrane of the round window is the preferred route of electrode placement into the scala tympani, but visibility of the membrane and access depends on the bony overhangs and the orientation of the round window.

If viewed through the facial recess at surgery without drilling, a maximum of approximately 30% of the inferior part of the vertical segment is visible.[6] The anatomical variation of round window orientation can make surgery difficult and can mean that a cochlear implant is not

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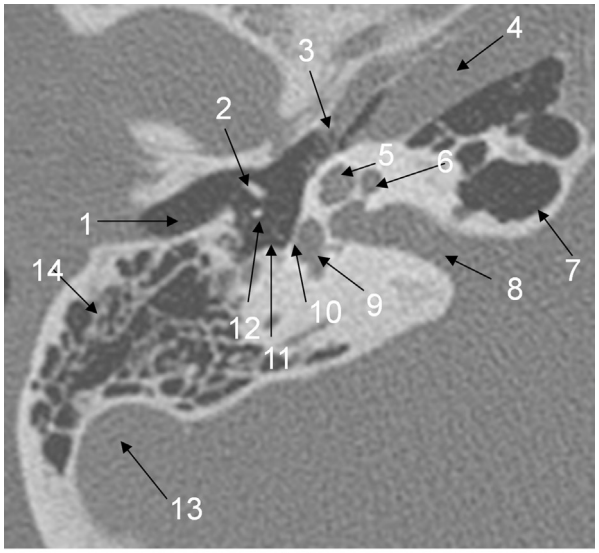
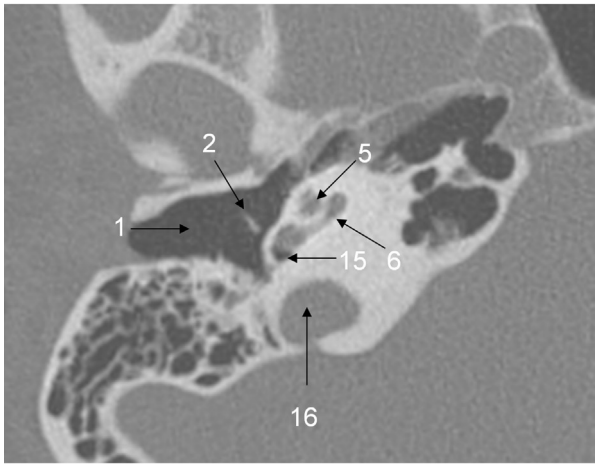
http://dx.doi.org/10.1016/j.crad.2013.10.020



(a)



(b)

Figure 1 Normal anatomy: axial CT images at the level of (a) oval and (b) round windows. 1. external auditory canal, 2. handle of malleus, 3. Eustachian tube, 4. horizontal petrous carotid canal, 5. middle and apical turn of cochlea, 6. basal turn of cochlea, 7. petrous apex air cell, 8. internal auditory canal, 9. vestibule, 10. stapes footplate at oval window, 11. posterior crus of stapes, 12. long process of incus, 13. sigmoid sinus, 14. mastoid air cells, 15. round window, 16. jugular fossa.

situated correctly in the cochlea.[7] If a membranous cochleostomy is not possible, electrodes are placed through a bony cochleostomy (Fig 3).

Pre-surgical evaluation with both CT and magnetic resonance imaging (MRI; to demonstrate presence of a cochlear nerve and the anatomy of the round window) is mandatory. Postoperatively, CT is often performed for anatomical assessment.

Otosclerosis

Otosclerosis (or otospongiosis) is an autosomal dominant disease of incomplete penetrance, where the mature lamellar bone of the otic capsule is replaced by spongiotic bone. The disease is the most common cause of adult mixed (conductive and sensorineural) hearing loss. Although patients frequently complain of unilateral hearing loss, CT demonstrates bilateral disease in more than half the cases.[8] CT is the best initial method for the diagnosis and assessment of otosclerosis, allowing assessment of whether one or both ears are involved, demonstrating variant anatomy and the severity.[9] Although there are severity gradings for otosclerosis, a clear anatomical description of the extent of disease is most helpful for clinicans.[10] Coronal reformats are particularly helpful for demonstrating oval window anatomy and the relationship of the facial nerve. MRI diagnosis of otosclerosis is challenging; active plaques manifest as intermediate signal on both T1-weighted (W) and T2W sequences with some post-gadolinium enhancement around the periphery of the demineralized bone.[11,12]

The most common disease pattern is fenestral otosclerosis (Fig 4) and the most common site of involvement is the fissula antefenestrum, the area anterior to the oval window. The stapes footplate may become thickened in isolation or more commonly as part of more generalized fenestral otosclerosis. If the measurement of the footplate is greater than 0.6 mm (normal thickness is 0.3–0.5 mm) this should be considered abnormal.[9]

Fenestral otosclerosis of the round window is less common and diminishes the success of surgery (Fig 5). Perichochlear disease manifests as spongiotic foci surrounding or in contact with the cochlea or internal auditory canal. Hearing loss may be conductive, mixed, or sensorineural, depending on the pattern of involvement. Surgical treatment involves stapedectomy and placement of a stapes prosthesis.

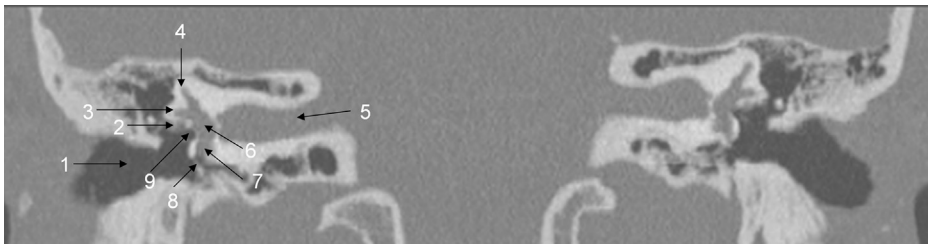


Figure 2 Coronal CT image demonstrating normal anatomy of the oval and round windows. 1. external auditory canal, 2. tympanic facial canal, 3. lateral semicircular canal, 4. superior semicircular canal, 5, internal auditory canal, 6. vestibule, 7. basal turn of cochlea, 8. round window niche, 9. oval window recess.