Magnetic Resonance Imaging (MRI) and High Resolution Computed Tomography (HRCT): Can they improve the evaluation of Middle ear cholesteatoma?

Poster No.: C-1249
Congress: ECR 2013
Type: Educational Exhibit
Authors: M. T. Fernández Taranilla, I. Herrera Herrera, R. Moreno de la Presa, J. M. Garcia Benassi, R. Gonzalez Gutiérrez, E. Bárcena Ruiz; Toledo/ES
Keywords: Neuroradiology brain, Ear / Nose / Throat, CT, MR, Complications, Surgery, Inflammation, Pathology
DOI: 10.1594/ecr2013/C-1249

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.
As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.
You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.
Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.
www.myESR.org
Learning objectives

Middle ear cholesteatoma is a common inflammatory disease that requires surgery due to potentially serious intracranial complications. Diagnosis of cholesteatoma is mainly clinical, with computed tomography (CT) used to evaluate disease extension before surgery. Certain patterns of bone erosion are specific, but CT attenuation does not allow differentiation from other inflammatory middle ear diseases. With its high tissue discrimination and contrast resolution, magnetic resonance imaging is valuable in diagnosis of cholesteatomas. The learning objectives of this educational exhibit are:

1. To review the role of HRCT and MRI in the diagnosis of middle ear cholesteatoma before and after surgery.
2. To report the advantages and limitations of new MRI techniques with Echo planar diffusion weighted (EPI-DW) and non Echo planar diffusion weighted (non EPI-DW) imaging.

Background

First of all, we are going to explain the most important temporal bone anatomy in order to better understand the pathological findings (Fig 1).

The anatomy of this region include the:

- external ear that contains the external auditory canal and auricle (outer ear).
- Middle ear and eardrum which is called the tympanic membrane that contains three ear bones or ossicles: Malleus, incus and stapes.
- The inner ear contains the cochlea, a snail-shaped bone which transforms sounds into nerve impulses. The vestibule, contains the utricle and saccule which sense motion in relation to gravity and three semicircular canals which sense rotational motion.

The mastoid air cells, are air cells which are behind the external auditory canal and the middle ear. The anatomy of the temporal bone is complex and is further complicated by the small size and three-dimensional orientation of associated structures. Computed tomography (CT) has revolutionized imaging of the temporal bone. Recent advances in multisection CT scanners allow acquisition of high-resolution volumetric data that enable image reformation in any plane (Fig 5).

Middle ear cholesteatomas have an erosive potential along the ossicles and bony walls of the middle ear cavity, mostly by means of an inflammatory response that activates osteoclastic activity.
Because serious intracranial and labyrinthine complications may arise, surgery is the elective treatment, with the goal of eradicating disease while simultaneously trying to preserve anatomy and function.

TYPES OF CHOLESTEATOMAS

Most middle ear cholesteatomas (98%) are acquired. These are usually related to chronic inflammatory middle ear disease combined with disturbed ventilation of the middle ear. The most accepted pathogenic mechanism is invagination of tympanic membrane retraction pockets owing to eustachian tube dysfunction, although other theories have been proposed.

According to its origin there are two types:

- **Congenital** (2%): intact eardrum.
  - Location in the temporal bone variable. Otoscopic diagnosis may be difficult.
- **Acquired** (98%): tympanic membrane perforation.
  - Pars tensa: also called sinus cholesteatomas (less common)
  - Pars flaccida: attic cholesteatoma, the most common.

**In an attic cholesteatoma**, the most common form of acquired cholesteatoma, the pars flaccida, posteriorly and superiorly located, invaginates toward the Prussak space. Erosion of the scutum and medial ossicular displacement by the growing cholesteatoma are specific findings at computed tomography (CT).

**Less common pars tensa cholesteatomas**, also called sinus cholesteatomas, extend toward the posterior tympanic recesses (sinus tympani and facial recess) and from there to the medial epitympanic space, producing lateral ossicular displacement.

**Congenital middle ear cholesteatomas** are less frequent (2% of cases), and their location in the temporal bone is more variable. When located in the middle ear cavity, a whitish retro tympanic mass is seen at otoscopy behind an intact eardrum and otoscopic diagnosis may be difficult (Fig 5a). Histologically, they are identical to congenital epidermoid cysts located elsewhere (meninges, skull base, spinal canal, brain) and are also produced by trapping of ectoderm during fetal development.

Images for this section:
Fig. 1: First of all, we are going to explain the most important temporal bone anatomy in order to understand better the pathological findings.
Fig. 2: The auditory ossicles of the middle ear and the structures surrounding them. Fig 3: The mechanism of hearing. Sound waves enter the outer ear and travel through the external auditory canal until they reach the tympanic membrane, causing the membrane and the attached chain of auditory ossicles to vibrate. The motion of the stapes against the oval window sets up waves in the fluids of the cochlea, causing the basilar membrane to vibrate. This stimulates the sensory cells of the organ of Corti, atop the basilar membrane, to send nerve impulses to the brain.
**Fig. 3:** Fig 4: The two labyrinths of the inner ear. The bony labyrinth is partially cut away to show the membranous labyrinth within.
Fig. 4: The anatomy of the temporal bone is complex and is further complicated by the small size and three-dimensional orientation of associated structures. Computed tomography (CT) has revolutionized imaging of the temporal bone. Recent advances in multisection CT scanners allow acquisition of high-resolution volumetric data that enable image reformation in any plane.
34-year-old patient with left otorrhea and hearing loss on the left side.

- Otoscopy: tympanic membrane perforation with white pearly mass was seen.

- CT: coronal CT reveals occupation of Prussak space and tympanic tegmen defect.

**Fig. 5:** CT features of acquired cholesteatomas. (a) Primary acquired attic cholesteatoma of the left ear in a 25-year-old man. Coronal CT image shows occupation of the Prussak space (*), erosion of the scutum, and eroded ossicles.
CT FINDINGS:

Attic cholesteatoma, the most common form of acquired cholesteatoma, the pars flaccida, posteriorly and superiorly located, invaginates toward the Prussak space. Cholesteatoma has an erosive potential along the ossicles and bony walls of the middle ear cavity, mostly by means of an inflammatory response that activates osteoclastic activity. The main CT findings are the followings: (Fig 6, 7, 8).

- Soft tissue mass attenuation in Prussak space
- Medial ossicular displacement by the growing cholesteatoma are specific findings at computed tomography (CT)
- Extension into the mastoid antrum
- 70% erosion of the ossicle
- Erosion of the scutum and the short process of incus.
- Tympanic membrane perforation
- Tympanic tegmen defect

MRI FINDINGS:

With its high tissue discrimination and contrast resolution, magnetic resonance imaging is valuable in diagnosis of cholesteatomas. Let's see the main techniques:

- **Delayed postcontrast image (DPI):** was the first specific MR imaging technique to be used in cholesteatoma diagnosis. T1-weighted images are obtained 45-60 minutes after intravenous administration of paramagnetic contrast material. Diagnosis is based on the lack of contrast enhancement in non perfused cholesteatomas as opposed to the enhancing granulation and inflammatory tissue.

- **Diffusion-weighted imaging (DWI)** is highly specific due to the high keratin content of cholesteatomas. The main diagnostic criterion for cholesteatoma at DWI is lesion hyperintensity, compared with the signal intensity of brain, on $b = 0 \text{ sec/mm}^2$ images that persists or increases on high $b$ value (800-1000 sec/mm$^2$) images. (Fig 9)

- **New non-echo-planar DWI sequences (Non-EPI DWI),** such as periodically rotated overlapping parallel lines (PROPELLER) with enhanced reconstruction, are superior to conventional echo-planar DWI (EPI-DWI), since they minimize susceptibility artifacts at the skull base and increase sensitivity for detection of lesions as small as 2 mm. This technique is
indicated when clinical diagnosis is difficult and high tissue specificity is necessary, as in congenital, temporal bone, or atypical acquired middle ear cholesteatomas and residual or recurrent disease after surgery. Moreover, Non-echo-planar DWI has been proposed for screening of postsurgical (residual or recurrent) cholesteatomas, thus obviating many second-look revision surgeries, especially after more conservative canal wall up surgery (Fig 10).

**DIFFERENTIAL DIAGNOSIS:**

Until the advent of DPI and DWI techniques, specifically intended for cholesteatoma imaging results of MR imaging were nonspecific in demonstrating the different causes of middle ear inflammatory disease (mucosal edema, granulation tissue, fluid, scar tissue, or cholesteatoma) (Fig 12). Except for the characteristic T1 hyperintensity of cholesterol granuloma, all of these entities show variable degrees of T1 hypointensity and T2 hyperintensity, mainly depending on their water and protein content.

- **In congenital temporal or middle ear cholesteatomas**, the integrity of the tympanic membrane and their variable location, together with their rarity and small size, make clinical and otoscopic diagnosis difficult at times. The high tissue specificity of DWI becomes useful in this clinical setting. Given the small size of congenital cholesteatomas, non-EPI sequences are preferred over less sensitive EPI DWI. (Fig 13)

- **Cholesterol granuloma of the middle ear**, unlike its counterpart in the petrous apex, has little clinical relevance, given its nonaggressive nature. Coexistence with cholesteatoma is frequent due to their common etiologic factors (chronic middle ear disease, hemorrhage, surgery). When differentiation from other causes of middle ear masses—such as fluid, inflammatory mucosa, granulation tissue, cholesterol granuloma, surgical scar, or encephalocele—is clinically relevant, tissue-specific imaging techniques (MR imaging, and more specifically diffusion-weighted imaging [DWI]) become very useful. (Fig 14).

- **Chronic otitis media** shows retained inflammatory secretions, which may also simulate a nonenhancing cholesteatoma. For the ENT-surgeon the differentiation between chronic otitis media and cholesteatoma is important. Both diseases often occur in poorly pneumatized mastoids. Erosion of the lateral wall of the epitympanum and of the ossicular chain is common in cholesteatoma (around 75%). Erosion can occur in chronic otitis, but reportedly in less than 10% of patients. Displacement of the ossicular chain can be seen in cholesteatoma, not in chronic otitis. Cholesteatoma can present with a non-dependent mass while chronic otitis shows thickened mucosal lining. However, in both diseases the middle ear cavity can be completely opacified, obscuring a cholesteatoma (Fig 15).
INTRACRANEAL COMPLICATIONS:

• **Encephalocele**: Coronal high-resolution CT shows brain parenchyma filling the residual cavity (Fig 16*). Findings related with temporal bone encephalocele as a complication of cholesteatoma. Diagnosis of encephalocele is usually straightforward on coronal or sagittal T1- and T2-weighted high-resolution images.

• **Labyrinthine fistula**: The high resolution coronal CT shows an image of the right ear at the level of the horizontal semicircular canal. Note the complete erosion of the ossicle, the tegmen tympani and the fistula of the horizontal semicircular canal (Fig 17).

• **Acute Labyrinthitis**: Labyrinthitis has three radiologic stages: acute, fibrous, and labyrinthitis ossificans. In the acute stage, contrast-enhanced T1-weighted MR imaging may show abnormal enhancement of the labyrinth. MR imaging also allows detection of cochlear obstruction in the fibrous stage, before abnormalities are detectable with CT. Labyrinthitis ossificans involves pathologic ossification of the bony labyrinth and cochlea and is well-depicted with CT (Fig 18).

• **Facial Palsy**: Perineural extension of a cholesteatoma along the facial nerve may also occur, in which case MR imaging is important, to exclude a neoplasm. Sensorineural hearing loss develops by cholesteatomatous involvement of the internal auditory canal. The labyrinthine segment of the facial nerve canal also appears widened. The facial nerve enters the petrous bone via the internal auditory canal. The nerve exits this canal anterioly along the facial canal. The first genu of the facial nerve then passes around the anterior aspect of the otic capsule of the inner ear (Fig 19).

POSTOPERATIVE CHOLESTEATOMA:

Identification of recurrent cholesteatoma and differentiation from postoperative granulation tissue is important in a patient who has undergone mastoidectomy for cholesteatoma. The MR imaging findings of recurrent cholesteatoma include a hyperintense mass on T2-weighted images that has intermediate-to-low T1-weighted signal intensity and that enhances minimally after the administration of contrast material. Cholesteatomas are hyperintense at DWI due to their high keratin content and show no enhancement at DPI (Fig 20).

In this slide we analyze the strengths and drawback of the very promising non-echo-planar imaging (non-EPI) versus EPI DWI techniques. (Fig 21).
Both EPI and non-EPI DWI techniques are highly specific for cholesteatoma. Although false-positive results are described, most of them are easily identifiable on the basis of the clinical context or type of surgery performed (Fig 22,23,24).

Until the advent of DPI and DWI techniques, specifically intended for cholesteatoma imaging, results of MR imaging were nonspecific in demonstrating the different causes of middle ear inflammatory disease (mucosal edema, granulation tissue, fluid, scar tissue, or cholesteatoma) but with the newest and very promising non-echo-planar imaging (Non-EPI) DWI techniques that have been developed during the past decade the sensitivity and specificity for diagnosis of middle ear cholesteatoma have improved.

Images for this section:

![Acquired cholesteatoma of the pars flaccida](image)

**Fig. 6:** Attic cholesteatoma with tympani tegmen defect.
Acquired cholesteatoma of the pars flaccida

Coronal CT:

- Attic cholesteatoma: erosion of the scutum and medial ossicular displacement by the growing cholesteatoma are specific findings at the computed tomography (CT).

Fig. 7: Attic cholesteatoma, the most common form of acquired cholesteatoma, the pars flaccida, posteriorly and superiorly located, invaginates toward the Prussak space. Erosion of the scutum and medial ossicular displacement by the growing cholesteatoma are specific findings at computed tomography (CT).
Fig. 8: Main findings of cholesteatoma on high resolution CT.
Imaging findings

- High resolution computed tomography of temporal bone is mandatory for the initial preoperative evaluation of the extension of cholesteatoma and for correct surgical planning.

- CT cannot, however, differentiate between cholesteatoma, cholesterol granuloma, granulation, brain or fibrous tissue and mucoid secretion in the post-mastoidectomy cavity.

Fig. 9: Fig *: Soft tissue mass in Prussak space and blunting of the scutum in an attic cholesteatoma.
Cholesteatoma

MRI (Fig 9)

- **Delayed Postcontrast imaging (PDI):** Diagnosis is based on the lack of contrast enhancement.
- **Diffusion-weighted imaging (DWI):** is highly specific due to the high keratin content of cholesteatomas.

**Fig. 10:** MRI findings in cholesteatoma.
Fig. 11: New non-echo-planar DWI sequences, such as periodically rotated overlapping parallel lines with enhanced reconstruction, are superior to conventional echo-planar DWI, since they minimize susceptibility artifacts at the skull base and increase sensitivity for detection of lesions as small as 2 mm.
Differential diagnosis

- **Pars tensa cholesteatoma**
  - Origin: medial epitympanic space
  - Postero superior disruption of the tympanic membrane
  - Extends:
    - Medially towards the ossicular chain.
    - Posteriorly: facial recess and tympanic sinus.

- **Congenital cholesteatoma (2%)**
  - Intact tympanic membrane

- **Cholesterol granuloma**
  - T1 weighted image hyperintensity
  - Chronic otitis media (OMC)
  - Usually there is no erosion of the ossicular chain.

*Fig. 12: Main different diagnosis.*
Fig. 13: Characteristics findings of the congenital attic cholesteatoma.
**Cholesterol granuloma**

- No erosion of the ossicular chain
- No enhance and no restricted diffusion
- Characteristic T2 WI hyperintensity from the granulatton tissue and peripheral low signal from hemosiderin deposition.

---

**Fig. 14**: Characteristic findings of Cholesterol granuloma
**Chronic otitis media**

- No displacement of the ossicular chain
- Erosion can occur in chronic otitis, but reportedly in less than 10% of patients. Scutum intact.
- Thickened mucosal lining instead of non-dependent mass

**Fig. 15:** Characteristic findings of chronic otitis media.
Complications: Encephalocele

54-year-old patient with a history of surgery for a right cholesteatoma. At CT, the tegmen tympani was eroded, and a nonspecific mass occupied the middle ear cleft.

Coronal high-resolution CT shows brain parenchyma filling the residual cavity (*). Findings related with Temporal bone encephalocele as a complication of cholesteatoma.

Fig. 16: Coronal high-resolution CT shows brain parenchyma filling the residual cavity (*). Findings related with Temporal bone encephalocele as a complication of cholesteatoma.
Fig. 17: The high resolution coronal CT shows an image of the right ear at the level of the horizontal semicircular canal. Note the complete erosion of the ossicle, the tegmen tympani and the fistula of the horizontal semicircular canal.
Acute labyrinthitis

- 48 year old woman with vertigo. Coronal CT images show abnormal sclerosis of the bony labyrinth and cochlea (*).

Axial T2-weighted MR image shows absence of fluid signal intensity in the right cocha and semicircular canals with enhancement of the membranous labyrinth corresponding to an acute labyrinthitis.

**Fig. 18:** Axial T2-weighted MR image shows absence of fluid signal intensity in the right cocha and semicircular canals with enhancement of the membranous labyrinth corresponding to an acute labyrinthitis.
Fig. 19: Perineural extension of a cholesteatoma along the facial nerve may also occur, in which case MR imaging is important, to exclude a neoplasm. Sensorineural hearing loss develops by cholesteatomatous involvement of the internal auditory canal.
**Fig. 20:** In this slide we analyze the strengths and drawback of the very promising non-echo-planar imaging (non-EPI) and EPI DWI techniques.
Fig. 21: Until the advent of DPI and DWI techniques, specifically intended for cholesteatoma imaging, results of MR imaging were nonspecific in demonstrating the different causes of middle ear inflammatory disease (mucosal edema, granulation tissue, fluid, scar tissue, or cholesteatoma) but with the newest and very promising non-echo-planar imaging (Non-EPI) DWI techniques that have been developed during the past decade the sensitivity and specificity for diagnosis of middle ear cholesteatoma have improved.
Fig. 22: Identification of recurrent cholesteatoma and differentiation from postoperative granulation tissue is important in a patient who has undergone mastoidectomy for cholesteatoma. The MR imaging findings of recurrent cholesteatoma include a hyperintense mass on T2-weighted images that has intermediate-to-low T1-weighted signal intensity and that enhances minimally after the administration of contrast material. Cholesteatomas are hyperintense at DWI due to their high keratin content and show no enhancement at DPI.
Fig. 23: In this slide we compare the Non-EPI DWI with an equivalent EPI diffusion-weighted image (b = 1000 sec/mm²), a large proportion of the lesion is obscured by susceptibility artifacts and its delineation is poorer.
Conclusion

CT scan is the procedure of choice for identifying tegmen erosion and when there is suspicion of an existing encephalocele, but MRI is essential to differentiate between cholesteatoma, brain herniation and inflammatory tissue. New non-EPI DWI techniques allow highly specific diagnosis of cholesteatoma, an achievement not possible with CT or conventional MR imaging techniques. These new MRI techniques are fast, produces easy-to-interpret images, and does not involve injection of paramagnetic contrast material. Moreover, Non-EPI DWI are very helpful in recurrent and residual cholesteatoma because the specificity of DWI allows timely surgery, thus preventing intracranial complications, and minimizes radiation from follow-up CT studies. After surgery, non-EPI DWI is emerging as a screening technique to select which patients should undergo revision surgery by permitting effective detection of residual disease.

References


Personal Information