Cholesteatoma: utility of non-echo-planar diffusion-weighted imaging


Resumo
Colesteatomas são lesões císticas congênitas ou adquiridas que acometem as orelhas e que podem apresentar padrões típicos aos estudos de tomografia computadorizada, em função de suas características expansivas e tendência a promover erosão óssea. Entretanto, particularmente nos casos de resíduo ou recorrência pós-cirúrgica, a distinção entre colesteatoma e tecido inflamatório pode ser bastante difícil e, não raro, impossível com base somente nos achados tomográficos. A avaliação por ressonância magnética pode ser útil, particularmente neste contexto, uma vez que as sequências pós-contraste obtidas tardiamente e a difusão podem demonstrar padrões distintos nestas duas situações. Os artefatos condicionados pela interface ar/osso na região das mastoides podem limitar bastante a utilização das sequências pós-contraste obtidas tardiamente e a difusão-weighted imaging pode demonstrar padrões distintos nestas duas situações. Os artefatos condicionados pela interface ar/osso na região das mastoides podem limitar bastante a utilização da sequência de difusão echo-planar. A sequência de difusão sem echo-planar é uma alternativa na solução deste problema por estar menos sujeita a este tipo de artefato, fornecendo ainda imagens com maior resolução espacial e com espessuras de corte mais finas, as quais permitem a detecção de colesteatomas de pequenas dimensões.

Keywords: Colesteatoma; Ressonância magnética; Difusão-weighted imaging.

INTRODUCTION
Cholesteatomas are cystic lesions of aggressive behavior, composed of keratinized stratified squamous epithelium. It is constituted of an epithelial matrix surrounded by an inflammatory stroma with variable thickness containing cellular degeneration by definition, in cases of congenital or acquired, affecting the ears and presenting typical imaging patterns at computed tomography because of its expansile nature and tendency to erode bone. However, particularly in cases of lesion residue or recurrence after surgery, the distinction between cholesteatoma and inflammatory tissue based solely on computed tomography findings may be quite difficult, if not impossible. Magnetic resonance imaging might be very useful, particularly in such a context, since delayed postcontrast and diffusion-weighted images can demonstrate different imaging patterns in these two situations. Artifacts related to air-bone interface in the mastoid region may represent a relevant limitation to the utilization of echo-planar diffusion-weighted imaging. Non-echo-planar diffusion-weighted imaging represents an alternative to resolve this problem, once this method is less subject to this type of artifact, besides offering images with higher spatial resolution and thinner slice thickness, allowing the detection of small-sized cholesteatomas.

Keywords: Cholesteatomas; Magnetic resonance imaging; Diffusion-weighted imaging.
pally the malleus head, the long process and the body of incus. After growth, the cholesteatoma invades the antrum and the mastoid process, eroding further structures of the middle ear such as the facial nerve canal, the tegmen tympani and the posterior semicircular canal wall\(^1\,^2\).

The etiopathogenesis of congenital and acquired cholesteatomas still remains under discussion, and there are several theories to explain the origins of such entity.

The treatment consists in surgical resec-
tion of the epithelial matrix. However, a high number of patients submitted to surgical treatment remain with residual or recurrent cholesteatoma, many times identified only at the second operative time. There may be a new growth of the cholesteatoma either from the non-resected epithelial matrix (residual cholesteatoma) or from the development of a new matrix on the retracted tympanic membrane resulting from scarring (recurrent cholesteatoma)\(^3\).

The eradication of cholesteatomas has represented a challenge for surgeons. Several procedures have been utilized, either with open or closed surgical technique, but the ideal surgical method still remains controversial. The different techniques rely on the sparing or not of the posterior wall of the external auditory conduct, either connecting or not the mastoid cavity with the exterior.

Open surgical techniques include mastoidecomy (abrasion of the posterior wall of the external auditory meatus, with removal of remainders of tympanic membrane, malleus and incus, in association with meatoplasty); modified radical mastoidecomy (partial removal of the attic and of the posterior wall of the meatus); and radical mastoid cavity reconstruction (radical mastoidecomy with reconstruction of the tympanic bulla utilizing the temporal fascia). Among the closed surgical techniques, tympanotomy is aimed at creating an incision on the posterior wall of the external auditory meatus, in front of the facial nerve in order to remove the cholesteatoma near the stapes and the round window, while mastoidectomy with tympanoplasty is a procedure performed in a single surgical time in cases where there is no doubt on the total excision of the cholesteatoma. More conservative techniques present the disadvantage of requiring a re-
vision surgery (second look), but leads to better outcome in relation to hearing pres-
ervation. According to several published studies, the incidence of residual or recur-
rent cholesteatomas seems to be lower with open surgical techniques\(^4\,^5\).

**IMAGING STUDIES**

Computed tomography (CT) still re-
mains as the method of choice for diagno-
sis and assessment of cholesteatomas ex-
tent. It can demonstrate ossicular erosion as well as possible complication such as erosion of tegmen tympani and lateral semicircular canal\(^6\). Unfortunately, however, after surgery most of the patients present total or subtotal opacification of the middle ear, so it is not possible to identify the presence of any inflammatory process, abscess, scar or granulomatous tissue, cholesterol granuloma and cholesteatoma at CT\(^7\).

As shown on Figures 1A to 1E, at CT, the patient with post-mastoidecomy re-
sidual cholesteatoma presents a mass with soft tissue density obstructing the surgical cavity which, at magnetic resonance imag-
ing (MRI), demonstrated diffusion restric-
tion at non echo-planar imaging. Peripheral enhancement is observed at delayed phase (45 minutes after contrast injection), spin echo, T1-weighted sequence with fat sup-
pression. A second postoperative follow-up with these same sequences allows the dem-

![Figure 1A](image1a.png)  
*Figure 1A. CT, coronal plane: postoperative status of conservative mastoidectomy. Presence of material with soft tissue density obstructing the surgical cavity (arrow). The tomographic finding is nonspecifc and might correspond either to fibrotic/inflammatory tissue or residual/recurrent cholesteatoma.*

![Figure 1B](image1b.png)  
*Figure 1B. MRI, coronal plane, HASTE diffusion-weighted (non echo-planar) sequence. Note diffusion restriction in residual cholesteatoma at left (arrow).*

![Figure 1C](image1c.png)  
*Figure 1C. MRI, coronal plane, spin echo, T1-weighted sequence with paramagnetic contrast injection. Note the subtle peripheral contrast-enhancement, a typical finding of cholesteatoma (arrow).*

![Figure 1D](image1d.png)  
*Figure 1D. MRI, coronal plane, T2-weighted sequence with paramagnetic contrast injection. Note the subtle peripheral enhancement, a typical finding of cholesteatoma (arrow).*

![Figure 1E](image1e.png)  
*Figure 1E. MRI, sagittal plane, T1-weighted sequence with paramagnetic contrast injection. Note the subtle peripheral enhancement, a typical finding of cholesteatoma (arrow).*
onstration, in a different moment, an intense contrast enhancement and absence of diffusion restriction compatible with the presence of surgically confirmed inflammatory granulation tissue.

Recently, MRI including diffusion echo-planar imaging (EPI) has gained relevance in the diagnosis of cholesteatoma. Initially, such sequence was utilized in the assessment of cerebral ischemia. It is based on the demonstration of the movement of free water molecules and possible restriction to such a movement in pathological cases. Fitzek et al. were the first ones to demonstrate that cholesteatoma was visualized with high signal intensity at diffusion EPI sequences, more specifically at b1000 images. However, diffusion EPI presents low spatial resolution, relatively thick sections and higher susceptibility to artifacts in regions of air-bone interface, representing disadvantages which many times hinder the diagnosis of cholesteatomas, particularly in cases of lesions measuring $< 5$ mm in diameter\textsuperscript{(8)}. Such a limitation can be clearly observed on Figure 2D, where the artifact hinders the visualization of the focus of diffusion restriction, while at the image on Figure 2C acquired with non echo-planar sequence, the diffusion restriction was clearly demonstrated. Toyama et al.,
in a study with 17 patients, have found 91.5% sensitivity, 60% specificity, 84.6% positive predictive value, and 75% negative predictive value, concluding that diffusion EPI combined with contrast-enhanced imaging is useful in the differential diagnosis of recurrent cholesteatoma and granulation tissue.

Jeunen et al. have found sensitivity, specificity, PPV and NPV of 54%, 90%, 92% and 47%, respectively in a study involving 31 patients and utilizing diffusion EPI. In the case of residual or recurrent cholesteatomas, sensitivity, specificity, PPV and NPV were 83%, 82%, 83% and 82%, respectively. In such study, residual cholesteatomas were correctly identified in 15 out of 18 patients, and small-sized lesions (2–5 mm) were missed in three patients.

Recent studies have demonstrated the value of non-EPI diffusion weighted imaging in the diagnosis of primary cholesteatomas (Figures 2A to 2D) and also in postoperative recurrence. Single shot turbo spin echo (SSTSE) diffusion-weighted or multi-shot fast spin echo (FSE) imaging present lower susceptibility to artifacts and can be acquired with thinner sections, with higher spatial resolution (Figures 3A and 3B), allowing the detection of small-sized lesions, such as the one shown in Figure 4, with 3 mm in diameter. Dubrulle et al. have evaluated TSE diffusion-weighted imaging for detecting recurrent cholesteatomas, but the threshold for detection of small-sized cholesteatomas in this study was 5 mm, equal to the threshold for EPI sequences. Other studies indicate that SSTSE presents high sensitivity and specificity, detecting cholesteatomas with up to 2 mm in diameter.

De Foer et al. have found 90% sensitivity, 100% specificity, 100% PPV, and 96% NPV for non-EPI sequences in the study of patients with residual cholesteatoma. In this study, cholesteatomas measuring 2 to 6 mm in diameter were diagnosed.

Non-EPI diffusion-weighted imaging acquisition time is longer than for echo-planar imaging and presents two significant limitations. Motion artifacts may blur hyperintense b1000 images, provoking signal iso-signal intensity and conditioning a false-negative result. Spontaneously evacuated cholesteatoma is also a possible cause of false-negative result, once the contents of desquamated and degraded keratin responsible for the diffusion restriction shall not be present in cases of automastoidectomy. In such cases, the cholesteatoma content is evacuated into the external auditory meatus, and can displace the matrix far away from its original positioning in the middle ear and in the mastoid antrum. Thus, it is important to highlight that both diffusion weighted EPI and non-EPI imaging may fail in the detection of cholesteatoma due to the absence of keratin (responsible for the hyper signal intensity).

Images acquisition with MRI T1-weighted sequences with fat saturation, 30–45 minutes after gadolinium injection has been originally described by Williams and collaborators based on the fact that cholesteatoma is a non-enhancing avascular tissue whereas inflammatory, granulomatous and cicatricial tissues are poorly vascularized and do present slow contrast enhancement. Such T1-weighted sequence could demonstrate the exact location of the cholesteatoma in the middle ear and mastoid process, as well as the surrounding inflammatory reaction.

Ayache et al. have found 90% specificity and 100% sensitivity after utilizing contrast agent. However, residual pearls measuring up to 3 mm could not be diagnosed with such technique. The time required for images acquisition after contrast injection represents the main limitation of the technique, and it should be highlighted that early imaging may lead to false positive results for cholesteatoma.
The combination of post-contrast MRI with non-EPI diffusion-weighted sequences presents higher sensitivity and specificity than CT for detecting residual cholesteatomas, conditioning the reduction of the number of tympanic cavity revision surgeries. However, the utilization of non-EPI diffusion-weighted sequences without necessity of delayed contrast-enhanced imaging has been defended by some authors, since the combined utilization of such sequences adds little diagnostic sensitivity and specificity to the study. Also, diffusion-weighted imaging alone presents further advantages, namely, reduction of the total images acquisition time and costs reduction.[13]

REFERENCES