MRI as an Alternative to Second Look Mastoid Surgery

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Abstract The main goal of surgery of cholesteatoma is eradication of the disease and revision surgery is indicated when a dry and safe ear has not been achieved. Residual cholesteatoma usually occurs at the sites that are difficult to reach with an operating microscope, such as posterior tympanum and anterior epitympanic recess. Computed tomography can be performed to delineate the extent of disease. High-resolution computed tomography scanning is important for planning for surgery and is indicated for all revision mastoid operations. Magnetic resonance imaging is superior to computed tomography in tissue characterization for diagnosis of recurrent cholesteatoma. To evaluate the cases of recurrent cholesteatoma comparing the intraoperative surgical findings with the preoperative MRI radiological findings and if the preoperative MRI can replace the second look surgery for cholesteatoma. This study was applied on 60 patients that have a recurrent cholesteatoma after previous mastoid surgery. A preoperative radiological evaluation was done by Magnetic resonance, surgical management was done by canal wall up or canal wall down mastoidectomy to exclude residual disease. Then, radiological, and surgical findings correlation was done. Diffusion-weighted MRI successfully detected 42 cases out of the 45 cases of surgically proved cholesteatoma, it has accuracy 95%, sensitivity 93.33%, specificity 100%, PPV 100% and NPV 83.33%. MRI is better than CT in tissue characterization for diagnosis of recurrent

cholesteatoma, and can replace the unnecessary second look surgery of cholesteatoma

Keywords Cholesteatoma · Residual · CT · MRI · Microscope

Introduction

A cholesteatoma consists of an accumulation of desquamated keratin epithelium in the middle ear cleft or any other pneumatized part of the temporal bone. Cholesteatoma causes destruction to adjacent areas via pressure necrosis, as it causes erosion of the ossicles, horizontal semicircular canal, uncovers the facial nerve, causes exposure of dura of the temporal fossa or cerebellum, or causes other serious damage to important structures within or adjacent to the temporal bone. The desquamated keratin is shed continuously by the matrix and forms the central mass of the cholesteatoma, similar to the layers of an onion. The term cholesteatoma is a misnomer, since the entity does not contain cholesterol [1].

The two primary procedures used to treat cholesteatoma are the canal wall down (CWD; open-cavity) and the canal wall up (CWU; closed-cavity) procedures. The CWD procedure provides sufficient access to the facial recess and tympanic sinus, with adequate surgical exposure, and is associated with a low recurrence rate of cholesteatoma. However, an incompletely cleaned cavity leads to formation of granulation tissue and otorrhea. This “cavity problem” in the open cavity is caused by bacterial or fungal infection and disturbed external auditory canal (EAC) skin migration. Conversely, the CWU procedure maintains the shape of the EAC with normal skin migration, which allows quick postoperative wound healing, but

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provides an inadequate surgical view so the recurrence rate of cholesteatoma is high compared with CWD procedure [2].

Residual disease and recurrent disease are 11–27 and 5–13% respectively in those undergoing the closed procedure, whereas residual or recurrent disease occurs in 2–10% of those undergoing the open procedure [3].

A residual cholesteatoma develops from the matrix that was not removed at tympanoplasty and depends on the surgical maneuvers performed by the otologist. Residual cholesteatoma usually occurs in the sinus tympani, oval window, middle cranial fossa, and bone dehiscence of the facial canal. Residual cholesteatomas in the epitympanum and sinus tympani tends to occur due to incomplete removal of the matrix due to insufficient surgical view because of inadequate drilling [2].

The manifestation of recurrent cholesteatoma depends largely on the topographic distribution of the underlying disease. Attic cholesteatomas are associated with high risk of subsequent recurrent cholesteatomas. On the other hand, they almost always destroy the lateral attic wall, thus increasing the risk of development of retraction pocket and recurrent cholesteatoma. Cholesteatomas localized in the retro tympanum (sinus cholesteatoma), especially if they were located in facial recess and tympanic sinus, are inclined to develop into recurrent cholesteatomas [4].

The primary goal of cholesteatoma surgery is the eradication of infection and/or disease and revision surgery is considered when a dry and safe ear has not been obtained [5].

Although the diagnosis of cholesteatoma usually depends on history and otoscopic examination, its presence and extent may not always be entirely clear. This is especially in postoperative ears, in which recurrent or residual disease may present in areas hidden from direct examination. The considerable variability of the size and location of cholesteatoma can considerably affect the surgical approach and the expectations. Similarly, the potential involvement of vital adjacent structures can also present hidden risks. For these reasons, the important role of the imaging is clear to be a valuable adjunct to the clinical management of these patients [6].

High-resolution computed tomography (HRCT) plays an important role in the diagnosis and detection of the extension of middle ear cholesteatoma; however, if soft tissue opacity in the cavity of the middle ear is seen on high-resolution CT, the diagnosis of the mass cannot be confirmed. However, magnetic resonance imaging (MRI) has been presumed to distinguish soft tissue. In the past, middle ear cholesteatoma was diagnosed using MRI by distinguishing granulation tissue with the characteristic peripheral enhancement of cholesteatoma matrix and central non-enhancing cholesteatoma on T1-weighted imaging

after gadolinium administration. In the past few years, the diffusion weighted MRI appeared to have an increasing role in the evaluation of patients with acquired middle ear cholesteatoma [7].

Recent refinements of diffusion-weighted MRI (DWMRI) have provided an accurate diagnosis of smaller collections of keratin debris within an ear that would otherwise be impossible to distinguish from fluid or edematous mucosa on HRCT. So, the selective use of HRCT and DW-MRI can provide complementary information that can help the otologic surgeon in the management of cholesteatoma [6].

Although there are signs on high-resolution CT to suggest residual or recurrent cholesteatoma, it cannot differentiate recurrent or residual cholesteatoma from inflammation, fibrosis, granulation tissue or cholesterol granuloma in the middle ear cleft [8].

MRI can differentiate granulation tissue from cholesteatomatous tissue, but often fails to clearly detect residual or recurrent cholesteatoma in the ears postoperatively. Therefore, non echo- planar DW image (DWI) techniques have been tested to see if they could overcome these limitations [9]. In this study, we try to evaluate the cases of recurrent cholesteatoma comparing the intraoperative microscopic findings with the preoperative MRI radiological findings.

Patient and Methods

This study was carried out on 60 patients 36 males and 24 females, their age ranged from 12 to 55 years. Patients were selected from Outpatient Clinic of ENT Department, Zagazig University Hospitals in the period from August 2014 to May 2016. They all had undergone previous surgery for chronic suppurative otitis media with cholesteatoma and presented with a clinical picture suggesting recurrent cholesteatoma such as chronic ear discharge with or without hearing loss, vertigo, tinnitus, otalgia, and headache. All patients were subjected to preoperative evaluation including history, complete ENT examination and investigations). Surgical management was done by CWU or CWD mastoidectomy. Radiological, surgical findings correlation was done. All patients were subjected to preoperative pure tone audiometry, Preoperative magnetic resonance imaging.

The study was done for all patients using (1.5 T) super conducting MR imager (Philips Achieva). The examination was done using standard head matrix coil apparatus with small field of view. Recommended protocols include:

- Axial and coronal T2-weighted fast spin echo (SE) images (TR/TE, 4000–3000/110, 2-mm thick sections,

200 × 200 mm field of view, and 128 × 128 matrixes).

- Axial and coronal T1-weighted fast SE images (TR/TE, 550–450/15, 2-mm thick sections, 200 × 200 mm field of view, 128 × 128 matrixes) before administration of contrast material.
- Coronal 3D T2 fast SE images (TR/TE, 4000/250, 2-mm thick sections, 200 × 200 mm field of view, 128 × 128 matrixes).
- Coronal and axial multishot diffusion –weighted fast SE images (TR/TE, 2800/92, 1.5 mm thick sections, 200 × 200 mm fields of view, 192 × 256 matrices, b value of 0 and 1000 Sec/mm²) without measurement of apparent diffusion coefficient.
- Gadopentate dimeglumine (Magnivist; Schering, Germany) was injected at a dose of 0.1 mmol/Kg. Post contrast coronal T1-weighted SE images were obtained with the same parameters immediately and delayed (30–45 min) after intravenous injection of contrast material.

Technique

Surgical management:

All patients underwent second look revision surgery for eradication of middle ear pathology + reconstruction of the middle ear

Surgical Technique:

In this prospective study, these cases were operated on by using either canal wall up (CWU) or canal wall down (CWD) technique

We compare the intraoperative microscopic findings with the preoperative MRI radiological findings.

Results

This study included 60 patients. 36 males (60%) and 24 females (40%). Their ages ranged from 12 to 55 years (mean = 28.65 ± 11.954) all of them had a clinical picture of cholesteatoma. The demographic data are presented in Table 1. In this study 24 right ears (40%), and 36 left ears (60%) were operated. 30 patients (50%) were operated by canal wall up (CWU) and 30 patients (50%) had undergone canal wall down (CWD). All cases displayed hyperintense signal in T2WI, low hypointense signal in T1WI and hyperintense signal in T2 3D WI. No of our cases shows early post contrast enhancement, however, after 30–45 min 21 cases (35%) showed marginal enhancement (cholesteatoma surrounded by granulation), 24 cases (40%)

showed no delayed enhancement (cholesteatoma) and 15 cases (25%) showed significant homogenous pattern of enhancement (granulation) (Table 2).

In this study Diffusion-weighted MRI had successfully detected 42 cases out of the 45 cases of surgically proved cholesteatoma, three cases falsely diagnosed by MRI as granulation tissue (the 3 false negative cases corresponded to cholesteatomas less than 5 mm) (Table 3). The mean duration of follow-up for the patients was 8.7 ± 4.889 months. 3 cases of 60 patients (5%) showed a postoperative intermittent otorrhea after 8–12 months postoperatively, which was controlled by regular suction clearance, both had CWU procedure.

Discussion

The aim of otologic surgery for chronic otitis media is to make the ear safe and to preserve or restore the hearing. Residual cholesteatoma tends to occur in areas that are difficult to reach with an operating microscope, such as posterior tympanum and anterior epitympanic recess [9]. The effective imaging allows for better selection of cases requiring surgical revision and to avoid unnecessary surgical exploration. Most of the reports stated that, no single imaging study has been proven to be sensitive and specific enough to replace open or endoscopic surgery [10].

Cholesteatoma in a non-operated patient can be reliably evaluated with a CT or conventional MRI scans. Following surgery, a CT scan may be able to exclude cholesteatoma in the absence of opacification in a well aerated tympanomastoid cavity. However, the presence of any opacity in the tympanomastoid cavity on a CT scan cannot differentiate between recurrent or residual cholesteatoma and other postoperative changes such as granulations or inflammatory tissue and fluid [11].

MRI can discriminate between residual cholesteatoma and granulation. Diffusion-weighted imaging (DWI) and delayed postcontrast T1-weighted (T1 W) sequences have both been suggested. Delayed postcontrast T1 spin-echo sequences improve the diagnosis of recurrent cholesteatoma and can differentiate between scar tissue, which shows delayed enhancement, and cholesteatoma, which does not show delayed enhancement; conversely, inflammatory tissue displays early enhancement [12].

In this study the conventional MRI signal-intensity characteristics of cholesteatoma are not specific; as all cases in this study displayed hypointense/isointense signal on T1WI and hyperintense signal on T2WI and T23D compared with brain tissue, our results were in agreement with Ilica et al. [13], Barath et al. [14], Abdulmonaem et al. [15] and Teschner et al. [16]. In this study, we evaluated the potential to use spin-echo-planar diffusion-weighted

Table 1 Shows the age and sex distribution of the studied group

Age	Male	Female	Percentage (%)
10 to < 20	6	3	15
20 to < 30	9	18	45
30 to < 40	15	0	25
40 to < 50	3	0	5
50 to < 60	3	3	10
Total	36	24	100

Mean age = 28.65 with standard deviation 11.954

Table 2 MRI signal and pattern of enhancement in the lesion of the studied group

MRI sequence	Signal	No. of cases	Percentage (%)
T2WI	Hyperintense	60	100
T1WI	Low hypointense	60	100
T2 3D WI	Hyperintense	60	100
Post contrast T1WI:			
Early	Enhanced	0	0
	Not enhanced	60	100
Delayed (after 30–45 min)	Marginal enhancement	21	35
	No enhancement	24	40
	Diffuse homogenous enhancement	15	25

Table 3 Relation between DWI findings and surgical findings

	DW-MRI findings	Surgical findings
Cholesteatoma	42 (70%)	45 (75%)
Granulation tissue	18 (30%)	15 (25%)
Total	60 (100%)	60 (100%)

Sensitivity = 93.33%, specificity 100%, positive predictive value = 100%, negative predictive value = 83.33%, accuracy = 95%

MRI in the diagnosis of cholesteatoma. The DWI showed that cholesteatoma appeared hyperintense in DW images while other tissues (inflammatory and granulation tissues) were hypointense on DW images. We found that Diffusion-weighted MRI successfully detected 42 cases out of the 45 cases of surgically proved cholesteatomas with accuracy 95%, sensitivity 93.33%, specificity 100%, PPV 100% and NPV 83.33%. (The 3 false negative cases had cholesteatomas less than 5 mm). We found DW-EPI is more reliable in detecting post-operative cholesteatoma. Our results were nearly similar to previous results reported by Abdelghany [17] who described sensitivity 100%, specificity 100%, PPV 100% and NPV 100%. Also Vercruysse et al. [18]

described a sensitivity of 81% and a specificity of 100% with a PPV of 100% and an NPV of 40% for detecting cholesteatomas using DW-EPI in patients who had not undergone surgery, and Aikele et al. [19] also found DW-EPI to be more reliable in detecting post-operative cholesteatoma. Reported a sensitivity of 77%, specificity 100%, positive predictive values 100% and negative predictive values 75%; in detecting residual or recurrent cholesteatoma using the combination of standard MR imaging sequences and DWI; missing three small residual cholesteatoma pearls (< 5 mm). Another report by Stasolla et al. [20] reported a sensitivity of 86%, Specificity 100%, positive predictive values 100% and negative predictive values 92%; in detecting recurrent cholesteatoma using echo-planar DWI. In their series only one small cholesteatoma of 2 mm was missing, while the size of the other cholesteatomas varied from 4 to 14 mm were detected, also recent study by McJunkin [21] described 81% sensitivity and 100% specificity. The false negative cases were found to be retraction pocket lesions with little or no keratin accumulation.

While Abdulmonaem et al. [15] described sensitivity 73.3%, specificity 60%, PPV 84% and NPV 60%. They have 4 cases were false negative and not diagnosed by DWI their sizes were (2–3 mm), and also Jeunen et al. [22] found sensitivity 54%, specificity 90%, PPV 92% and NPV 47%, in their study. They concluded that DW EPI lacks reliability to replace a routine second-look surgery. In the study of Lehman et al. [23] they reported that the Non -EPI provides the heights sensitivity (100%), specificity (100%), NPV (100%) and (PPV (100%) for all the observers with a significant difference compared to echo planar diffusion (36.1, 100, 58.2, 100% respectively) and post contrast MRI (91.2, 81.2, 89.2, 84.5%), respectively.

The size of the lesion (less than 5 mm) and the susceptibility artifacts at the air-bone interface of the temporal lobe and the temporal bone are considered to be the major limitations for detecting cholesteatomas on standard MRI sequences and EPI DWI [24].

DWI is considered to be highly effective imaging modality for screening of cholesteatoma. Its sensitivity can be augmented when associated with standard MR imaging sequences. The air-bone artifact of DWI at the tegmen, the low resolution and relative thick slices of EP DWI decrease its role in the detecting small less than 5 mm in size.

EP-DWI is affected by movement, such as head movement, small molecular motion and micro movement of the brain tissue due to blood pulsation. These may result to phase errors, ghosting and motion artefacts, so the sensitivity, specificity may be decreased [25].

MR imaging is superior to CT in tissue characterization. DWI has proved its high diagnostic value in diagnosis of recurrent cholesteatoma. Water molecules in

cholesteatomas show diffusion restriction, giving the high signal in the DWI images; DW EPI has been shown to be accurate in differentiating inflammatory tissue from cholesteatoma in the non-surgically treated middle ear, as cholesteatoma demonstrates a clear hyperintensity on DW EPI sequences in contrast to inflammatory tissue.

Conclusion

CT is the most frequently used radiological modality for preoperative diagnosis of recurrent cholesteatoma, but it is unable to differentiate between cholesteatoma, granulation, effusion or mucosal oedema. MRI is better than CT in tissue characterization for diagnosis of recurrent cholesteatoma. MRI can effectively exclude unnecessary second look surgery in cases presumed to have recurrent cholesteatoma.

Compliance with Ethical Standards

Conflict of interest All the authors declare that they have no conflict of interest.

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