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Original article

Contribution of magnetic resonance imaging to the diagnosis of middle ear cholesteatoma: Analysis of a series of 97 cases

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ABSTRACT

Objectives: To evaluate the reliability of magnetic resonance imaging (MRI) for the diagnosis of middle ear cholesteatoma and to determine the contribution of each MRI sequence.
Patients and methods: A series of 97 cases was reviewed, corresponding to 89 patients (43 women, 46 men). Each patient was assessed by the following MRI protocol: T1-weighted, T2-weighted, early contrast-enhanced T1-weighted, delayed contrast-enhanced T1-weighted, and diffusion-weighted sequences. All patients were operated, for the first time in 16 cases and for second-look surgery in 81 cases. Radiological findings were compared to surgical and histological findings. Sensitivity, specificity, positive predictive value, and negative predictive value were calculated for each sequence.
Results: Seventy-four cholesteatomas were diagnosed at surgery. These lesions had a mean diameter of 8.29 ± 5.46 mm. The smallest cholesteatoma in this series was 2 mm in diameter. Diffusion-weighted and delayed contrast-enhanced T1-weighted sequences had a sensitivity of 84.9% and 90.4%, a specificity of 87.5% and 75%, a positive predictive value of 95.4% and 91.7%, and a negative predictive value of 65.6% and 72%, respectively. T1-weighted, T2-weighted, and early contrast-enhanced T1-weighted sequences had a low specificity.
Conclusions: MRI is a reliable imaging modality for the diagnosis of middle ear cholesteatoma. Diffusion-weighted and delayed contrast-enhanced T1-weighted sequences were discriminant. In the context of postoperative follow-up of cholesteatoma, these sequences allow better selection of cases requiring second-look surgery.

1. Introduction

Middle ear cholesteatoma is defined as the presence of keratinized squamous epithelium in the middle ear cavities. In the vast majority of cases, the positive diagnosis of cholesteatoma is based exclusively on clinical examination, especially otoscopic findings. Computed tomography (CT) is recommended in the context of preoperative assessment of cholesteatoma [1] in order to exclude osteitis complications, to try to specify extensions of the cholesteatoma and to evaluate the anatomical conformation of the tympanomastoid cavity. In some cases, when the diagnosis cannot be confirmed by clinical examination alone, CT scan can provide arguments in favour of cholesteatoma by showing opacity with rounded contours associated with adjacent osteolysis [2].

The treatment of cholesteatoma is surgical, based on two techniques, called canal wall up (CWU) and canal wall down (CWD) tympanoplasty. CWU tympanoplasty ensures a more comfortable postoperative course for the patient, but is associated with a higher residual cholesteatoma rate [3]. Tympanic membrane grafting also prevents satisfactory otoscopic surveillance. For these reasons, systematic second-look surgery was performed 12 to 18 months after a first CWU tympanoplasty to detect and treat any residual lesions.

Computed tomography, as well as conventional morphological magnetic resonance imaging (MRI) T1-weighted, T2-weighted, and early contrast-enhanced T1-weighted sequences have been shown to present a number of limitations for the surveillance of patients operated for middle ear cholesteatoma [4].

Over the last decade, a number of studies have tended to demonstrate the capacity of new MRI sequences to distinguish cholesteatoma from other types of postoperative opacities,

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questioning the need for systematic second-look surgery: delayed contrast-enhanced T1-weighted sequences 45 to 60 minutes after gadolinium injection [5,6] and diffusion-weighted imaging (DWI) [7].

In this study, we tried to evaluate the contribution of each MRI sequence and combinations of the various sequences to the diagnosis of middle ear cholesteatoma based on systematic surgical confirmation of imaging findings.

2. Patients and methods

A single-centre, prospective, longitudinal study was conducted from June 2004 to January 2011 in a series of 89 patients (43 women and 46 men, M/F sex ratio: 1.07), with a mean age of 41 ± 21 years at the time of MRI. All patients presented an indication for middle ear surgery in the context of management of cholesteatoma (first surgery or second-look surgery). All patients were assessed by preoperative temporal bone MRI in the same neuroradiology department on a Siemens Avanto 1.5 Tesla machine (Magnetom Avanto, Siemens Medical Solutions, Erlangen, Germany) or a Siemens Sonata 1.5 Tesla machine (Magnetom Sonata, Siemens Medical Solutions, Erlangen, Germany). The following protocol was systematically applied: axial and/or coronal unenhanced T1-weighted spin echo sequences, axial and/or coronal T2-weighted spin echo sequences, coronal and axial early contrast-enhanced T1-weighted fat-saturated spin echo sequences, coronal and axial early contrast-enhanced T1-weighted fat-saturated spin echo sequences 30 to 60 minutes after gadolinium injection, coronal or axial diffusion-weighted imaging, with axial echo planar imaging (EPI) sequences (sonata machine) or coronal non-echo planar imaging half Fourier single-shot turbo spin echo (EPI HASTE) sequences (Avanto machine), with a *b* value of 1000 mm^2/s, without measuring the apparent diffusion coefficient. MRI images were interpreted before surgery by the senior radiologist in charge of the examination. Each examination was interpreted by a single radiologist. A total of five different radiologists, all experienced in the interpretation of temporal bone imaging, were involved in the study. The various MRI sequences were not interpreted separately and, when necessary, were overlayed with lesion marking by software provided by the manufacturer. The size of the lesions was determined on DWI.

All patients were operated by the same surgical team. The mean interval between MRI and surgery was 4 months. All data concerning the surgical procedure were retrieved from the operation report. The presence or absence of cholesteatoma was recorded and constituted the "gold standard" for the detection of cholesteatoma in this study, and was used as the basis for all statistical analyses. Cases of hyperkeratosis and retraction pockets filled with squames (precholesteatomatous state) were classified with true cholesteatomas. The presence of other abnormalities such as fibrosis, inflammation, cholesterol granuloma, meningocele, or abscess was also noted. Histological examination was performed to confirm the diagnosis. Two separate operations on the same ear were performed in eight patients and MRI was performed before each of these operations, resulting in a total cohort of 97 cases. Sixteen cases (16.49%) were operated for the first time and the ear had been previously operated in 81 cases (83.51%). The mean interval between the date of previous surgery and MRI for these 81 cases was 31 months.

Sensitivity (Se), specificity (Sp), positive predictive value (PPV) and negative predictive value (NPV) values for each MRI sequence were calculated (together with their 95% confidence intervals) on the basis of operative findings. The results of the "EPI DWI" and "Non-EPI DWI" groups were analysed separately and the areas under the ROC curve ((Se + Sp)/2) were compared between the two groups. A similar analysis was also performed between "first surgery" and "previously operated ear" groups.

The normal distribution of quantitative variables was verified by the Shapiro-Wilk test; quantitative data were compared between groups by Student's test or Mann-Whitney test when the conditions of Student's test were not met. Qualitative parameters were compared by Fisher's exact test or Chi-square test.

All analyses were performed with a type 1 error of 5% using STATA v.10 software (Stata Corp).

3. Results

Seventy-four cases of cholesteatomatous lesions were diagnosed during surgery, i.e. in 76.29% of cases. These cases included 63 cholesteatomas (Fig. 1), five cases of hyperkeratosis, two cholesteatomas associated with cholesterol granuloma, and four retraction pockets filled with squames. Another 23 cases (23.71%) presented inflammatory lesions in eight cases, fibrotic lesions in 11 cases, a simple retraction pocket in one case, one mastoid abscess, one meningocele, and total absence of lesions in one case. Histological examination was performed in 88 of the 97 cases and confirmed the surgical findings in every case. All MRI characteristics of middle ear cholesteatoma and its differential diagnoses are summarized in Table 1.

The lesions detected had a mean diameter of 8.29 ± 5.46 mm. The smallest cholesteatoma measured 2 mm in diameter (Fig. 2) and the largest cholesteatoma measured 25 mm in diameter. T1-weighted, T2-weighted, and early contrast-enhanced T1-weighted sequences presented a sensitivity of 98.6, 91.8 and 95.9%, and a specificity of 4.2, 20.8 and 29.2%, respectively. DWI and delayed contrast-enhanced T1-weighted sequences had a sensitivity of 84.9% and 90.4%, a specificity of 87.5% and 75%, a positive predictive value of 95.4% and 91.7%, and a negative predictive value of 65.6% and 72%, respectively. Se, Sp, PPV, and NPV values for each sequence are presented in Table 2 together with their 95% confidence intervals.

Enhancement of a peripheral rim on delayed contrast-enhanced T1-weighted sequences of cholesteatoma was present in only 30 (40.5%) of the 74 cases.

Diffusion-weighted imaging (DWI) sequences were acquired by EPI in 10.3% of cases and non-EPI HASTE in 89.7% of cases. In the "EPI DWI" group, DWI had a sensitivity of 57.1% [18.4–90.1], a specificity of 100% [29.2–100], a positive predictive value of 100% [39.8–100], a negative predictive value of 50% [11.8–88.2], and an area under the ROC curve of 0.79 [0.59–0.98]. In the "Non-EPI DWI" group, DWI had a sensitivity of 87.9% [77.5–94.6], a specificity of 85.7% [63.7–97], a positive predictive value of 95.1% [86.3–99], a negative predictive value of 69.2% [48.2–85.7], and an area under the ROC curve of 0.87 [0.78–0.95]. Comparison of areas under the ROC curve revealed a significant difference between the two groups ($P < 0.05$).

No significant difference was observed between the "first surgery" and "previously operated ear" groups.

The two cases of cholesterol granuloma were associated with cholesteatoma, with a false-negative result in one case: radiological diagnosis of isolated granuloma, while the associated cholesteatoma was not detected. Two false-negatives were observed among the five cases of hyperkeratosis (6.75% of all cholesteatomatous lesions) and one false-negative was observed among the four cases of retraction pockets filled with squames. The case of mastoid abscess corresponded to a false-positive, in the context of a lesion measuring 28 mm in diameter. One case of isolated meningocele was correctly diagnosed on the frontal T1-weighted sequence. Discordant results between DWI (absence of high-intensity signal) and the delayed contrast-enhanced T1-weighted sequences (absence of enhancement) were observed in four cases, in which the intraoperative diagnosis was cholesteatoma.