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Value of high-resolution computed tomography and magnetic resonance imaging in the detection of residual cholesteatomas in primary bony obliterated mastoids

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Abstract

Purpose: The objective of this study was to assess the value of high-resolution computed tomography (HRCT) and that of magnetic resonance imaging (MRI), including postcontrast T_1-weighted images and echo-planar diffusion-weighted (EP-DW) images, in the detection of residual cholesteatomas after primary bony obliteration of the mastoid.

Patients and methods: Twenty-three patients underwent a second-look surgery 8 to 18 months after they underwent a primary bony obliteration technique. All patients were evaluated by HRCT and MRI before their second-look surgery. A retrospective analysis was performed.

Results: A residual cholesteatoma was found in 2 of the 23 patients; both cases of cholesteatoma had a diameter less than 4 mm. In these 2 patients, residual cholesteatoma was found in the middle ear cavity and not in the obliterated mastoid. In all cases, HRCT showed a homogeneous obliteration of the mastoid cavity. On MRI, only one cholesteatoma pearl was detected using contrast-enhanced T_1-weighted imaging. Findings from the EP-DW imaging were negative for all cases.

Conclusion: This study demonstrates that HRCT is still the imaging technique of choice for the evaluation of bony obliterated mastoids. It shows the low sensitivity and specificity of HRCT for the characterization of an associated opacified middle ear and those of contrast-enhanced T_1-weighted imaging and EP-DW imaging for the detection of small residual cholesteatomas after primary bony obliteration.

1. Introduction

The surgical goals in the treatment of primary cholesteatomas include full eradication of the pathology, prevention of recurrences, controlling the hygienic status of the affected ear, and restoration of hearing [1]. Several authors reported on the additional value of mastoid bony obliteration for diminishing recurrences [2-6]. Although primary bony obliteration provides excellent results with low recurrence rates, it also carries with it the risk of obliterating and obscuring residual cholesteatomas. Follow-up by means of imaging is mandatory to prevent late complications after possible obliteration of residual cholesteatomas. The aim of this study was to assess the value of high-resolution computed tomography (HRCT) and that of magnetic resonance imaging (MRI), including contrast-enhanced T_1-weighted images and echo-planar diffusion-weighted (EP-DW) images, in detecting residual cholesteatomas in the middle ear and bony obliterated mastoids.

2. Material and methods

Between December 11, 2002, and March 17, 2004, 23 patients underwent a primary bony obliteration technique

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for their cholesteatoma. In all patients, during the first-stage surgery, the cholesteatoma was removed by an intact canal wall technique followed by primary bony obliteration of the mastoid and epitympanic space using bone pâté mixed with fibrin glue. During this surgery, reconstruction of the tympano-ossicular system was performed either by allograft [7,8] or by fascia. Our series consisted of 23 consecutive patients (12 male patients and 11 female patients) with an average age of 31.6 years (median, 35.7 years; range, 8.7–61.2 years). All patients underwent an HRCT and an MRI with an average of 20 days (median, 15 days; range, 1–57 days) before their second-look surgery. Between January 7, 2004, and May 31, 2005, all patients underwent a second-look procedure with an average of 13.2 months (median, 12.9 months; range, 8.1–18 months) after their first-stage surgery. In all cases, a transcanal approach with a Roosen incision was performed to evaluate the middle ear space.

2.1. Imaging technique

All CT scans were performed on a 16-row multislice CT scanner (LightSpeed, GE, Milwaukee, WI) using an axial volume scan (140 kV; 250 mA; 1-second rotation; 5.62 pitch; high-resolution bone algorithm) with coronal reformations. Axial slices were acquired in 1.25-mm thickness and were reformatted to 0.625 mm, centered on the left and right ears, with an interval of 0.2 mm. Magnetic resonance imaging was performed with a superconductive 1.5-T system (EchoSpeed Horizon, GE) using a circularly polarized head coil. The examination was centered—for all sequences but the 3-dimensional fast spin echo (FSE) T_2-weighted images and the DW images—on the affected ear using a small field of view (FOV; 140 mm) with a saturation band on the contralateral ear. Coronal FSE T_1-weighted imaging (repetition time [TR]/echo time [TE], 475/14 ms; slice thickness, 3 mm; spacing, 0; matrix, 256 × 224; number of excitations [NEX], 2; FOV, 140 × 140 mm), T_2-weighted imaging (TR/TE, 3000/102 ms; slice thickness, 3 mm; spacing, 0; matrix, 256 × 224; NEX, 5; FOV, 140 × 140 cm), axial 3-dimensional FSE T_2-weighted imaging (TR/TE, 4000/180 ms; slice thickness, 0.8 mm; matrix, 256 × 256; NEX, 2; FOV, 100 × 100 mm), and spin echo-planar DW imaging (TR/TE, 10 000/minimum ms; slice thickness, 3 mm; matrix, 128 × 128; *b* values, 0 and 1000 s/mm; FOV, 220 mm) were performed before the injection of gadolinium. Apparent diffusion coefficient maps were not calculated because of the expected small volume of the lesions. After the injection of gadolinium (0.1 mmol/kg), coronal and axial T_1-weighted images, initially the coronal series and secondly the axial series, were obtained, hence serving as an early delayed-phase sequence.

Table 1
Study results

Patient	Side	Time between primary surgery and second-look surgery (mo)	Clinical findings		Surgical results	HRCT		MRI		EP-DW imaging
			Ear discharge	Tympanic membrane		Middle ear	Mastoid	Middle ear	Mastoid	
1	L	12.9	–	Perforation	–	STD	–	–	MS	–
2	L	14	–	Intact	–	A	–	–	MS	–
3	L	13.8	–	Intact	–	STD	–	–	MS	–
4	L	10.8	–	Intact	–	STD	–	–	MS	–
5	L	8.1	–	Intact	–	A	–	–	MS	–
6	R	12.3	–	Retraction	–	STD (NA)	–	–	MS	–
7	L	12.6	–	Intact	–	A	–	–	MS	–
8	L	12.9	+	Retraction/ Granulation	–	STD	–	–	MS	–
9	L	13.6	–	Intact	–	STD	–	–	MS	–
10	R	18	–	Intact	–	STD	–	–	MS	–
11	R	12.4	–	Intact	+	STD	–	+	MS	–
12	L	13.6	–	Intact	–	A	–	–	MS	–
13	L	12.2	+	Intact/Granulation	+	STD	–	–	MS	–
14	R	17.6	+	Intact/Granulation	–	STD (NA)	–	–	MS	–
15	L	13.4	–	Intact	–	STD	–	–	MS	–
16	R	17.4	–	Intact	–	A	–	–	MS	–
17	R	12.4	–	Perforation	–	A	–	–	MS	–
18	R	11.6	–	Intact	–	A	–	–	MS	–
19	R	15.6	–	Intact	–	STD (NA)	–	–	MS	–
20	R	13.2	–	Intact	–	A	–	–	MS	–
21	R	12.1	–	Intact	–	STD	–	–	MS	–
22	R	11.8	–	Intact	–	A	–	–	MS	–
23	R	14.5	+	Intact/Granulation	–	A	–	–	MS	–

L indicates left; R, right; STD, soft tissue density; A, aerated; NA, not aerated.
For clinical findings, + indicates presence of otorrhea; –, dry. For surgical results, + indicates presence of cholesteatoma; –, absence of cholesteatoma. For HRCT, – indicates no punched-out or soft tissue enhancement. For MRI, – indicates negative; +, positive; MS, mixed signal intensity.

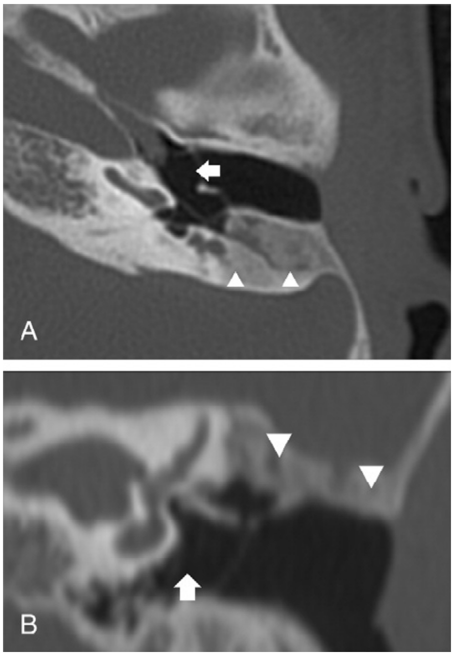

Fig. 1. (A) Axial HRCT image of the left ear at the level of the round window and the basal turn of the cochlea. Note the aerated middle ear cavity (arrows) and the bony obliterated mastoid (arrowheads). (B) Coronal reformation of the left ear at the level of the round window demonstrating the reconstructed ossicular chain in the aerated middle ear (arrows). Note the homogeneously obliterated mastoid (arrowheads).

2.2. Radiologic interpretation

Two radiologists with long-standing experience in head and neck imaging evaluated in consensus all CT and MR images. They were blinded as to the identity of patients, clinical data, and operative results. A consensus agreement was made for the evaluation of residual cholesteatomas, which were marked either as positive (ie, residual cholesteatoma present) or as negative (ie, residual cholesteatoma absent). The interpretation on HRCT was based on the presence of soft tissue within the middle ear and/or bony obliterated mastoids and punched-out lesions in the obliterated mastoid. On MRI, interpretation relied on the signal intensity of the soft tissue extension on nonenhanced T_1-weighted images and T_2-weighted images. Evaluation of the enhancement after the intravenous injection of gadolinium checked for nonenhancing cholesteatomas and/or peripheral enhancing cholesteatoma matrices. Echo-planar DW imaging was performed to look for characteristic hyperintense cholesteatoma pearls.

3. Results

The study results are summarized in Table 1.

3.1. Surgical results

A residual cholesteatoma was found in 2 of the 23 patients (9%) during their second-look surgery. The cholesteatoma pearls were both found in the retrotympa-

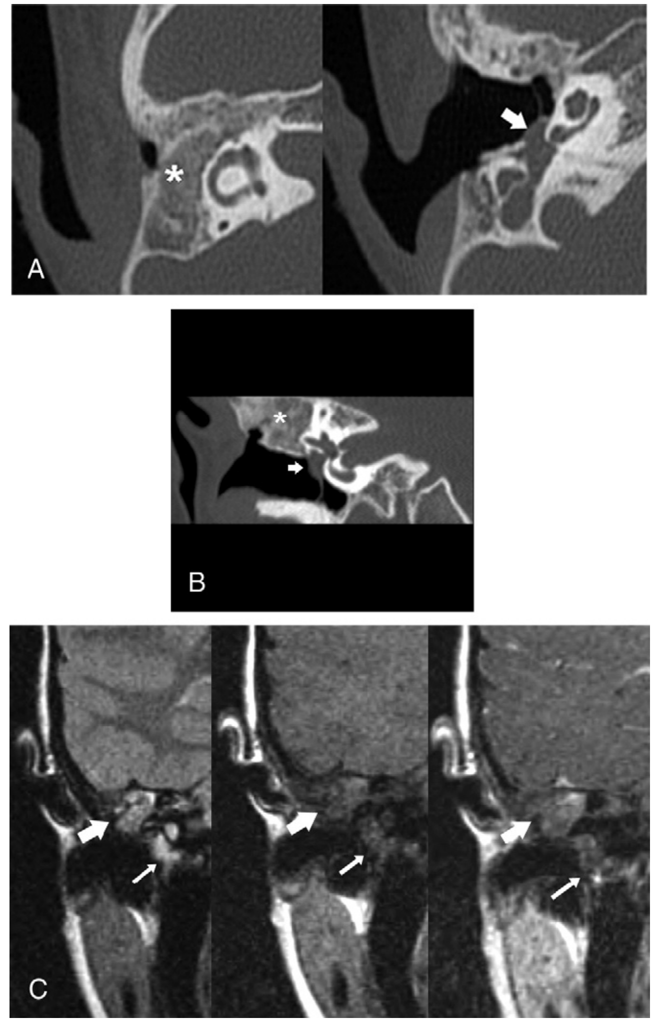

Fig. 2. Findings for a 10-year-old boy who underwent primary bony obliteration technique of the right ear and a small residual cholesteatoma in the retrotympanum. (A) The left panel shows an axial HRCT image of the right ear at the level of the horizontal semicircular canal. The mastoidectomy cavity is filled with bone chips and pasta (asterisk). No punched-out soft tissue lesion was found. The right panel shows an axial HRCT image of the right ear at the level of the round window and the basal turn of the cochlea. Note a specific soft tissue lesion in the retrotympanum (arrow). Because of the rounded aspect of the lesion, a residual cholesteatoma was suspected. (B) Coronal reformatted HRCT image of the right ear at the level of the vestibulum and the lateral semicircular canal. The mastoidectomy cavity and epitympanum are filled with bone chips and pasta (asterisk). The rounded soft tissue mass in the retrotympanum is again suggestive of a residual cholesteatoma (arrow). (C) Coronal MR images centered on the right ear at the level of the vestibulum and the lateral semicircular canal. The left panel is a T_2-weighted image showing a rounded, mainly hyperintense, lesion in the hypotympanum (small arrow). The middle panel is a T_1-weighted image showing that the lesion in the hypotympanum is hypointense (small arrow). The right panel is a T_1-weighted image taken after intravenous administration of gadolinium showing that the lesion in the hypotympanum displays only a peripheral enhancement (small arrow). Note the filling of the mastoidectomy cavity with mixed signal intensities as a result of the primary bony obliteration technique on all sequences (large arrows). Discrimination of enhancement in the filled cavity was difficult. On DW images (not shown), no clear hyperintense signal was found.

num. One of the residual pearls measured 2 mm in diameter; the other, 4 mm. The preoperative clinical case findings are also outlined in Table 1.

3.2. High-resolution computed tomography scan evaluation

An aerated middle ear was found in 43.5% of the patients (10/23; Fig. 1A and B). A soft tissue obliterated middle ear was seen in 56.5% of the patients (13/23), with a complete opacification of the middle ear cavity in 13% (3/23). In the bony obliterated mastoids, no soft tissue defect or punched-out lesion was detected (Fig. 1A and B and Fig. 2A and B).

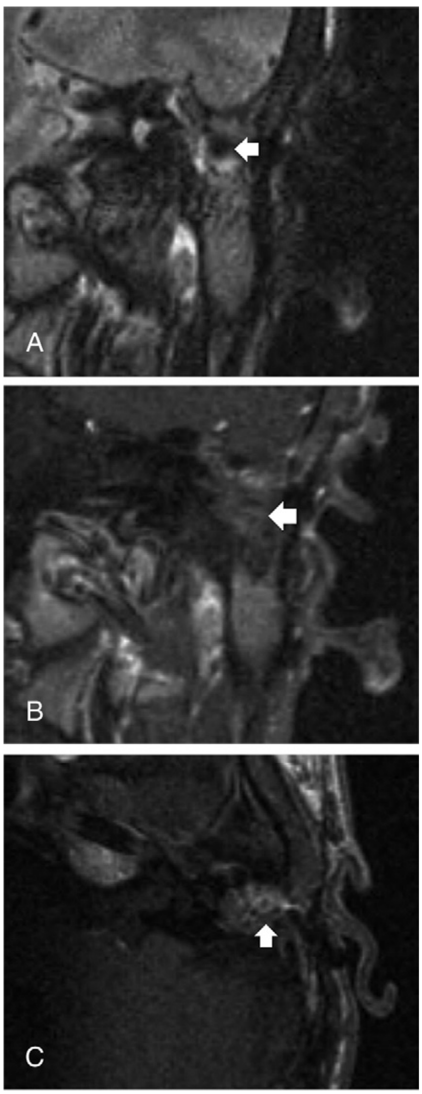

Fig. 3. Findings for a 10-year-old boy who underwent primary bony obliteration technique of the right ear and a small residual cholesteatoma in the retrotympanum. (A) Coronal T_2-weighted image of the left ear at the level of the vestibulum and the lateral semicircular canal showing the mixed and inhomogeneous signal intensities of the bony obliterated mastoid (arrows). (B) Coronal T_1-weighted MR image of the left ear after intravenous administration of gadolinium showing inhomogeneous enhancement of the obliterated mastoid (arrows). Recognition of an eventual characteristic central nonenhancing cholesteatoma was impossible. (C) Axial postgadolinium T_1-weighted MR image at the level of the vestibulum again showing inhomogeneous enhancement of the obliterated mastoid, making the diagnosis of an eventual residual cholesteatoma impossible.

3.3. Magnetic resonance imaging evaluation

Only 1 of the 2 surgically detected residual cholesteatomas was clearly detected on contrast-enhanced T_1-weighted images as a posterior hypotympanal nonenhancing hypointensity (Fig. 2C). None of the residual cholesteatomas was seen on EP-DW imaging. No false-positive finding was seen in this series.

4. Discussion

A complete eradication of the pathology, together with prevention of recurrent cholesteatomas, is the main surgical goal in the treatment of primary cholesteatomas. Other important goals in cholesteatoma surgery are controlling the hygienic status of the ear and preserving or improving hearing status [1]. The best way to obtain these surgical goals is to try to restore normal anatomy and physiology after total eradication of the pathology and its etiologic factors. In our department, we use—among other techniques—an intact canal wall tympanoplasty with additional bony mastoid obliteration in one surgical procedure to eradicate the pathology and prevent recurrences. Obliteration of the attic and mastoid by means of bone pâté prevents new retractions of the tympanic membrane and, therefore, recurrent cholesteatomas. With this technique, we adapt the middle ear to the defective physiology in combination with preservation of normal external ear canal. Several authors described the advantages of bony obliteration of the mastoid and achieved excellent results with a low recurrence ratio [2-6].

The use of this technique implies the risk of obliterating residual cholesteatomas. Therefore, accurate imaging follow-up of obliterated mastoids is necessary to prevent late complications after possible obliteration of residual cholesteatomas. High-resolution computed tomography has been shown to be very effective in detecting small pearls in obliterated mastoids, presenting as punched-out lesions in the bone density of these obliterated mastoids. However, in the case of an associated opacified middle ear, HRCT is not able to differentiate these soft tissue masses after primary surgery and is characterized by low sensitivity and specificity [9-12]. In our study, we found no punched-out soft tissue lesion inside the obliterated mastoid cavities. However, in 61% of the patients, we found an associated opacified middle ear, hiding at surgery a small cholesteatoma in 2 cases. High-resolution computed tomography was unable to further characterize this soft tissue opacification and to detect these cholesteatomas.

Magnetic resonance imaging may provide additional information and lead to a more accurate diagnosis [13,14]. Apart from an excellent soft tissue contrast, MRI offers the possibility of using various pulse sequences, including EP-DW imaging, and the administration of intravenous contrast material. Recently, several reports described the value of delayed contrast-enhanced T_1-weighted images, which make the differentiation between an enhancing scar tissue and a nonenhancing cholesteatoma possible [15,16]. The value of EP-DW imaging in the detection of primary and residual cholesteatomas has been previously reported by several authors [17-19]. Congenital, acquired, and residual cholesteatomas have a high signal intensity on EP-DW imaging. The T_2 shine-through effect is probably responsible for this hyperintensity on EP-DW imaging [17]. The major limitations for detecting cholesteatomas on standard MRI sequences and DWI are the size of the lesion (5 mm) and the susceptibility artifacts at the air-bone interface of the temporal lobe and the temporal bone [20]. In our study, on standard MRI sequences, we found mixed and confusing signal intensities in the obliterated mastoids as a result of the presence of a bone pâté, thus making the diagnosis of cholesteatoma in the obliterated mastoid impossible (Fig. 3A–C). Therefore, we mainly relied on HRCT for the evaluation of the obliterated cavity. In our study, the size of the residual cholesteatoma also seemed to be a limiting factor (ie, 2 and 4 mm) for MRI. Only one cholesteatoma in the middle ear could be recognized as a characteristic nonenhancing hypointense lesion on a postcontrast T_1-weighted image (Fig. 2C). Furthermore, none of the cholesteatomas was visualized on DWI sequences, probably again because of the small size of the residual cholesteatomas, the low resolution, the relatively thick slices, and the important air-bone interface artifact of the echo-planar DWI sequences. The development of new non–EP-DW sequences seems to be very promising in overcoming this size limitation and in reducing this air-bone interface artifact [20]. On the basis of these results, we conclude that HRCT is still recommended as the initial screening procedure to be applied when using the bony obliteration technique. In the absence of punched-out soft tissue lesions in the obliterated cavity or in the absence of soft tissue extension in the middle ear, follow-up HRCT can be performed.

The presence of any associated soft tissue lesion in the middle ear can then eventually further be characterized with the use of delayed contrast-enhanced T_1-weighted imaging with DWI, taking into account that small residual pearls (<5 mm) still cannot be detected. Therefore, staging after primary bony obliteration in cholesteatoma remains to be necessary.

The value of new non–EP-DW imaging techniques in association with delayed postcontrast T_1 sequences seems to promising but remains to be studied in the evaluation of primary bony obliterated mastoids.

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