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False-Positive Cholesteatomas on Non-Echoplanar Diffusion-Weighted Magnetic Resonance Imaging

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Objectives: To investigate false-positive findings on non-echoplanar (non-EPI) diffusion-weighted magnetic resonance imaging (DWI) in patients under surveillance post-cholesteatoma surgery.

Study Design, Setting, Subjects, and Methods: A retrospective review was performed on patients diagnosed with cholesteatoma who underwent surgical resection and were then followed by serial non-EPI DWI using half-Fourier acquisition single-shot turbo spin echo (HASTE) sequence. All patients had at least two annual follow-up imaging studies.

Results: False-positive findings were identified in four patients. The size of the suspected lesions was 4 to 12 mm. Otoendoscopy was used during all primary cases and Argon laser was used in one case. In all cases, the entire cholesteatoma was removed, and no residual disease was detected at the end of the procedures. One patient underwent revision surgery but only cartilage graft was found in the area of concern. All patients had stable or resolved hyperintense areas in the subsequent HASTE sequences.

Conclusion: False positive findings can occur with non-EPI DWI MRI and patients need to be counseled accordingly before revision surgery. Decreasing intensity and dimension of a suspected lesion and a positive finding in an area other than the location of the initial cholesteatoma may favor a false positive. If a false positive finding is suspected when the surgeon is confident of complete resection of the cholesteatoma, an MRI can be repeated in 6 to 12 months to assess changes in the dimension and intensity of the area of concern. Cartilage grafts may cause restricted diffusion on DWI sequences. **Key Words:** Cholesteatoma—Diffusion-weighted magnetic resonance imaging—Half-Fourier acquisition single-shot turbo spin echo—Magnetic resonance imaging—Non-echoplanar diffusion weighted imaging—Recidivism—Surveillance.

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Cholesteatoma recidivism and its surveillance remain a challenge in otologic surgery (1). The recidivism rate, encompassing residual, and recurrent cases, has been reported at 5 to 17% after canal-wall-down (CWD) surgeries and 9 to 70% after intact-canal-wall (ICW) surgeries (2). Historically, a staged, second-look surgery in 6 to 12 months after the initial surgery has been the gold standard to address potential residual or recurrent disease (3). These second-look surgeries are associated with higher costs and increased number of postoperative visits compared with single-stage surgeries, and no cholesteatoma is found in approximately 52.0 to 67% of patients (3–5).

Diffusion-weighted magnetic resonance imaging (DWI) has gained popularity in the past decade as the preferred imaging study for cholesteatoma surveillance (6–9). The non-echo-planar (non-EPI) DWI has been found to be superior to echo-planar DWI and other magnetic resonance imaging (MRI) variants as it enables differentiation between cholesteatoma and inflammation, has thinner slices, and generates less artifact (10). As such, the non-EPI technique can potentially decrease unnecessary second-look surgeries (11). A 2011 systematic review estimated the pooled sensitivity and specificity of non-EPI DWI in finding cholesteatomas to be 91.4 and 95.8%, respectively (10).

With increasing utilization for post-surgical cholesteatoma surveillance, false-positive non-EPI DWI images can drive unnecessary revision surgeries. While sensitivity, specificity, and positive predictive value have been well-described in the literature, false-positive non-EPI DWIs have not. Therefore, in the current study we

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investigated false-positive cases in our patient population under surveillance with non-EPI DWI after cholesteatoma surgery to describe their characteristics and management outcomes.

METHODS

This study was approved by the University of California Irvine Institutional Review Board. A retrospective chart review was performed on patients with a history of surgery for removal of cholesteatoma all performed by the senior author during 2007 to 2017. In our practice, non-EPI DWI is used for cholesteatoma surveillance in most patients on an annual basis for 3 years. A final MRI is obtained at the 5-year postoperative time point. The patients are also clinically followed on an annual or semi-annual basis for a thorough otologic examination. We perform a canal wall down mastoidectomy on most cholesteatoma patients, and obliterate the mastoid cavity with cartilage grafts and bone pate.

The study inclusion criteria were cholesteatoma surveillance with serial non-EPI DWIs and at least two annual follow-up imaging studies. False positive cases were defined as patient with areas of hyperintensity with subsequent decrease or resolution in follow-up imaging. Additionally, patients with positive MRIs who underwent second look and had no evidence of cholesteatoma were included in the study. Data for demographics, side and type of surgery, location of initial cholesteatoma, and findings on DWI were collected and analyzed. MRI examinations were performed on one of three machines using a standard head coil and included coronal non-EPI DWI (HASTE, half Fourier acquisition single-shot turbo spin echo) without contrast injection. This includes a 1.5-T MRI scanner (Avanto, Siemens, Erlangen, Germany) with the following coronal DWI parameters: repetition time (TR)/echo time (TE), 2000/109 ms and 3 mm slice thickness with 3.3 mm spacing; field of view (FOV) 220 × 220 mm; *b*-value 0 and 1000; a 3-T MRI scanner (TrioTim, Siemans, Erlangen, Germany) with the following coronal DWI parameters: TR/TE 2500/92 ms and 3 mm slice thickness with 3 mm spacing; FOV 220 × 220 mm; *b*-value 0 and 800; or a 3-T MRI scanner (MAGNETOM Vida, Siemens, Erlangen, Germany) with the following coronal DWI parameters: TR/TE 4500/68 ms and 3 mm slice thickness with 3.9 mm spacing; FOV 204 × 204 mm; *b*-value 0 and 800.

RESULTS

Of 369 patients followed by serial MRIs for cholesteatoma surveillance, four patients were identified who met the inclusion criteria. Table 1 summarizes their demographics and characteristics. The age at the time of surgery ranged from 5 to 57 years. All underwent CWD surgeries with bone and cartilage grafts for obliteration of the mastoid and scutum (Table 1). One patient had a middle cranial fossa approach for a congenital epidermoid, which involved the tegmen tympani and the geniculate ganglion and labyrinthine portion of the facial nerve. Intraoperative otoendoscopy was used in conjunction with microscopy in all primary cases to assist in detection of any potential residual disease that could not be directly visualized via the operative microscope. Argon laser was used in one case to assist in vaporizing microscopic foci of residual disease (case No. 4). In all cases, the entire cholesteatoma was removed, and no residual disease was visualized at the end of the procedure.

Review of the postoperative images revealed findings concerning for recurrent cholesteatoma in all patients as summarized in Table 1. The size of the areas of restricted diffusion ranged from 4 to 8 mm. The first patient in our series underwent a second look surgery with no cholesteatoma found intraoperatively, and only cartilage grafts present in the area corresponding to the noted hyperintensity on the HASTE sequence. Patients followed with clinical examination and imaging all showed stable or resolved areas of previous hyperintensity (Fig. 1).

DISCUSSION

Our study highlights four cases of false positive MRI DWI HASTE sequences. One patient underwent surgery which showed no evidence of cholesteatoma. The other

TABLE 1. *Demographics and patient characteristics*

No.	Age	Sex	Ear	Cholesteatoma Location	Surgery Type	Laser	Otoendoscopy	DWI Findings	Revision Surgery	Subsequent Imaging
1	50	M	R	Mastoid and EAC	CWD CG BG	−	+	8 mm focus in antrum by tegmen	−	Stable
2	48	F	R	Epitympanum and mastoid antrum down to horizontal canal	CWD CG BG	−	+	6 mm focus in mastoid antrum 4 mm in Prussak's space	−	Resolved
3	57	M	R	Epitympanum and mastoid involving tegmen mastoideum	CWD CG BG	−	+	10 mm focus in mastoid antrum	+	Resolved
4	5	F	R	Tegmen tympani and labyrinthine portion of facial nerve	Middle fossa approach BG	+	+	5 mm focus in tegmen tympani and floor of middle fossa	−	Resolved

BG indicates bone graft; CG, cartilage graft; CWD, canal wall down; DWI, diffusion-weighted imaging; EAC, external auditory canal; F, female; L, left; M, male; R, right.

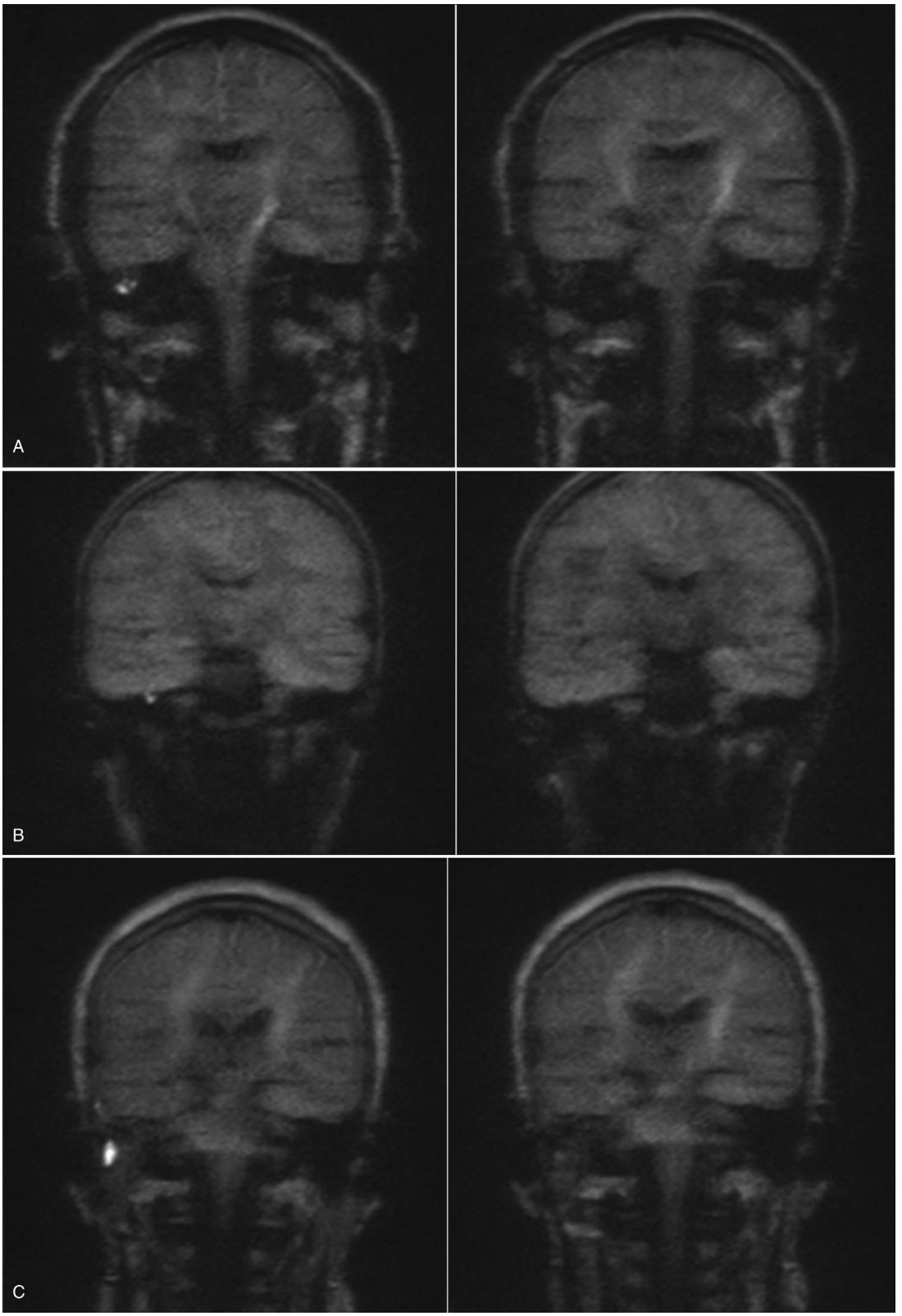

FIG. 1. Non-echoplanar DWI images with false positive findings. *A*, A 10 mm focus was noted at 12 months post-op (*left* panel). A revision surgery was performed but no cholesteatoma was identified. The focus resolved in subsequent imaging studies and no concerning foci were noted up to 52 months post-op (*right* panel). *B*, A 5 mm focus was noted in tegmen tympani and floor of middle fossa at 65 months post-op (*left* panel) in case No. 4. This focus later resolved and no recidivism was noted at 84 months post-op (*right* panel). *C*, A 12 mm focus was noted in mastoid at 12 months post-op (*left* panel), which resolved at 18 months (*right* panel). DWI indicates diffusion-weighted magnetic resonance imaging.

patients had subsequent imaging that revealed stable or completely resolved areas of hyperintensity.

Size and location of a cholesteatoma, as well as surgical approach and surgeon experience can influence recidivism (5,9,12). Certain locations including the posterior crus of the stapes, sinus tympani, and lateral epitympanum are difficult to visualize intraoperatively, especially in ICW procedures (13). As such, surgeons may perform a CWD procedure, or augment procedures with otoendoscopy and lasers to decrease the risk of residual disease (14,15).

Various imaging modalities have been evaluated for postoperative cholesteatoma recidivism surveillance. The outcomes for computed tomography (CT) scanning are poor, with reported sensitivity and specificity of 43.8 and 51.3% in detecting residual or recurrent cholesteatoma (16). T2-weighted and post-gadolinium T1-weighted MRIs have also been found to have a low sensitivity and specificity of 57.1 and 63.6%, respectively (17). DWI is an MRI technique based on detecting molecular diffusion, where tissues in which water molecules have restricted movements, such as keratin debris, return with high signal intensity (18). Of several described methods of performing DWI, non-EPI sequences can detect cholesteatomas as small as 3 mm, and have been found to be superior to echo-planar sequences with respect to sensitivity (91.4% versus 70.6%) and specificity (95.8% versus 87.3%) (10,19). Echoplanar DWI sequences are more prone to artifact at the junction between the tissues with different magnetic susceptibilities, such as in the temporal bone where air-bone and bone-brain interfaces exist (9,10). Non-EPI DWI sequences (such as HASTE) have the advantage of reducing the artifact at the bone-brain junction and better demonstrating residual cholesteatoma, especially when superiorly located (10). Apparent diffusion coefficient (ADC) mapping of decreased signal intensity ratios can be of benefit in avoiding confounding by T2 shine-through in non-EPI DWI cholesteatoma surveillance (20). However, this process is technically challenging for small lesions and not routinely performed at our institution. This is a limitation of our study, and the incorporation of ADC mapping to interrogate hyperintense non-EPI DWI signals in cholesteatoma surveillance warrants further investigation.

Imaging surveillance is most appropriate in cases where the disease is not extensive, and the entire cholesteatoma matrix and its keratin debris have been reliably resected (21). False-positive cases of cholesteatoma are rare in non-EPI DWI, but can occur (22,23). In one study, 27 patients underwent second-look surgery after detection of increased signal intensity on non-EPI DWI and two were found to be false-positives (24). In other studies of non-EPI DWIs, false-positives have been reported as a result of encephalocele (25), abscess cavity (26), bone pate (27), and wax/keratin debris (28,29).

All four of the patients in our series had cartilage or bone grafts in the area that showed restricted diffusion. In the patient who underwent surgery, only cartilage graft was present at the area of concern. This suggests that cartilage grafts may mimic cholesteatoma appearance on non-EPI DWI series in the short term. Therefore, we think our work is the first to add cartilage grafts into the differential for a false-positive. If a false-positive finding is suspected and the surgeon is confident of complete initial resection, a non-EPI DWI study should be repeated in 6 to 12 months. Decreasing dimensions and intensity of a suspected lesion and a positive finding in an area other than the location of the initial cholesteatoma may favor a false-positive. If the lesion persists, has increasing dimension/intensity, or the patient develops additional findings consistent with residual disease, a revision surgery must be considered.

CONCLUSION

False-positive findings can occur in non-EPI DWI in patients under imaging surveillance after cholesteatoma surgery. Decreasing dimensions of a suspected lesion and a positive finding in an area other than the location of the initial cholesteatoma may favor a false positive. Cartilage grafts may cause diffusion restriction and result in false-positive findings. If a false-positive finding is suspected when the surgeon is confident of complete resection of the cholesteatoma, a non-EPI DWI MRI can be repeated in 6 months to 12 months to assess changes in the dimensions and intensity of the area of concern.

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