ORIGINAL ARTICLE

Value of Non Echo-Planar Diffusion-Weighted Magnetic Resonance Imaging in the Detection of Middle Ear Cholesteatoma

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OBJECTIVE: This study was conducted to determine the clinical value of diffusion-weighted magnetic resonance imaging (MRI) (DWI) in detecting the presence of cholesteatoma.

MATERIALS AND METHODS: Fifty-six patients (21 female and 35 male; mean age, 43 years old) who underwent middle ear surgery were referred to the Radiology Department for preoperative DWI study. MRI (1.5-T) was performed using fast advanced spin echo (FASE) DWI, T2-weighted spin echo imaging (T2WI), and T1-weighted spin echo imaging (T1WI).

RESULTS: DWI identified 41 of 48 cholesteatomas involving the middle ear cavity (sensitivity, 85.4%). Seven patients with middle ear cholesteatoma who showed negative DWI findings (false-negative cases) had limited keratin accumulation due to simple atelectasis or meticulous evacuation of keratin debris before the MRI study. No false-positive cases were found in this study (specificity, 100%). The positive and negative predictive values were 100% and 53.3%, respectively. The minimum size of middle ear cholesteatoma detected by the current MRI system was 5mm.

CONCLUSION: DWI was useful for the detection of middle ear cholesteatoma.

Diagnosis and extension of middle ear cholesteatoma are mainly performed using high-resolution computed tomography (CT); however, if soft tissue opacity in the cavity of the middle ear is seen on high-resolution CT, diagnosis of the mass is not possible. In contrast, magnetic resonance imaging (MRI) has been proposed to distinguish soft tissue. In the past, middle ear cholesteatoma was diagnosed using MRI by distinguishing granulation tissue with the characteristic peripheral enhancing of cholesteatoma matrix and central non-enhancing cholesteatoma on T1-weighted imaging after gadolinium administration[1]. Recently, it has been possible to identify cholesteatoma itself with diffusion-weighted MRI (DWI) [2-4]. We have used DWI combined with conventional MRI to detect cholesteatoma since 2002. The purpose of our study was to evaluate the value of DWI to detect cholesteatoma in patients who have undergone middle ear surgery.

MATERIALS AND METHODS

Patients

From October 2002 to July 2006, 56 patients were referred to the University of Miyazaki Hospital for MRI. The patients were 35 males and 21 females, with a median age of 42.8, ranging from 3 to 76. Operative diagnoses were as follows: 48 cases of cholesteatoma and 8 cases of non-cholesteatomatous tissue, as shown in Table 1. Non-cholesteatomatous tissues were scar tissue in 3 cases, inflammatory granulation tissue in 3 cases, cholesterol granuloma in 1 case and granulation tissue (developed as a result of foreign body) in 1 case.

Imaging technique

MRI was performed using a 1.5-T MR unit in all clinical cases. Single shot half-Fourier fast advanced spin echo (FASE) DWI (TR/TE,12,000/108 ms; slice thickness 5 mm; matrix 80x80; b value, 900 s/mm; scan time, 204 s) was performed. In addition, T1-weighted spin echo imaging (T1WI) (TR/TE, 420/15ms; slice thickness 2.5 mm, spacing 0.5mm) and T2-weighted spin echo imaging (T2WI) (TR/TE 4000/108ms; slice thickness 2.5 mm, spacing 0.5mm) were performed. The apparent diffusion coefficient (ADC) map was automatically calculated.

Imaging evaluation

Radiologists at our hospital gave their impressions of all MRI, including DWI, before surgery. Radiologists were given short clinical and CT information before the examinations. Cholesteatoma was diagnosed on DWI as a marked hyperintense signal with reference to the cerebellar tissue of the same scan. All cases were classified as positive or negative according to the above-described signal characteristics. The sensitivity, specificity and positive and negative predictive values were assessed. Cholesteatoma size was the maximum diameter of DWI.

RESULTS

Table 2 shows agreement between surgical findings and the presence/absence of cholesteatoma on DWI before surgery.

Of 56 patients, we observed 41 true-positive (TP) cases, no false-positive (FP) cases, 8 true-negative

Table-1: Operative Findings

Cholesteatoma	First operation	Petrous cholesteatoma	1	30	48
		Congenital cholesteatoma	2		
		Acquired cholesteatoma	27		
	Re-operation	Recurrent cholesteatoma	8	18	
		Residual cholesteatoma	10		
Non-cholesteatomatous tissue		Cholesterol granuloma	1		8
		Granulation due to foreign body	1		
		Scar tissue	3		
		Inflammatory granulation tissue	3		

(TN) cases, and 7 false-negative (FN) cases. In 5 of 7 FN cases, the diameter of the cholesteatoma mass was less than 5 mm. The remaining 2 cases had limited keratin accumulation due to simple atelectasis or meticulous evacuation of keratin debris that had been performed before the MRI study. Cholesteatoma size on DWI in which cholesteatoma could be identified ranged from 5mm to 40mm. According to the results, sensitivity, specificity, positive predictive value, and negative predictive value were 85.4% (41/48), 100% (8/8), 100% (41/41), and 53.3% (8/15), respectively.

Table-2: Results of DWI in Diagnosis of All Cases

	Cholesteatoma (+) [a]	Cholesteatoma (–) [a]
DWI(+) [b]	41 True positive	0 False positive
DWI(–) [b]	7 False negative	8 True negative

[a]Presence (+) or absence (–) of cholesteatoma
[b]Positive (+) or negative (–) DWI evaluation

There were 21 postoperative cases, including 18 cases of recurrent or residual cholesteatoma, 2 cases of granulation tissue and 1 case of cholesterol granuloma. We observed 16 TP cases, no FP cases, 2 TN cases, and 3 FN cases in this group. Table 3 shows the agreement between image observation and surgical observation. Sensitivity, specificity, positive predictive value, and negative predictive value are 88.9% (16/18), 100% (3/3), 100% (16/16) and 60% (3/5), respectively.

Table-3: Results of DWI in Diagnosis of Postoperative Cases

	Cholesteatoma (+) [a]	Cholesteatoma (–) [a]
DWI(+) [b]	16 True positive	0 False positive
DWI(–) [b]	2 False negative	3 True negative

[a]Presence (+) or absence (–) of cholesteatoma
[b]Positive (+) or negative (–) DWI evaluation

TP cases: residual cholesteatoma (case 1) and petrous cholesteatoma (case 2), FN case: congenital cholesteatoma (case 3) and TN case: cholesterol granuloma (case 4) are presented below.

Case 1: 43-year-old male, right residual cholesteatoma.

Canal wall-up tympanoplasty had been performed for attic cholesteatoma two years ago. On follow-up observation, a tympanic cavity ventilation tube placed in the previous surgery was identified; however, no evidence suggesting a retraction pocket or cholesteatoma was observed. Since soft tissue opacity in the middle ear and mastoid cavity was found on CT (Fig. 1a) performed two years after surgery, MRI was performed. T2WI showed a hyperintense mass (Fig. 1b) and DWI showed a markedly hyperintense mass (Fig. 1c). The surgery confirmed the cholesteatoma that was surrounded with granulation tissue in mastoid cavity.

Figure-1: true positive case of residual cholesteatoma (case 1), Axial CT and MRI findings **(a)** CT, **(b)** T2WI, **(c)** DWI, arrow: cholesteatoma

Case 2: 45-year-old male, left petrous cholesteatoma.

This patient had petrous cholesteatoma in both ears. He had undergone 3 surgeries on his right ear in 1998, 2000 and 2004 at another hospital. No recurrent cholesteatoma was found. Left petrous cholesteatoma was identified in the first surgery, so he needed clinical follow-up. Since he had had otorrhea from 1 year previously, he was referred to our hospital for surgery. On otoscopic examination, a polyp was identified in posterior inferior quadrant of the tympanic membrane, and cholesteatoma was identified at the epitympanum. Osteolytic soft tissue opacity extending through the petrous bone was identified on CT (Fig. 2a); therefore, MRI was performed. T2WI showed a hyperintense mass (Fig. 2b) and DWI also showed a notably hyperintense mass (Fig. 2c). During the surgery, a large cholesteatoma mass spreading from the apex of the petrous bone to the epitympanum was observed.

Case 3: 3-year-old female, right congenital cholesteatoma.

Figure-2: true positive case of residual cholesteatoma (case 2), Axial CT and MRI findings **(a)** CT, **(b)** T2WI, **(c)** DWI, arrow: cholesteatoma

She had hearing loss in the right ear and was referred to our hospital. Since a white mass was seen through the eardrum, congenital cholesteatoma was suspected in the right tympanic cavity. Soft tissue opacity of 4mm diameter in the right tympanic cavity was identified on CT (Fig. 3a), and a slightly hyperintense mass was seen on T2WI (Fig. 3b); however, no notably high signal was seen on DWI (Fig. 3c); therefore, it was difficult to make a diagnosis of cholesteatoma. During surgery, a pearl-like cholesteatoma of 4mm diameter contacting the eardrum was identified at the front of the malleus (Fig. 3d).

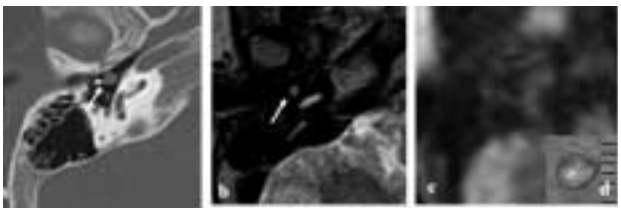

Figure-3: false negative case of congenital cholesteatoma (case 3), Axial CT and MRI findings **(a)** CT, **(b)** T2WI, **(c)** DWI, **(d)** extraction cholesteatoma, arrow: choleseatoma

Case 4: 16-year-old female, right cholesterol granuloma

Figure-4: true negative case of cholesterol granuloma (case 4), Axial CT and MRI findings **(a)** CT, **(b)** T2WI, **(c)** DWI, arrow: cholesteatoma

Canal wall-up tympanoplasty had been performed for right attic cholesteatoma 7 years previously at our hospital. After surgery, the patient attended regular follow up examination. Feelings of fullness in the right ear and otalgia had started to appear 6 months previously, and granulation tissue was identified at the epitympanum. Soft tissue opacity spreading from the tympanic cavity to the mastoid cavity was identified on CT (Fig. 4a); therefore, MRI was performed. T1WI and T2WI showed a hyperintense mass in the same area (Fig. 4b) but DWI showed no remarkably intense mass (Fig. 4c); therefore, cholesterol granuloma was suspected. Surgery revealed cholesterol granuloma.

DISCUSSION

DWI has been used primarily in intracranial disease such as the detection of early cerebral ischemic changes in acute stroke[5,6] . Single shot echo planar imaging (EPI) DWI is susceptible to artifacts, resulting in difficulty in evaluating the temporal bone area. Therefore, imaging procedures that have little susceptibility to artifacts, such as fast spin echo imaging (FSE) DWI[7], line scan DWI[8] and PROPELLER-DWI are used, and we used FASE-DWI[7]. Recently, with the appearance of parallel imaging, EPI artifacts have been reduced and DWI can be performed with less distortion, so DWI has been applied for various organs, such as the lung, liver and prostate. DWI for temporal bone areas has been applied to diagnose cholesteatoma and its use has been reported since 2002.[2,4].

DWI provides information regarding the molecular diffusion of water in the examined tissue. On DWI, the signal intensity of mobile water molecules is lower than that of immobile water molecules. Generally, hyperintensity on DWI shows up in cases of super- to subacute phase bleeding, cellular edema, high viscosity liquid and high cell density, such as neoplastic lesions. Cholesteatoma is a complex lesion consisting of a matrix lined with squamous epithelium which produces keratin; cystic lumen filled with desquamation debris in the middle ear. Therefore, the contents have extremely high viscosity and their

diffusion is restricted. Furthermore, cholesteatoma itself is hyperintense on T2WI, so it is thought that cholesteatoma presents markedly hyperintense signal on DWI [9,10].

In our study, sensitivity, specificity, positive predictive value, and negative predictive value of DWI in all cases were 85.4%, 100%, 100%, and 53.3%, respectively, and in postoperative cases were 88.9%, 100%, 100%, and 60%. Previous studies on the detection of cholesteatomas have reported a sensitivity range of 77-100% and a specificity of 93.7-100%[2,4]. Our results were broadly consistent with these results.

Analysis of our surgical results revealed 7 FN cases, in 3 of which, the diameter of the cholesteatoma mass was less than 5 mm. The remaining 4 cases had limited keratin accumulation due to simple atelectasis or meticulous evacuation of keratin debris before MRI. As described in case 3, it was difficult to detect congenital cholesteatoma on DWI of 4mm. Congenital cholesteatoma was revealed in normal sequence MRI, so it was thought that the low resolution of DWI was the cause of FN. Aikele et al. and Vercruysse et al. reported that cholesteatoma of 4 to 6mm is the diagnostic limit; therefore, it is considered that the diagnosis limit of cholesteatoma size was around 5mm in the spatial resolution of our sequence[3,4].

FP cases were not found in the present study; however, there are reports that magnetic susceptibility artifacts, cholesterol granuloma and abscess show hyperintensity on DWI as well as cholesteatoma[2,11-13]. One report stated that cholesterol granuloma showed high signals in the past; however, cholesterol granuloma did not show high signals in our study, as described in case 4. In addition, cholesterol granuloma can also be diagnosed on normal sequence MRI. There are some reports that abscesses show hyperintensity in the brain, and that they are also hyperintense in the temporal bone area[6,13]. Cases of abscess were not included in this study, and a study of such cases may be necessary in the future. As for granulation tissue, only a part of cholesteatoma contents shows hyperintensity even when the cholesteatoma is surrounded by granulation tissue. Peripheral granulation tissues were not revealed, as described in case 1, so it was easy to distinguish between cholesteatoma and granulation tissues. It is especially useful to distinguish soft tissue opacity in postoperative cases.

Since FP cases were not identified, cholesteatoma can be positively suspected when hyperintensity is identified on DWI. On the other hand, FN cases were found in 12.5%, so it cannot be rejected that cholesteatoma may be overlooked. It should especially be noted that cholesteatoma with a diameter of 5mm or less may be overlooked. It is conceivable that these cases could be comprehensively diagnosed in combination with the clinical course, CT and MRI with DWI. On the other hand, as for identification of soft tissue opacity, which is difficult to diagnose on CT and cases which cannot be detected by a simple clinical examination, DWI is especially useful for diagnosis.

CONCLUSION

The value of DWI to detect middle ear cholesteatoma was confirmed in our results. In particular, it seems important that cholesteatoma can be diagnosed without contrast agents that are necessary for current MRI image procedures. If spatial resolution of DWI is improved, MRI with DWI will have an important role in cases including residual cholesteatoma after canal wall-up tympanoplasty, congenital cholesteatoma, and petrous cholesteatoma, in which the diagnosis of cholesteatoma is difficult to make using clinical evaluation and CT.

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