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Original Article

Value of Echo-Planar Diffusion-Weighted Magnetic Resonance Imaging for Detecting Tympanomastoid Cholesteatoma

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OBJECTIVE: The aim of this study was to evaluate the diagnostic accuracy of echo-planar diffusion-weighted magnetic resonance imaging (EP-DWI) and high-resolution computed tomography (HRCT) in the detection and localization of cholesteatoma.

MATERIALS and METHODS: Fifty-four patients were prospectively included in this study. Patients with suspected primary or residual cholesteatoma were evaluated by EP-DWI and HRCT before tympanomastoid surgery. Radiological findings were correlated with intraoperative findings.

RESULTS: EP-DWI and HRCT accurately predicted the presence or absence of cholesteatoma in 49 of 54 (90.7%) and 37 of 54 (68.5%) patients, respectively. The sensitivity, specificity, and positive and negative predictive values of EP-DWI were 88.4%, 92.8%, 92%, and 89.6%, respectively. However, sensitivity, specificity, and positive and negative predictive values of HRCT were 69%, 67.8%, 66.6%, and 73.07%, respectively.

CONCLUSION: This study demonstrates that EP-DWI is more reliable in predicting the presence and localization of cholesteatoma compared with HRCT, before tympanomastoid surgery.

KEYWORDS: Cholesteatoma, diffusion weighted magnetic resonance imaging, mastoidectomy

INTRODUCTION

Middle-ear cholesteatoma is usually managed by surgery. Surgical methods include well-established open or closed mastoidectomy techniques. Canal wall up surgery provides many benefits to patients during the follow-up period. However, canal wall up surgery is associated with a 20%-30% incidence of residual cholesteatoma, and recurrent disease rates may be higher when the cholesteatoma is located in the sinus tympani and hypotympanum [1, 2]. The detection of residual or recurrent disease cannot be assessed adequately solely by clinical examination and traditionally, many surgeons prefer to perform second-look surgery to diagnose residual disease [3].

HRCT has commonly been used for assessing the extent and location of cholesteatomas. However, HRCT cannot differentiate nonspecific soft tissue changes from residual or recurrent cholesteatoma in the tympanomastoid cavity, following mastoidectomy [4, 5] HRCT has more reliable findings when the middle ear and mastoidectomy defect are well-aerated, and it provides the details of bone destruction and extent of soft tissue lesions. In contrast, diffusion-weighted magnetic resonance imaging (DW-MRII) has resulted in better diagnostic performance in the detection of cholesteatoma compared with HRCT. Several studies have shown the reliability of DWI-MRI in the diagnosis of cholesteatoma, with the echo-planar and non-echo-planar imaging technique [6-8].

The aim of this prospective study was to evaluate the accuracy of EP-DWI and HRCT in the detection of cholesteatoma, before tympanomastoid surgery.

MATERIALS and METHODS

Study Design

This prospective blinded comparative study was performed at Otolaryngology department of Katip Çelebi University Atatürk Training Research Hospital between February 2010 and January 2013. 54 patients with clinically suspected primary or residual cholesteatoma were included in this study. Inclusion criteria were as follows: Patients with suspected middle ear cholesteatoma on clinical

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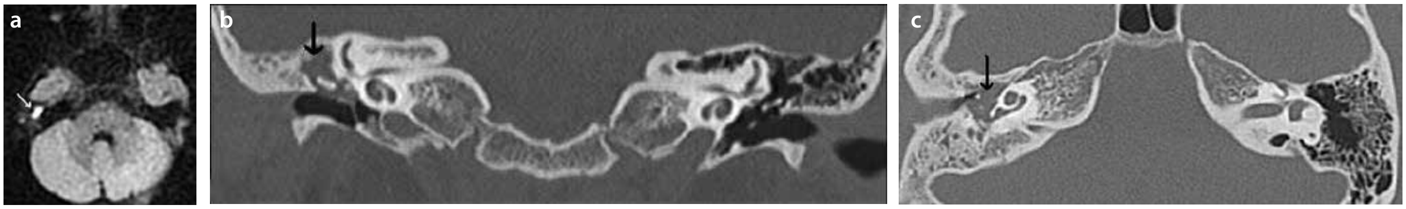

Figure 1. a-c. True positive image of the patient with cholesteatoma in the epitympanum. Axial DWI-MRI reveals high signal intensity in epitympanum due to cholesteatoma (white arrow) (a) Coronal HRCT image of the right middle ear. Cholesteatoma in the epitympanum without definite erosion of the ossicles (black arrow) (b) Axial view of HRCT (black arrow) (c)

examination were enrolled into the study. All patients underwent EP-DWI and HRCT before the surgery. HRCT scanning was performed and reviewed initially. EP-DWI was performed after HRCT scanning. Data was recorded for the presence or absence of cholesteatoma. The size and location of cholesteatoma was evaluated through intraoperative findings. Histological confirmation of diseased tissue was performed in all subjects. This study was approved by the Institutional Review Board of Katip Celebi University. Written informed consent was obtained from all the patients. (67/2012-488).

Patients' Characteristics

Fifty-four patients have been included in this study. The clinical, radiological, and surgical findings of the patients were recorded. There were 32 male and 22 female patients, with ages ranging from 14 to 66 years (average age, 33.6 years). Twelve of 54 patients had undergone their second surgery. The mean time interval between the radiological assessment and operation was 26.3 days (range, 2-64 days).

Imaging Technique

All computed tomography (CT) scans were performed on a 64-multislice CT scanner (Toshiba Aquilion; Tochigi, Japan) using axial, coronal, and sagittal images. Images were obtained in 3-mm thickness. Magnetic resonance imaging (MRI) was performed on a 1.5-T superconductive unit (GE; Milwaukee, WI, USA) with use of a circularly polarized head coil. Axial 3-mm-thick turbo-spin-echo T2-weighted images (TR 4.300 ms, TE 85 ms, FOV: 250×250, matrix: 128×128) and coronal and axial 3-mm-thick turbo-spin-echo T1-weighted images (TR 6000 ms, TE 85 ms, FOV: 250×250, matrix: 128×128) were obtained before contrast material administration. After the administration of gadolinium (0.1 mmol/kg), axial and coronal T1-weighted spin-echo images were obtained with the same parameters

Radiologic Interpretation

A head and neck radiologist (N.E.) evaluated all CT and MRI images, prior to surgery at the same time. Radiologist was blinded to the results of any surgery and clinical data. Primary or residual cholesteatomas were evaluated as positive (cholesteatoma present) or as negative (cholesteatoma absent) in HRCT and MRI. A positive finding of cholesteatoma on HRCT meant presence of soft tissue, scutum blunting, and erosion of the tegmen tympani and ossicles. On MRI, the criteria were low signal intensity on non enhanced T1-weighted images and increased signal on T2-weighted images. Evaluation of the enhancement was also performed after the intravenous administration of gadolinium. EP-DWI was performed to evaluate characteristic hyperintense cholesteatoma pearls.

RESULTS

Fifty-eight patients met the inclusion criteria and were enrolled in our study. Four did not follow-up; hence, an overall of 54 patients who completed the follow-up were included in this study. Twelve patients (22.2%) underwent second-look operation and 42 (77.7%) underwent primary mastoidectomies. Of the 54 patients, 26 (48.1%) had cholesteatoma that consisted of 21 primary cholesteatoma, 5 had residual and/or recurrent cholesteatoma after tympanoplasty. Eleven of the 26 cholesteatomas were found in the epitympanum, 6 in the mesotympanum, and 9 in both the epitympanum and mastoid cavity. Preoperatively, EP-DWI accurately defined localization of the cholesteatoma in 24 (92.3%) patients. Type of surgery and localization of cholesteatoma of the patients are shown in Table 1.

Table 1. Summary of patients suspected of having tympanomastoidcholesteatoma

Cholesteatoma location and type of surgery	Patients (n:54)
Localization of cholesteatoma	26
Epitympanum	11
Mesotympanum	6
Epitympanum-mastoid	9
Type of surgery	54
MRM	11
Atticotomy	8
Inside-out mastoidectomy	5
ICWM	18
Revision mastoidectomy	12

MRM: modified radical mastoidectomy; ICWM: intact canal wall mastoidectomy

The otoscopic examination findings of the 26 patients with cholesteatoma were as follows: positive otoscopic findings were observed in 18, negative otoscopic findings were observed in 8, and 12 had infected cholesteatoma.

Findings of EP-DWI Examinations

EP-DWI accurately predicted the presence or absence of cholesteatoma in 49 (90.7%) of 54 patients. Of 54 patients, we observed 23 true-positive (TP) patients (Figure 1a, Figure 1b, Figure 1c) (cholesteatoma observed during surgery and previously diagnosed by EP-DWI), 2 false-positive (FP) patients (Figure 2a, Figure 2b) (no cholesteatoma observed during surgery, but previously diagnosed by EP-DWI), 26 true-negative (TN) patients (no cholesteatoma observed during surgery or previously by EP-DWI), and 3 false-negative (FN) patients (cholesteatoma observed during surgery but not previously diagnosed by EP-DWI). The correlation between EP-DWI preoperative and operative findings is illustrated in Table 2. The sensitivity, specificity, and positive and negative predictive values of EP-DWI for cholesteatoma were 88.4%, 92.8%, 92% and 89.6%, respectively.

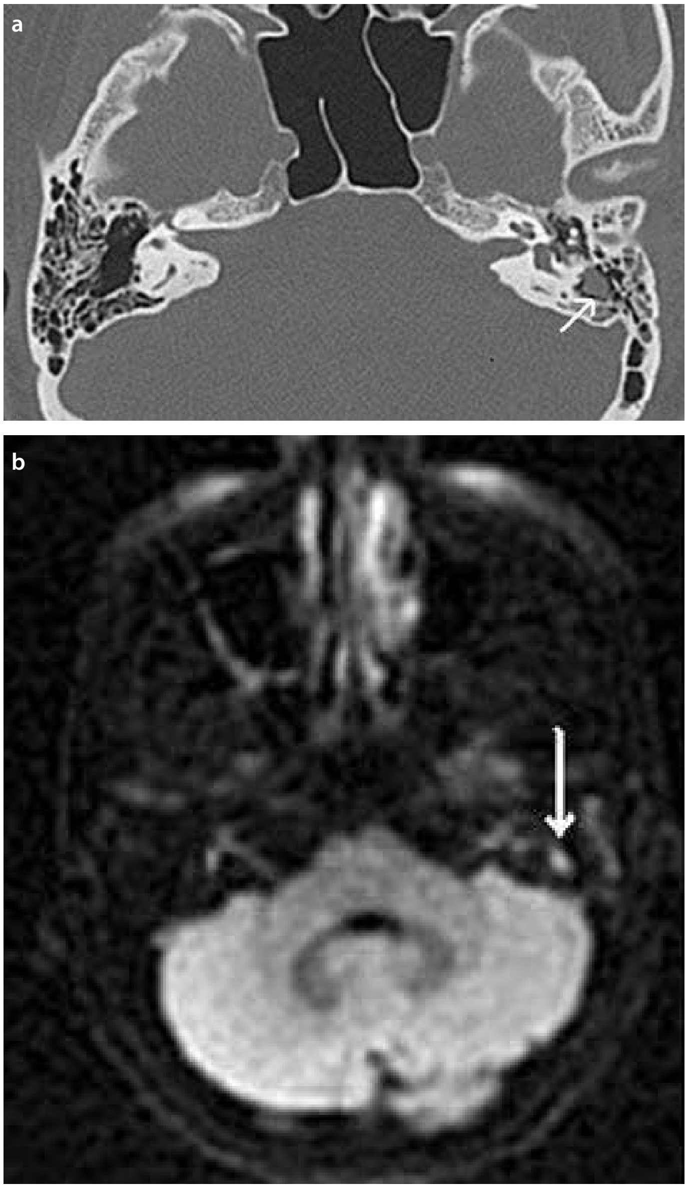

Figure 2. a, b. False positive image of the patient in the mastoid cavity. Axial HRCT view of the soft tissue in the mastoid (white arrow) (a) False positive image of the mastoid cavity. Axial DWI-MRI reveals high signal in the mastoid (white arrow) (b)

Findings of HRCT Examinations

Correct diagnosis using HRCT was made in 37 (68.5%) of 54 patients (Figure 1b, Figure 1c). Of the 54 patients, we observed 18 TP, 9 FP, 19 TN, and 8 FN patients (Figure 2a) (Table 3). The sensitivity, specificity, and positive and negative predictive values of HRCT scan for cholesteatoma were 69%, 67.8%, 66.6%, and 73.07%, respectively. The sensitivity, specificity, and positive and negative predictive values of EP-DWI and HRCT for cholesteatoma are shown in Table 4. Figure 3 shows the disagreement between HRCT and EP-DWI. Figure 3a shows the soft tissue in the mastoid cavity in axial HRCT scan, whereas axial EP-DWI (Figure 3b) shows no cholesteatoma.

Definition and Calculation of Imaging Results

Sensitivity was defined as the capability to detect the presence of cholesteatoma and was calculated as follows: sensitivity = [TP/(TP+FN)]×100.

Table 2. Correlation between EP-DWI and operative findings

	Positive on EP-DWI (n:25)	Negative on EP-DWI (n:29)
Presence of cholesteatoma (n:26)	True-positive (n:23)	False-negative (n:3)
Absence of cholesteatoma (n:28)	False-positive (n:2)	True-negative (n:26)

EP-DWI: echo-planar diffusion-weighted magnetic resonance imaging

Table 3. Correlation between HRCT and operative findings

	Positive on HRCT (n:27)	Negative on HRCT (n:27)
Presence of cholesteatoma (n:26)	True-positive (n:18)	False-negative (n:8)
Absence of cholesteatoma (n:28)	False-positive (n:9)	True-negative (n:19)

HRCT: high-resolution computed tomography

Table 4. The sensitivity, specificity, and positive and negative predictive values of EP-DWI and HRCT for cholesteatoma

	Sensitivity	Specificity	PPV	NPV
EP-DWI	88.4	92.8	92	89.6
HRCT	69	67.8	66.6	67.8

EP-DWI: echo-planar diffusion-weighted magnetic resonance imaging; HRCT: high-resolution computed tomography; PPV: positive predictive values; NPV: negative predictive values

Specificity was defined as the capability to detect the absence of cholesteatoma and calculated as follows: specificity = [TN/(TN+FP)]×100.

Positive predictive value (PPV) was defined as the probability that patients with a positive finding for cholesteatoma truly have cholesteatoma and was calculated as follows: PPV=[TP/(TP+FP)]×100.

Negative predictive value (NPV) was defined as the probability that patients with a negative imaging for cholesteatoma truly do not have cholesteatoma and was calculated as follows: NPV=[TN/(TN+FN)]×100.

DISCUSSION

CT scan is generally the first imaging procedure that is performed for evaluating cholesteatoma because of its improved visualization of osseous structures. However, it often fails to differentiate cholesteatoma from non specific soft tissue changes after primary surgery, with low sensitivity and specificity [9]. CT is also used to search for residual and recurrent cholesteatoma, following mastoidectomy. CT is most useful when the middle ear and mastoidectomy defect are aerated. Ganaha et al evaluated CT scan for the detection of cholesteatoma and demonstrated a sensitivity, specificity, and positive and negative predictive values 71.1%, 78.5%, 93.3% and 39.2%, respectively [10]. However, De Foer et al. [11] evaluated the value of HRCT and EP-DWI in the evaluation of residual cholesteatoma and reported that HRCT could be used as the initial radiologic imaging for the bony obliterated mastoids. In our study, the sensitivity, specificity, and positive and negative predictive values of HRCT scan for cholesteatoma were 69%, 67.8%, 66.6% and 73.07%, respectively.

DWI-MRI may provide additional information and has resulted in findings with better diagnostic accuracy. MRI has various pulse sequences, including EP-DW imaging, and the administration of intravenous contrast material. Various types of DW sequences have recently been

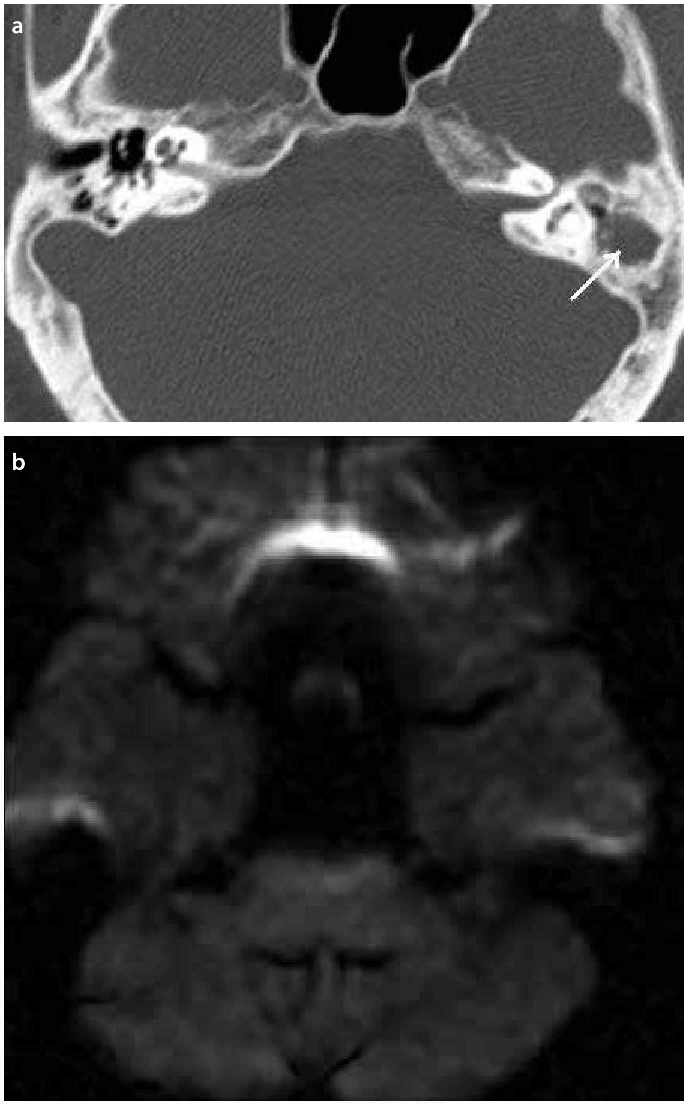

Figure 3. a, b. Disagreement of HRCT scan and EP-DWI Axial HRCT scan shows the soft tissue in the mastoid cavity (arrow) (a) Axial DWI shows no cholesteatoma (b)

described in the literature for assessing cholesteatoma. Initial studies described EP-DWI. More recent studies have analyzed non-echo planar imaging sequences. A review study has reported that EP-DWI showed a specificity range of 73%-100% and a positive predictive value within 80%-100%, whereas specificity range and positive predictive value in non EPI-DWI were 87%-100% and 89%-100%, respectively [1]. The diagnostic value of EP-DWI in evaluating of primary and residual cholesteatomas has been previously reported by several authors [6, 7, 10]. Cimsit et al. and Jeunen et al. [12, 13] reported that the sensitivity, specificity, and positive and negative predictive values of EP-DWI for cholesteatoma were 100%, 93%, and 92% and 100% and 54%, 90%, and 92% and 47%, respectively. Our study demonstrated sensitivity, specificity, positive and negative predictive values of 88.4%, 92.8%, and 92% and 89.6%, respectively. In addition, there is a good correlation between surgery and EP-DWI in terms of anatomic localization. Khemani et al. [8] reliably identified the anatomical site of residual or recurrent cholesteatoma with EP-DWI. In our study, of 26 patients, EP-DWI accurately predicted the location of the cholesteatoma in 24 patients.

DWI may fail to detect small cholesteatomas of <5 mm. This is attributed to several factors including, artifacts at the air-bone interface, and relatively thick slices [6, 14]. A 3-mm slice thickness was used in HRCT and EP-DWI in this study. The current study showed that there were 3 and 8 false-negative results in EP-DWI and HRCT, respectively. The diameter of the cholesteatoma mass was ≤3 mm in all these 3 patients in EP-DWI. Ganaha et al. [10] reported that there were 18 false-negative patients in 59 patients with cholesteatoma. In 10 of these 18 patients, the diameter of the cholesteatoma mass was <5 mm. Similarly, Huins et al. [15] reported 2 false-negative patients in 32 consecutive patients with suspected primary or residual cholesteatoma. Cholesteatoma was <2 mm in these patients. However, De Foer et al. [11] emphasized that EP-DWI has high sensitivity, specificity, and positive and negative predictive values and offer to use EP-DWI instead of second-look surgery for assessing residual cholesteatoma.

Postoperative soft tissue changes such as granulation tissue, cholesterol granuloma, and other pathologic tissues can occur in the tympanic cavity. In such cases, it is difficult to diagnose recurrent cholesteatoma. EP-DWI has also reliable results in revision operations [16]. Venail et al. [17] evaluated and localized cholesteatomas using EP-DWI, in 7 of 31 patients who underwent second-look surgery for recurrent cholesteatoma. The sensitivity and specificity were 75% and 84.2% in patients with residual cholesteatomas >3 mm, respectively.

Finally, considering only cholesteatomas >5 mm, the sensitivity and specificity increased to 100% and 88%, respectively [17]. Similarly, Profant et al. [18] accurately showed residual cholesteatoma in 12 of 14 patients with EP-DWI. In our study, 12 patients with suspected residual/recurrent cholesteatoma had undergone second-look surgery. Preoperative EP-DWI accurately predicted the presence or absence of residual cholesteatoma in 10 of 12 patients. There was 1 false-negative and 1 false-positive scan in patients with second-look surgery.

This study demonstrates that EP-DWI is a reliable technique for imaging cholesteatoma. In addition to detecting the presence of residual or recurrent cholesteatoma, this study has also shown that EP-DWI can predict and localize cholesteatoma with higher diagnostic rates compared with HRCT.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Katip Çelebi University (67/2012-488).

Informed Consent: Written informed consent was obtained from all participants.

Peer-review: Externally peer-reviewed.

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