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Original Article

Is Fusion Imaging Mandatory to Detect the Localization of Middle Ear Cholesteatomas? Inter-rater Reliability in Assessment

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Abstract

Objective: Non-echo planar diffusion-weighted imaging sequence and fusion imaging are increasingly used in the diagnosis of cholesteatoma. But it is still challenging to locate cholesteatomas and differentiate from other opacifications. This study aimed to evaluate whether the exact localization of cholesteatomas could be detected without fusion imaging using diffusion and T2-weighted magnetic resonance images in combination with computed tomography.

Methods: The study included patients with a diagnosis of cholesteatoma and had both temporal bone magnetic resonance imaging and computed tomography between 2017 and 2021. Presence of cholesteatomas was confirmed in non-echoplanar diffusion-weighted images prior to evaluation. Then, the localization of the lesion on computed tomography image was classified by detecting the equivalent of the lesion on T2-weighted thin-sliced images. All images were assessed by 2 independent radiologists. Kappa correlation coefficient was used to evaluate the interobserver agreement.

Results: Eighty-nine patients (49 female, 40 male) were included. The mean age was 39.07 (5-89). Interobserver agreement was moderate to almost perfect according to localization of cholesteatomas. The κ coefficient ranged between 0.48 and 0.83. The highest agreement was detected for the lesions located in the mesotympanium (κ=0.83), external acoustic canal, and mastoid bone. However, a moderate agreement was detected for lesions located in the medial epitympanic recess (κ=0.49).

Conclusion: Cholesteatomas which are placed in the mesotympanium, external auditory canal, and mastoid bone can be determined with high accuracy without fusion imaging.

Keywords: Tomography, diffusion, temporal bone, cholesteatoma

INTRODUCTION

Cholesteatomas are defined as the appearance of skin tissue in the inappropriate localizations; they are well-circumscribed non-neoplastic lesions observed in the temporal bone.[1] Middle ear cholesteatomas are common pathologies seen as a complication of untreated chronic otitis media, especially in underdeveloped countries.[2] While very small cholesteatomas can be detected with non-echo planar diffusion-weighted imaging (non-EPI DWI), anatomical details cannot be distinguished. Thin-section computed tomography (CT) provides excellent information on anatomical details.[2] Therefore, both CT and magnetic resonance imaging (MRI) are generally used in combination.

Diffusion-weighted imaging plays an important role in distinguishing cholesteatomas from other secretions, granulation tissue, scar tissue, and encephalocele.[3] Non-echo planar diffusion-weighted imaging, which is less affected by susceptibility artifacts, has high sensitivity (91%) and specificity (96%) in detecting cholesteatoma. Non-echo planar diffusion-weighted imaging sequence is superior to EPI DWI sequences in detecting the presence of cholesteatoma and has a higher positive predictive value. Therefore, it is recommended that it should be standardized in cholesteatoma imaging. However, its anatomical resolution is insufficient in a very small area such as the temporal bone.[3] At that point, thin-section high-resolution temporal bone CT becomes important. But, CT is still insufficient to distinguish cholesteaomas from other fluids and tissues.[3] On the other hand, MRI has the advantage of showing extension into the membranous labyrinth in some cases of cholesteatomas.[3] Therefore, fusion imaging combining CT and MRI has been the subject of study in recent years and has begun to be used.[4,5] However, fusion imaging has several limitations: it is cumbersome and requires the use of 2 different imaging modalities per patient. In this study, we aimed to classify cholesteatomas into anatomical groups by evaluating thin-sliced T2-weighted images and non-EPI DWI and CT scans together and to evaluate the reliability of localization of the lesions among observers.

METHODS

Prior to this retrospective study, approval was obtained from the university ethics committee. (ID: 2021/0496, date: 10/6/2021). Only patients having both thin-sliced temporal bone CT and temporal bone MRI were included to the study. Images with artefacts, without non-EPI DWI, and thin-section T2 sequences, without thin-section temporal bone scans, were excluded. Two independent observers (with 10 years of experience in neuroradiology and 5 years of experience in head and neck radiology) evaluated non-EPI DWI, thin-sliced T2, and thin-sliced CT images for all patients to classify localization of the cholesteatomas.

Imaging Technique and Diagnosis

For temporal bone CT, acquisition parameters were as follows: 100 mAs, 100 kV, 0.6 s rotation time, 1 mm/rotation (pitch, 0.984), 0.625 mm slice thickness, 2.8 s scan time, field of view of 200 mm and matrix of 512 × 512.

For temporal bone MRI, T1- and T2-weighted sequences with a 3 mm slice thickness, 3D-FIESTA sequence with 0.5 mm slice thickness, fluid-attenuated inversion recovery, and non-EPI diffusion-weighted sequence (b-value: 1000 s/mm^2) were achieved.

Localizations of cholesteatomas were described as external auditory canal, mastoid bone, periossicular chain, medial, lateral or superior epitympanic recess, mesotimpanium, hypotimpanium, Prussak's space, pars tensa, and pars flaccida (Figure 1). The localization, which was restricted in favor of cholesteatoma in diffusion MRI, was determined in thin-section T2 images, and its localization in the CT image was decided and detailed anatomically (Figures 2, 3, 4).

Statistical Analysis

The Statistical Package for the Social Sciences version 19.0. (IBM SPSS Corp.; Armonk, NY, USA). Quantitative data were interpreted using means and SDs and minimum and maximum values. Qualitative data were interpreted using frequencies, percentages, and ranges. Interobserver agreement assessed was based on the kappa coefficient (κ). $\kappa \leq 0$ is defined as no agreement, between 0.01 and 0.20 as none to slight, between 0.21 and 0.40 as fair, between 0.41 and 0.60 as moderate, between 0.61 and 0.80 as substantial, and between 0.81 and 1.00 as almost perfect agreement.[6]

MAIN POINTS

- While very small cholesteatomas can be detected with non-echo planar diffusion-weighted imaging (non-EPI DWI), anatomical details cannot be distinguished. Thin-section computed tomography (CT) provides excellent information on anatomical details.
- Fusion imaging, combining CT and magnetic resonance imaging (MRI), has been the subject of studies in recent years and has begun to be used.
- Fusion software is costly and time consuming. Moreover, it is not accessible at every center.
- Combined evaluation of high-resolution CT, non-EPI DWI, and T2-weighted MR can detect not only the presence of cholesteatoma but also its localization with high accuracy, even without the need for fusion images for many cholesteatomas.

RESULTS

One hundred thirty medical records were assessed. After initial evaluation, 89 patients [49 (55.05%) female, 40 (44.9%) male] with cholesteatoma were included the study. All cases were unilateral. There were 44 right- and 45 left-sided cholesteatomas. The mean age was 39.0 ± 62.2 (5-89). The most common localization was periossicular chain (n=37, 41.5%) and attic cavity superior (n=26, 29.2%) and the less common localization was lateral epitympanic recess (n=9, 10.1%). The hearing loss was noted for 60 patients and facial paralysis for only 1 patient. Twenty-eight patients had residual recurrent cholesteatoma in the mastoidectomy cavity, and these lesions were detected with almost perfect interobserver agreement (κ=0.81).

According to kappa correlation coefficient, interobserver agreement changed between almost perfect and moderate agreement. The kappa correlation coefficient was between 0.48 and 0.83 (Table 1).

DISCUSSION

In this study, the localization of cholesteatomas was divided into anatomical subgroups and evaluated with CT and MR images; the highest agreement was detected for the lesions located in the mesotympanium (κ=0.83), external acoustic canal (κ=0.81), and mastoid bone (κ=0.80-0.81). However, a moderate agreement was detected for lesions located in the medial epitympanic recess (κ=0.49) and Prussak's space (κ=0.51).

Non-echo planar diffusion-weighted imaging is very sensitive even for detecting very small cholesteatomas.[7] Especially for residual or recurrent cholesteatoma, non-EPI DWI parameters are more reliable (91% sensitivity and 96% specificity), but CT is perfect for anatomic detail.[2,8] Therefore, fusion studies were carried out with the idea of benefiting from the advantages of CT and MRI together. Few studies with a small patient group reported that fusion imaging is better than only CT or only MRI.[4,9] Fusion software is costly and time consuming. Moreover, it is not accessible at every center.[10] Fusion imaging studies are experimental level studies with a small patient group in the form of case series.[10] In studies conducted with a single observer, reliability was not evaluated due to interobserver agreement.[11] The current study aimed to investigate how reliably we could detect cholesteatomas without using fusion imaging with a larger patient group.

Some fusion studies focused on evaluating the presence of cholesteatoma. In these studies, the authors did not make a classification according to lesion localization.[4,5] But cholesteatoma localization is extremely important for surgical planning. There are many guidelines for classifying and staging cholesteatomas.[12] Radiological evaluation is very important to be able to do this before surgery and to guide surgical treatment. Therefore, in the current study, we focused on locating the cholesteatoma rather than detecting its presence.

Plouin-Gaudon et al[13] classified cholesteatoma localizations as hypotympanium, epitympanium, mastoid recess, and attical space in their CT-DWI fusion study with 10 children. However, we performed a more detailed examination with a larger patient cohort (89 patients and 13 different localizations). The number of patients, the evaluation of 2 observers, and the anatomical detailing increased the reliability of the current study.

Alzahrani et al[14] compared the results of CT-DWI fusion imaging and second-look surgery in 10 patients with residual cholesteatoma and recommended fusion imaging for the detection of residual cholesteatomas.

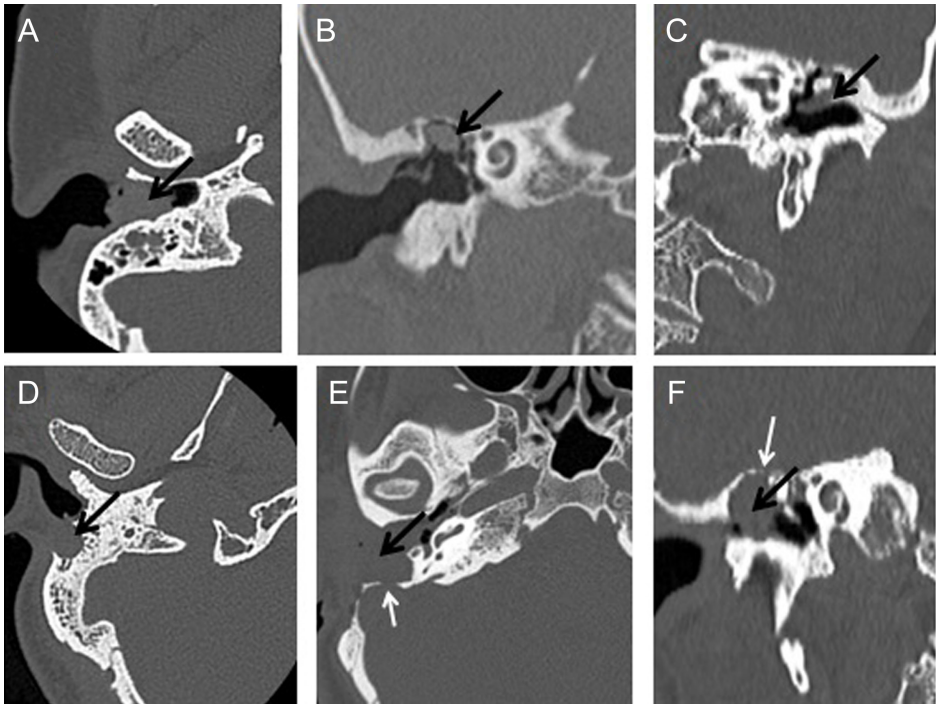

Figure 1. The localization definition examples in temporal bone CT images. (A) Right-sided cholesteatoma in external auditory canal (arrow). (B) Right-sided cholesteatoma in superior attic recess (arrow). (C) Left-sided pars flaccida cholesteatoma (arrow). (D) Right-sided mastoid air cell cholesteatoma with bony erosion (arrow). (E) Right-sided cholesteatoma in mastoidectomy cavity (black arrow) and bony erosion in the occipital bone (white arrow). (F) Right-sided cholesteatoma originating from the lateral epitympanic recess and extending into the external auditory canal (black arrow) and bony destruction in the tegmen tympani (white arrow). CT, computed tomography.

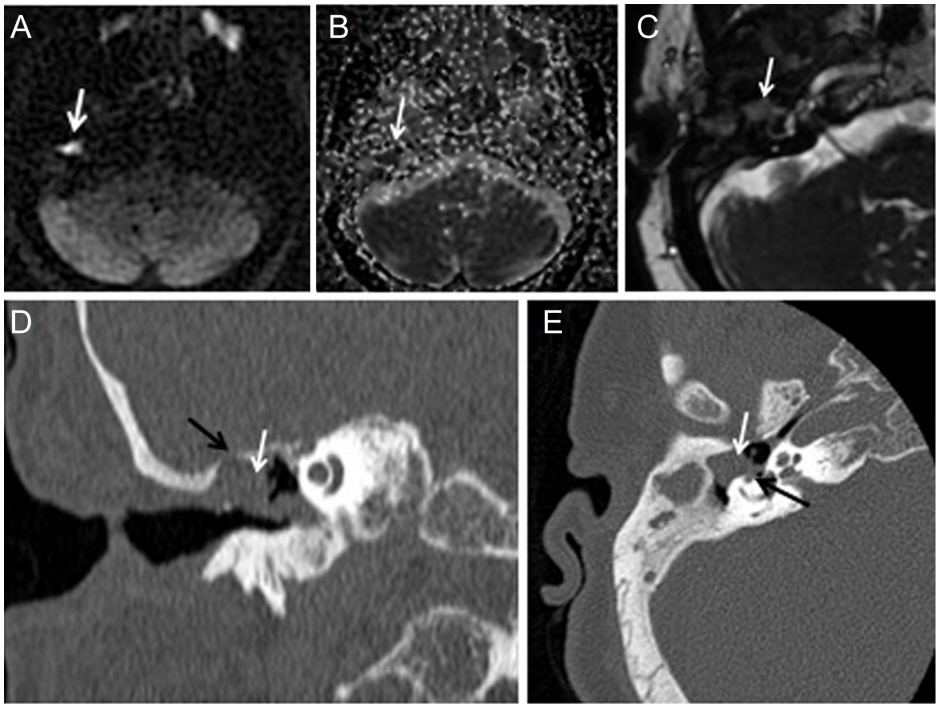

Figure 2. Right-sided millimetric nodular diffusion restriction non-echoplanar diffusion-weighted image (A) and apparent diffusion coefficiency map (B). (C) On thin-sliced T2-weighted image, the nodular lesion in tympanic cavity, fistulized to inner ear. (D) On coronal CT image, the opacity filling the tympanic cavity (white arrow) which is not all cholesteatoma when confirmed by MRI and bony destruction in tegmen tympani (black arrow). (E) Cholesteatoma located in the medial epitympanic recess (white arrow) fistulized into the semicircular canal (black arrow) in the axial CT image corresponding to the thin-section T2-weighted MR image. CT, computed tomography; MRI, magnetic resonance imaging.

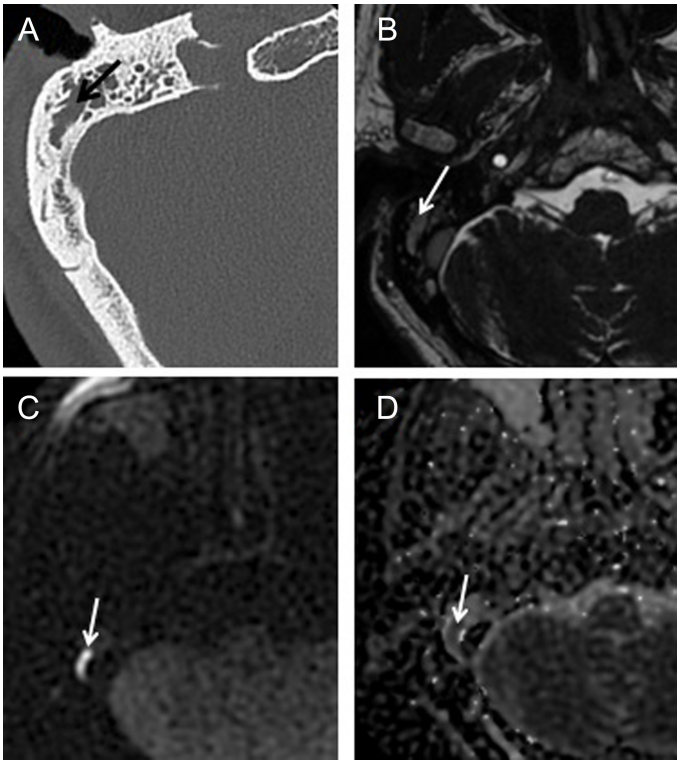

Figure 3. (A) In the axial CT image, opacifications (arrow) within the mastoid air cells on the right; it is difficult to distinguish cholesteatoma from other secretions with only CT. (B) Thin-sliced T2-weighted MR image shows hypointense secretions (arrow). (C, D) Fusiform-shaped diffusion restriction in this area (arrows) compatible with cholesteatoma. CT, computed tomography; MR, magnetic resonance.

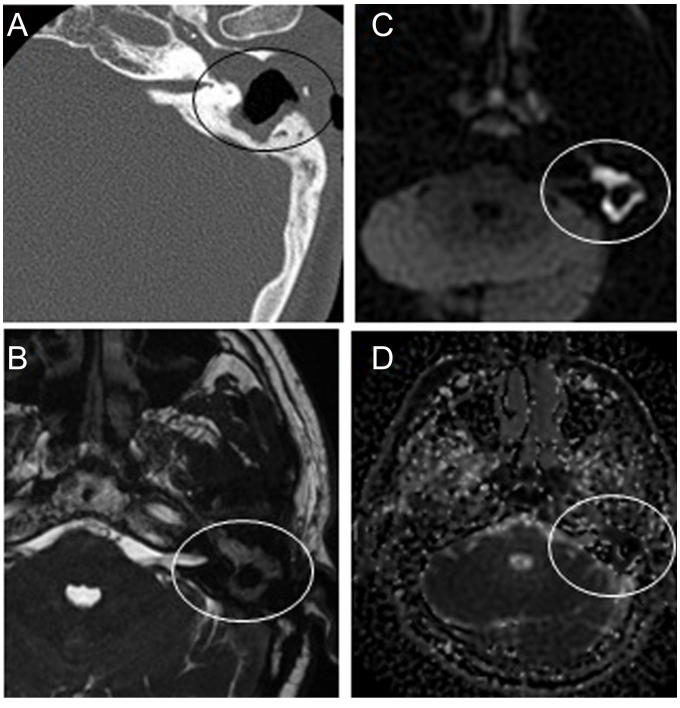

Figure 4. (A) Axial CT image, (B) T2-weighted thin-sliced image shows secretions in the same form as C, D. (C, D) Diffusion restriction (rings). CT, computed tomography.

Table 1. Interobserver Agreement According to Cholesteatoma Localizations

Cholesteatoma localization	κ
External auditory canal	0.81
Mastoid air cell	0.80
Mastoid antrum	0.80
Mastoidectomy cavity	0.81
Periossicular chain	0.76
Attic superior	0.66
Medial epitympanic recess	0.48
Lateral epitympanic recess	0.63
Prussak's space	0.51
Pars tensa	0.67
Pars flaccida	0.72
Mesotympanium	0.83
Hypotympanium	0.79

κ, kappa correlation coefficient.

In the current study, residual cholesteatoma was detected in 28 patients with high accuracy (almost perfect agreement, $\kappa = 0.81$) without the need of fusion imaging.

Benson et al[3] reported a fusion study using thin-section T2-weighted and diffusion sequences instead of fusion studies that always used CT and diffusion MR images. The authors aimed to remove CT necessity especially in postoperative and pediatric patients. The authors compared the surgical results with the evaluation of a single neuroradiologist. The accuracies of unfused DWI and fused DWI-T2 were reported as 76% and 82%, respectively.[3] In the current study, all images were evaluated by 2 experienced radiologist, and also CT-DWI-T2 images were evaluated in addition to single CT-DWI or T2-DWI fusion studies. The exact localization of the cholesteatoma was detected by cross-tabulating the T2 sequence with DWI instead of fusion imaging. Anatomical details confirmed this localization with CT.

To the best of our knowledge, this is the only study in which interobserver agreement was evaluated for the largest number of localizations for cholesteatoma. The lack of comparison with surgical results is a limitation of the study.

In conclusion, combined evaluation of high-resolution CT, non-EPI DWI, and T2 weighted MRI can detect not only the presence of cholesteatoma but also its localization with high accuracy, even without the need for fusion images for many cholesteatomas. However, fusion imaging may be essential for cholesteatomas placed in medial epitympanic recess and Prussak's space.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Istanbul Medeniyet University (Date: June 10, 2021, Decision No: 2021/0496).

Informed Consent: Written informed consent was obtained from all participants who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – U.P.O.S.; Design – U.P.O.S., B.A.;Supervision – A.F.;Resources – S.G.B.; Materials – N.G.; Data Collection and/or Processing – U.P.O.S., B.A.; Analysis and/or Interpretation – N.G.; Literature Search – S.G.B.; Writing Manuscript – U.P.O.S.; Critical Review – A.F.

Declaration of Interests: The authors have no conflicts of interest to declare.

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