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Original Article

Radiology Section

Role of Diffusion-weighted Magnetic Resonance Imaging in Differentiating Cholesteatoma from Chronic Suppurative Otitis Media: A Cross-sectional Study

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ABSTRACT

Introduction: Radiological imaging, such as High-resolution Computed Tomography (HRCT) of the temporal bone, has always held significant importance in diagnosing and staging Chronic Suppurative Otitis Media (CSOM). In preoperative cases of CSOM and cholesteatoma, HRCT describes the disease's extent to aid in surgical approach, while diffusion-weighted Magnetic Resonance Imaging (MRI) sequences can differentiate cholesteatoma from other common inflammatory middle ear diseases.

Aim: To determine the role of Diffusion-weighted Magnetic Resonance Imaging (DW-MRI) in differentiating between granulation tissue and cholesteatoma using histopathological findings as a reference standard.

Materials and Methods: A hospital-based cross-sectional study was conducted in the Department of Radiodiagnosis, Sri Manakula Vinayagar Medical College, Puducherry, India, from November 2018 to April 2020. A total of 40 patients who underwent HRCT of the temporal bone for preoperative evaluation of CSOM underwent diffusion sequence MRI, and their findings were compared with intraoperative and postoperative histopathological results. Findings such as soft-tissue masses with scutum and erosion of ear ossicles were analysed in HRCT, while diffusion restriction was observed in DW-MRI in cases of cholesteatoma. Data were collected using a prescribed proforma and analysed using Statistical Package for Social Sciences (SPSS) software version 24.0.

Results: The mean±Standard Deviation (SD) age of the patients was 43±20.41 years (27 males, 13 females). The most common presentations in this study were mucopurulent discharge and conductive hearing loss (20 out of 40 patients). Among the 16 patients diagnosed with cholesteatoma through histopathological examination, all (100%) were reported to have diffusion restriction present in the MRI. The sensitivity, specificity, Positive Predictive Value (PPV) and Negative Predictive Value (NPV) of DWI were all found to be 100% in diagnosing cholesteatoma. The sensitivity of HRCT was 81.25% and the specificity was 83.3%.

Conclusion: High-resolution computed tomography provides a surgical roadmap indicating the extent of involvement and bony structures, while DW-MRI imaging helps in differentiating cholesteatoma from CSOM. A combined preoperative approach using HRCT and DW-MRI imaging can aid in diagnosing cholesteatoma effectively.

Keywords: Ossicular erosion, Restricted diffusion, Scutum erosion

INTRODUCTION

Chronic suppurative otitis media is a chronic middle ear infection with or without discharge, often accompanied by a permanent perforation in the Tympanic Membrane (TM). Cholesteatoma is a benign lesion characterised by the abnormal accumulation of keratin-producing squamous epithelium and keratin fragments in the tympanic cavity and mastoid, causing local invasiveness and destruction of bony structures in the middle ear cavity [1].

The use of imaging methods, such as HRCT of the temporal bone, to differentiate cholesteatoma from other common middle ear inflammatory diseases remains controversial. Therefore, the diagnosis of cholesteatoma primarily relies on clinical presentation and otoscopic findings [2].

In HRCT, the evaluation of bony structure erosion, including the scutum, ossicular chain, lateral semicircular canal, fallopian canal and tegmen tympani/antri, can be performed more effectively. However, a major limitation of HRCT is its challenge in distinguishing cholesteatoma from other tissues like inflammatory tissue, polyps and exudate, especially when there is no air in the middle ear cavity and clear bone erosions are evident [3].

The MRI was previously utilised primarily for imaging inflammatory pathologies and suspected intracranial complications due to difficulties in visualising the anatomical landmarks of the temporal bone.

In conventional MRI sequences, cholesteatomas typically exhibit non specific signal intensities, appearing T1 hypointense/isointense and T2 hyperintense [2]. However, cholesteatomas demonstrate restricted diffusion because of their high keratin content [4]. Therefore, this limited-sequence MRI examination in addition to HRCT of the temporal bone may enhance the accurate diagnosis of this potentially hazardous yet treatable condition. In the present study, the aim was to determine the role of diffusion-weighted MRI in distinguishing granulation tissue from cholesteatoma, with histopathological findings serving as a reference standard.

MATERIALS AND METHODS

The present study was a hospital-based cross-sectional study conducted in the Department of Radiodiagnosis, Sri Manakula Vinayagar Medical College and Hospital (SMVMCH) in Puducherry, India, from November 2018 to April 2020. Institutional Ethical Committee approval (SMVMCH-ECO/AL/119/2018) was obtained. The sample size was determined based on the average total number of cases referred to the Department of Radiodiagnosis for preoperative assessment of CSOM and was fixed at 40 participants.

Inclusion criteria: All patients of any gender presenting with clinical features of CSOM such as chronic ear discharge and/or pain, referred to the Radiodiagnosis Department for preoperative assessment using HRCT were included.

Exclusion criteria: Patients with a history of previous operations for CSOM and cholesteatoma, patients with metallic implants or pacemakers and patients with claustrophobia or anxiety disorders were excluded from the study.

Study Procedure

After obtaining the patient's history, the patient underwent HRCT of the temporal bone and a Diffusion-weighted MRI sequence. HRCT temporal bone studies were conducted on a 16-slice CT scanner (Philips MX-16) using an axial volume scan with a section thickness of 0.67 mm, 120 kV reconstruction interval of 0.3 mm, and reconstruction algorithm of 360°. The rotation time was 0.4s, and an image matrix of 768×768 was used.

Subsequently, patients underwent a diffusion-weighted sequence MRI using a 1.5 Tesla Philips whole-body MR system with a standard imaging head coil. Axial non echo-planar single-shot turbo spin-echo diffusion-weighted imaging was conducted with the following parameters: 5/1.5 mm slice thickness, TE: 124 ms, TR: 1000 ms, FOV: 160 mm, diffusion factor: B 1000 s/mm^2. An acquisition time of 40s and a flip angle of 90 were utilised. The postprocessed Apparent Diffusion Coefficient (ADC) map was reconstructed. One week after the preoperative evaluation, surgery was performed. The findings were then compared postoperatively with histopathological reports.

STATISTICAL ANALYSIS

The data were entered into a Microsoft Excel sheet and analysed using SPSS software version 24.0. Ordinal/discontinuous variables were presented as frequencies and proportions, while discrete/continuous variables were presented as mean and standard deviation. The sensitivity, specificity, positive predictive value and negative predictive value of the diffusion sequence were compared with the gold standard histopathology report by constructing a 2×2 table.

RESULTS

Total of 40 patients were studied, of whom 27 (68%) were males and 13 (32%) were females, with a mean±SD age of 43±20.41 years. The age range of the study participants was 12-75 years [Table/Fig-1].

Variables	n (%)
Age (years) (Mean±SD) (Range)	43±20.41 (12-75)
Gender	
Male	27 (68)
Female	13 (32)

[Table/Fig-1]: Demographic distribution of patients (N=40).

The majority of the study participants exhibited unilateral involvement (33/40), with a higher incidence on the left side (23/40) compared to the right side (17/40).

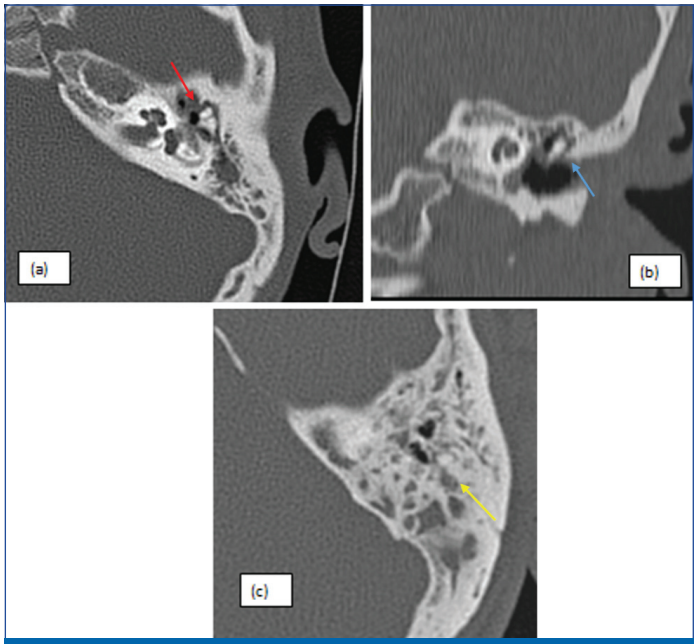
Participants presented with a combination of symptoms such as ear pain, pus discharge and conductive hearing loss. The most common clinical presentations were conductive hearing loss and pus discharge (20/40). Two patients with high fever and altered sensorium were diagnosed with brain abscesses based on imaging.

Using otoscopic findings, patients were categorised into safe (tubotympanic) and unsafe (atticoantral) types based on the type of TM perforation. The majority were classified as having the unsafe type, with 26 (65%) patients falling into this category [Table/Fig-2].

Parameters	n (%)
Laterality	
Unilateral	33 (82.5)
Bilateral	7 (17.5)
Lesion side	
Right	17 (42.5)
Left	23 (57.5)
Clinical presentation	
Otalgia	20 (50)
Ear discharge	20 (50)
Hearing loss	13 (32.5)
Fever and altered sensorium	2 (5)
Otoscopic findings	
Safe type	14 (35)
Unsafe type	26 (65)

[Table/Fig-2]: Clinical presentation of patients (N=40).

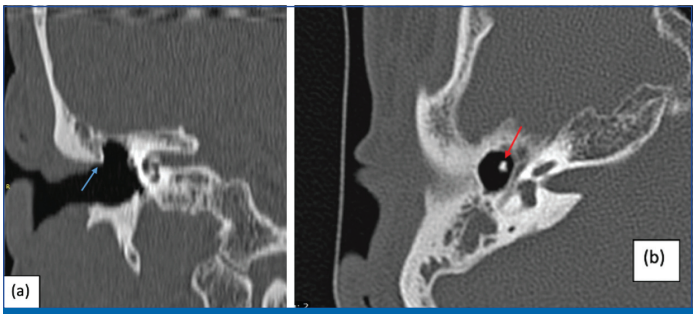
Preoperatively, HRCT of the temporal bone was performed, evaluating parameters such as the presence of a soft-tissue mass, erosion of the scutum and ear ossicles. In the present study involving 40 participants, all showed a soft-tissue density mass within the middle ear cavity [Table/Fig-3a,b,c]. Scutum erosion was observed in 20 (50%) patients and ossicular erosion was noted in 12 patients (30%) patients [Table/Fig-4a,b].



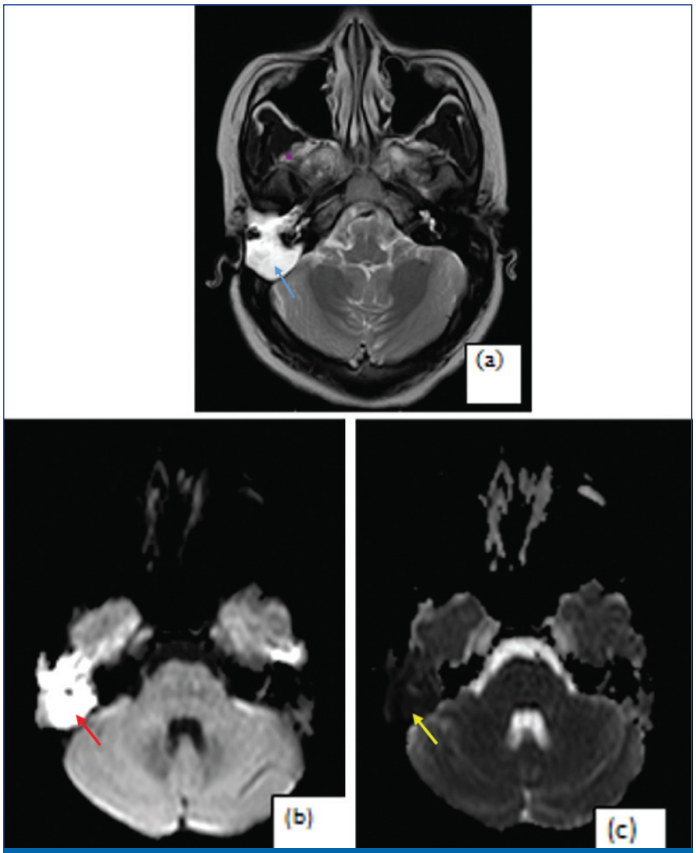
[Table/Fig-3]: Chronic Suppurative Otitis Media (CSOM). Axial HRCT temporal bone (a,c) image: showing soft tissue density lesion in the middle ear cavity with intact ice cream cone appearance (a) of incudomalleolar joint (red arrow) and (c) sclerosis of mastoid air cells (yellow arrow) - suggestive of mastoiditis. Coronal HRCT temporal bone (b) image: shows intact scutum and ossicle (blue arrow) with only soft tissue density lesion in the middle ear cavity.

Based on the presence of a soft-tissue mass, scutum erosion, ossicular erosion and the extent of the lesion, 17/40 (42.5%) participants were suspected to have cholesteatoma on HRCT. Subsequently, all study participants underwent diffusion-weighted sequence MRI, with 16 participants showing restriction [Table/Fig-5a,b,c].

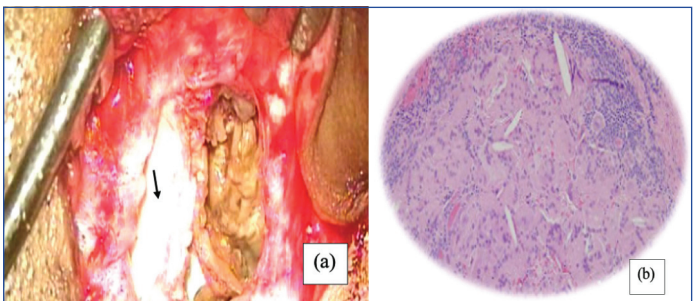
During intraoperative and postoperative follow-up, these 40 patients were monitored, and histopathology reports were evaluated. The 16 patients who exhibited restriction in diffusion imaging were confirmed to have cholesteatoma both intraoperatively and histopathologically [Table/Fig-6a,b].



[Table/Fig-4]: Cholesteatoma. Coronal reconstructed HRCT image (a) showing erosion of scutum (blue arrow); Axial HRCT temporal bone image (b) showing loss of ice cream cone appearance (red arrow) of incudomalleloar joint due to erosion of malleolus and incus.



[Table/Fig-5]: Cholesteatoma. Axial T2W image (a) shows hyperintense signal in the middle ear cavity (blue arrow); Axial DWI (b) and ADC map image (c) showing hyperintense signal in DWI (red arrow) with corresponding low signal in ADC image (yellow arrow) suggestive of restriction.



[Table/Fig-6]: Cholesteatoma. Intraoperative (a) and histopathology (b) image showing pearl like white keratinised tissue (black arrow) within the exposed middle ear cavity and also in postoperative histopathology (H&E stain, 40x) suggestive of cholesteatoma.

HRCT, when compared with DWI and gold standard histopathological findings, demonstrated 81.25% sensitivity, 83.3% specificity, 76.5% PPV and 87% NPV.

Comparing DW-MRI imaging findings with intraoperative and postoperative histopathological findings, the DWI sequence in MR imaging exhibited 100% sensitivity and specificity in differentiating cholesteatoma from CSOM preoperatively [Table/Fig-7-9].

HRCT	Histopathology		Total, n
	Cholesteatoma, n	Granulation tissue, n	
Cholesteatoma	13	4	17
CSOM	3	20	23
Total	16	24	40

[Table/Fig-7]: HRCT vs histopathology.

DWI	Histopathology		Total, n
	Cholesteatoma, n	Granulation tissue, n	
Diffusion restriction	16	0	16
Non restriction	0	24	24
Total	16	24	40

[Table/Fig-8]: DWI vs histopathology.

Imaging	Sensitivity	Specificity	PPV	NPV
HRCT	81.25%	83.3%	76.5%	87
DW-MRI	100%	100%	100%	100%

[Table/Fig-9]: Comparison data between HRCT and DW-MRI imaging.

DISCUSSION

The mean age of presentation was found to be in the middle-age group (35-44 years) in various studies [5-8]. Similarly, in the present study, the average age of presentation was around 43 years with a male predilection.

Preoperative HRCT of the temporal bone revealed a soft-tissue mass in all participants, with erosion of the scutum seen in 50% and ossicular erosion in 30% of patients. Sagar JN and Devasamudra RC reported that in HRCT, cholesteatoma appears as a non dependent soft-tissue density with bony erosions, showing a high degree of accuracy for middle ear ossicular erosion (96.8%), incus erosion (96.4%) and malleus erosion (100%) [5].

In another prospective study by Gomaa MA et al., where they correlated intraoperative findings with preoperative HRCT findings, scutum and lateral attic wall were the most commonly eroded bony structures in the middle ear wall (64.3%) and incus was the most commonly eroded ossicle (88.2%) in cholesteatoma seen on HRCT [9]. Similarly, in the present study, 20 patients had erosion of the scutum and 12 had ossicular erosion, all showing a soft-tissue mass.

A prospective study conducted by Abdelmaksoud AA et al., among 20 patients (9 males and 11 females) aged 15-35 years with a mean age of ±25 years, reported a sensitivity of 90.0%, specificity of 88.9%, and positive and negative predictive values of 90.9% and 88.9%, respectively, for diffusion-weighted imaging [10]. Kailasanathan N et al., concluded that DW-MRI is more accurate in diagnosing cholesteatoma compared to HRCT, with 100% sensitivity and NPV, 75% specificity and 97.3% PPV [11].

The superior rate of cholesteatoma detection by DWI was also observed in the present study and other studies as shown in [Table/Fig-10] [4,6-8,10,11]. Therefore, a combination of preoperative HRCT of the temporal bone and DW-MRI imaging is useful in the diagnosis of cholesteatoma.

Studies	Place and year of study	Sensitivity	Specificity	PPV	NPV
Abdelmaksoud AA et al., [10]	Egypt, 2019-20	90.9%	88.9%	90.9%	88.9%
Yiğiter AC et al., [6]	Turkey, 2010-13	88.4%	92.8%	92%	89.6%
Kailasanathan N et al., [11]	India, 2016	100%	75%	97.3%	100%
Dubrulle F et al., [7]	France, 2002-04	100%	91%	93%	100%
Aikele P et al., [8]	Germany, 2000-01	77%	100%	100%	75%

Naveen J et al., [4]	India 2018-19	91.6%	91.6%	95.6%	84.6%
Present study	India, 2018-20	100%	100%	100%	100%

[Table/Fig-10]: Comparison of Sensitivity, Specificity, Positive predictive value (PPV) and Negative predictive value (NPV) of DWI in the present study and other studies [4,6-8,10,11].

The DWI has the advantage of no radiation exposure, no contrast use and a short examination time. It can also differentiate scar tissue, granulation tissue, and inflammatory changes from cholesteatoma in patients with prior cholesteatoma resection, potentially avoiding the need for second-look surgery [2]. Newer DWI techniques like Multishot Echo-Planar Imaging (MS-EPI) and Readout-segmented Echo-planar (RESOLVE) DWI with thinner section acquisition and reduced susceptibility artifacts allow for the detection of small lesions. Additional techniques such as coloured image-fusion of DWI and anatomic sequences help better demonstrate findings to patients or clinicians [12-14].

Limitation(s)

The sample size was small in the present study. Previously operated cases were excluded from the study; therefore, the importance of the DWI sequence in the evaluation of recurrence/retained disease was not assessed. The findings cannot be generalised, as it was a single centre study.

CONCLUSION(S)

The HRCT of the temporal bone serves as the primary diagnostic imaging modality for the preoperative evaluation of middle ear pathologies such as cholesteatoma and CSOM; however, it is unable to differentiate between CSOM and cholesteatoma. The DWI sequence plays a significant role in distinguishing between cholesteatoma and CSOM, as cholesteatoma exhibits restricted diffusion. Therefore, the authors recommended a combined approach of HRCT and DW-MRI preoperatively for the evaluation of patients with CSOM and cholesteatoma.

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