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Role and utility of HRCT and MRI in detection and evaluation of cholesteatoma

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Abstract
Cholesteatoma is a common benign lesion of the middle ear characterised by accumulation of keratinous debris. It is associated with local bony erosions and hence serious intracranial and labyrinthine complications which prompts surgical intervention. Earlier, High resolution computed tomography (HRCT) was used in combination with clinical examination to arrive at a diagnosis. Computed tomography (CT) gives excellent definition of bony structures, but lacks sensitivity in differentiating between various causes of soft tissue densities. Magnetic resonance imaging (MRI) is more useful in evaluation of soft tissue details. We conducted this study with an aim of evaluating the role of diffusion weighted imaging in diagnosis of cholesteatoma and its utility to differentiate cholesteatoma from granulation/ inflammatory tissue. The study was conducted on forty patients between March 2018 and February 2019 who were clinically suspected of chronic suppurative otitis media with cholesteatoma. These patients were subjected to HRCT and Diffusion weighted MRI (DW-MRI) examination of temporal region and findings were correlated with intraoperative and histological features. Our study found that, HRCT had a sensitivity of 83.3% and specificity of 58.3% in detection of cholesteatoma, while MRI was found to accurately predict the presence of cholesteatoma in 91.6% of the cases evaluated. The sensitivity, specificity, positive predictive value and negative predictive value were 91.6%, 91.6%, 95.6% and 84.6%, respectively. Hence, we conclude that diffusion weighted magnetic resonance imaging is a useful technique for cholesteatoma imaging with high sensitivity and specificity. Combination of HRCT and MRI will be helpful to make an accurate diagnosis.

Keywords: Cholesteatoma, chronic otitis media, high resolution computed tomography, magnetic

1. Introduction

Cholesteatoma is a common inflammatory disorder of the middle ear, often described as "skin at wrong place". The term "Cholesteatoma" was coined by the German pathologist, Johannes Muller. It is a misnomer as the lesion is not a tumor and contains no fat [1]. They are rather enlarging collections of keratinous debris within a sack of stratified squamous epithelium trapped in the middle ear. They incite an inflammatory response which promotes osteoclastic activity that can erode the ossicles and bony walls of the middle ear cavity [1, 2].

Cholesteatomas can be congenital or acquired. Congenital cholesteatomas are very rare and occur due to persistence of embryonic epithelial rests in temporal bone. Various theories are postulated as pathogenic mechanisms for acquired cholesteatomas. Few common theories include migration of squamous epithelium through the defect in tympanic membrane; metaplasia of middle ear cuboidal epithelium; repeated infections and improper functioning of the eustachian tube causing negative pressure within the middle ear with subsequent retraction pocket formation; and post-surgical epidermal implantation [1].

They are commonly seen in third to fourth decade and females are more commonly affected than males [3]. Because it is associated with serious local and intracranial complications, surgery is the treatment of choice [4].

The diagnosis of this condition is by combination of clinical examination with cross sectional imaging. Radiological pre-operative assessment can be done with High resolution Computed tomography (HRCT) and Magnetic Resonance imaging (MRI). HRCT has excellent spatial resolution and helps to delineate key anatomical structures, predominantly the bony landmarks of the temporal bone.

However, HRCT cannot differentiate between fluid, cholesteatoma and other soft tissue (fibrosis or granulation tissue) [5, 6].
Use of MRI in inflammatory pathologies of the ear was limited due to the lack of clear visualization of the anatomical landmarks of the temporal bone on MRI sequences. MRI was only being used for imaging of suspected intracranial complications [7]. At conventional MRI sequences, cholesteatomas display non-specific signal intensities and appear T1 hypointense/isointense and T2 hyperintense to brain. These signal characteristics does not differentiate cholesteatoma from fluid and granulation tissue. Post-gadolinium studies may be helpful in such cases, where granulation tissue enhances and cholesteatoma does not [1]. However, diffusion weighted magnetic resonance imaging (DW-MRI) has been of immense value as described in literature. Cholesteatomas show restricted diffusion due to their high keratin content similar to the diffusion restriction seen in epidermoid cysts [4, 6]. Hence, this limited-sequence MRI examination along with HRCT of temporal bone may help in the accurate diagnosis of this potentially dangerous and treatable condition.
This study was undertaken to evaluate the role and utility of HRCT and DW-MRI in the diagnosis of cholesteatoma.

2. Materials and Methods

This is a prospective descriptive study carried out between March 2018 and February 2019 at Bangalore Medical College and Research Institute (BMCRI), Karnataka, India. Approval from the ethical committee of the institution was sorted. Written and informed consent was obtained from all the patients. Forty patients presenting to Department of Otorhinolaryngology, with clinical suspicion of chronic suppurative otitis media (CSOM) with cholesteatoma and referred to department of Radiodiagnosis for imaging, were included in the study. Patients with previous history of surgery for cholesteatoma and suspected recurrence were also included. All patients were subjected to HRCT of temporal bone and limited-sequence (DWI) MRI examination of temporal region. Cases with suspicion of intracranial complications underwent detailed MR evaluation without or with contrast. Imaging findings were compared and confirmed with intra operative findings and post-operative histological examination for the presence of cholesteatoma.
HRCT of the temporal bone was done on 128-slice CT scan machine (PHILIPS) with a pitch factor of 0.25, reconstruction slice thickness of 0.67 mm with reconstruction interval of 0.3 mm and reconstruction algorithm of 360°, rotation time of 0.4 s and an image matrix of 768 × 768. MRI examination was performed on a 1.5 Tesla Siemens Avanto Magnetom MR system. Axial Echoplanar DWI (EP-DWI) were obtained with following parameters: Repetition time (TR): 3100-3200ms; time to echo (TE): 90-100ms; field of view (FOV): 250x250mm; matrix: 256x256; B value: 1000s/mm^2. Subsequent Apparent diffusion co-efficient (ADC) images were derived.
HRCT and DW-MRI images were evaluated prior to surgery. Cholesteatomatous CSOM (C-CSOM) was diagnosed on HRCT by presence of non-dependent soft tissue with bony destruction such as blunting of scutum, erosions of bony walls of middle ear, ossicular erosions, labyrinthine involvement and facial canal/ intracranial extension. Cases of middle ear and mastoid opacification without bony erosions were labelled as Non-cholesteatomatous CSOM (NC-CSOM). On EP-DWI, primary or recurrent cholesteatomas were recorded as cholesteatoma present or absent based on diffusion restriction on DWI and ADC.
Data so collected was analyzed using SPSS 22 version software. For qualitative data, Chi-square test was used as test of significance. P value less than 0.05 will be taken as significant.

3. Results

On the basis of selection criteria, total of 40 cases were included in this study. All the patients underwent radiological pre-operative assessment with HRCT and DW-MRI of temporal region. Of this, four cases were lost to follow up due to refusal for surgery. Subsequently, 36 cases underwent mastoidectomy surgery.
Out of the 36 cases, 24 were diagnosed to be cholesteatoma post-operatively. This was confirmed by histopathological analysis which showed abundant squamous cells. While the rest 12 cases showed inflammatory tissue and were thought to be non-cholesteatomatous CSOM.
Cholesteatoma was most commonly seen in second to third decade (33.3%) and males were more commonly affected than females (55.5%).
Pre-operatively, based on imaging findings on HRCT and DW-MRI, diagnosis of cholestatomatous CSOM (Fig.1) was done in 25 and 23 cases respectively. While the remaining 11 in HRCT and 13 in MRI were diagnosed as non-cholesteatomatous CSOM (Fig. 2).
Results of HRCT and MRI are tabulated in the tables 1, 2, 3 & 4 below.

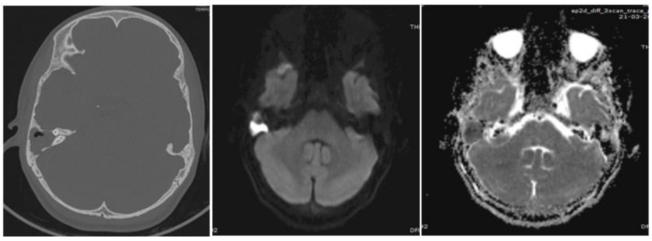
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Fig 1: A 26 year old male patient presented with pain and discharge from right ear. HRCT temporal (a) bone showed soft tissue attenuating content in right middle ear and mastoid with extensive erosions. Corresponding area shows diffusion restriction with high signal in DWI (b) and low signal in ADC (c) indicating cholesteatoma.

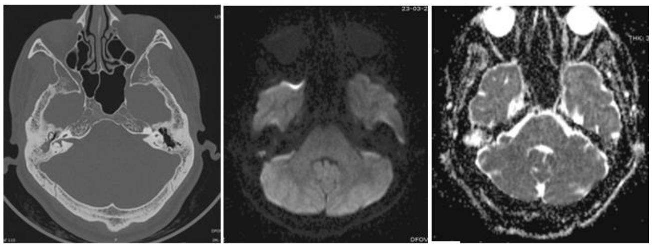
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Fig 2: A 39 year old male presented with ear pain, discharge and hearing loss on right side. HRCT temporal bone (a) showed soft tissue content in epitympanum and mastoid with erosions of scutum. Corresponding area does not show diffusion restriction with low signal on DWI (b) and high signal on ADC (c) indicating non cholesteatomatous CSOM.

Table 1: Cross-Tabulation of HRCT and Post-operative diagnosis

HRCT Diagnosis		Post-Operative diagnosis	
		Cholesteatoma	Non-Cholesteatomatous CSOM
Cholesteatoma	Count	20	5
	% of Total	80%	20%
Non-Cholesteatomatous CSOM	Count	4	7
	% of Total	36.3%	63.6%

*Not Significant P value- 0.144

Table 2: Cross-tabulation of MRI and Post-operative diagnosis

MRI Diagnosis		Post-Operative diagnosis	
		Cholesteatoma	Non-cholesteatomatous CSOM
Cholesteatoma	Count	22	1
	% of Total	95.6%	4.3%
Non-cholesteatomatous CSOM	Count	2	11
	% of Total	15.3%	84.6%

*Significant P value- 0.0001

Table 3: Comparison between results of HRCT and MRI

n=36	Cholesteatoma	Non- Cholesteatomatous CSOM	True positive	True negative	False positive	False negative
CT	25	11	20	7	5	4
MRI	23	13	22	11	1	2

Table 4: Comparison of diagnostic accuracy of HRCT and MRI

Variables	HRCT	MRI
Sensitivity	83.3%	91.6%
Specificity	58.3%	91.6%
Positive predictive value	80%	95.6%
Negative predictive value	63.6%	84.6%

4. Discussion

High resolution CT of the temporal bone has been the initial modality of choice for imaging of cholesteatoma. Soft tissue opacification of middle ear with destruction or erosion of bone is the hallmark of cholesteatoma [8]. HRCT demonstrates excellent bony anatomy of temporal bone, and hence better delineates bony erosions. Erosions of middle ear structures and its bony walls, mastoids, inner ear structures, facial nerve canal and other structures are better assessed [5, 8]. However, characterisation of soft tissue densities and differentiation of cholesteatoma from granulation tissue, fibrous tissue and mucoid secretions at CT is not possible. This also makes it difficult in post-operative cases in differentiating recurrent disease from simple granulation tissue. [9] Our study shows that HRCT had a sensitivity of 83.3% and specificity of 58.3% in detection of cholesteatomatous CSOM. This was comparable to studies by Thukral *et al*. [10] and Gomaa *et al*. [11] False negative cases could be attributed to presence of only soft tissue without bony destruction and inability to characterise the soft tissue at CT. False positive cases at CT can be attributed to mere bony deossification which can occur in non-cholesteatomatous CSOM being interpreted as destruction that occur in cholesteatoma.

MRI has been used in recent years to evaluate cholesteatoma and to look for post-surgical recurrence.[6] A study by Vaid *et al*. [6] compared ability of T1weighted (T1W), T2 weighted (T2W), DWI and post-contrast gadolinium sequences to evaluate for cholesteatoma. They found that both cholesteatoma and inflammatory tissue appeared hyperintense on T2W sequence and showed minimal enhancement on gadolinium studies. The sensitivity of routine MRI sequences for cholesteatoma detection was found to vary between 57 and 79 per cent, while its specificity was between 63 and 71 per cent [6]. Therefore, routine MRI alone was seen to be insufficient to assess cholesteatoma.

The use of Echo-Planar diffusion weighted MRI was initially described by Fitzek *et al*. [12]. On DWI, cholesteatoma show high signal intensity due to restricted diffusion while granulation and inflammatory tissue give a low signal intensity. This is based on the fact that diffusion MRI detects the Brownian motion of water molecules in a solvent [6]. Bound water molecules show restricted diffusion while, free water molecules show facilitated diffusion. Cholesteatoma and epidermoid cysts have bound water molecules and hence show diffusion restriction. In a study by Vaid *et al.*, comparing the features on DWI and routine sequences, they found DWI to have a sensitivity of 92.8%, specificity of 100%, positive predictive value of 100% and negative predictive value of 85% for detection of cholesteatoma [6]. This superior rate of cholesteatoma detection by DWI was also seen in our study and various studies conducted as shown in table 5.

Table 5: Comparison of Sensitivity, Specificity, Positive predictive value (PPV) and Negative predictive value (NPV) variables of our study and other studies

Studies	Sensitivity	Specificity	PPV	NPV
Our study	91.6%	91.6%	95.6%	84.6%
Vaid *et al*. [6]	92.8%	100%	100%	85%
Vercruysse *et al*. [17]	81%	100%	100%	40%
Foer *et al*. [16]	82.6%	87.2%	96%	56.5%
Evlice A *et al*. [13]	88%	93%	95%	82%

Studies by Evlice A *et al.*, Aikele *et al*. and Venail *et al*. showed that cholesteatoma less than 5mm in size can be missed by EP-DWI MR technique [13, 14, 15]. Vaid *et al*. Conducted study using non-ECHO planar (non-EPI) DWI sequence, which was found to have very high spatial resolution and could pick up very small cholesteatomas upto 2.5mm in size [6]. In a study by De Foer *et al*., performance of EPI and non-EPI DWI techniques were compared and found that non-EPI technique was found to be superior in detection of small cholesteatomas [16]. Other false negative cases in study by Evlice *et al*. was attributed to dry, hollow retraction pockets and air-bone artefacts at skull base [13]. Our study also found two false negative cases which could be attributed to the use of ECHO planar technique failing to detect small sized cholesteatomas. One false positive case in our study was attributed to susceptibility artefact due to air-bone interface. Other causes of false positive diagnosis in studies by Evlice *et al*. [13] and Venail *et al*. [15] were attributed respectively to tympanosclerosis and Silastic strip used in the previous surgery.

HRCT was ineffective in post-operative cases for detection of recurrent cholesteatoma. However, MRI was able to demonstrate restricted diffusion in these cases in our study which was confirmed at repeat surgery. This very well correlates with the previous studies in literature [18]. It could be stated that MR imaging guides the treating surgeon to decide for the second-look surgery in post-operative cases.

5. Conclusion

Cholesteatoma is a condition associated with dangerous complications without early diagnosis and treatment. Its management depends upon accurate diagnosis. HRCT depicts the bony involvement while MRI characterizes the soft tissue. Combined utilization of HRCT and MRI will be helpful for accurate diagnosis of primary, recurrent and residual cholesteatoma. Thus, pre-operative imaging lays down excellent surgical road map helping the surgeon for appropriate patient management.

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