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ROLE OF DIFFUSION WEIGHTED MAGNETIC RESONANCE IMAGING IN EVALUATION OF CHOLESTEATOMA

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Abstract

Objective

To evaluate the diagnostic performance of Diffusion-Weighted Magnetic Resonance Imaging (DWI-MRI) in the detection of cholesteatoma and assess its potential to replace second-look surgery.

Methods

This prospective observational study recruited 65 patients with suspected cholesteatoma and compared DWI-MRI findings with histopathological examination (considered the gold standard). HRCT temporal bone scans were also performed for comparison.

Results

- DWI-MRI demonstrated high sensitivity (94.23%) and specificity (100%) for cholesteatoma detection.
- DWI-MRI outperformed HRCT in both primary (93.8% vs. 87.5%) and recurrent/residual cholesteatoma cases (80% vs. 25.0%).
- Mean ADC values were significantly lower in cholesteatoma compared to granulation tissue and inflammatory tissue.

Discussion

DWI-MRI emerged as a valuable tool for cholesteatoma diagnosis due to its high sensitivity, specificity, and tissue characterization capabilities. It offers a non-invasive alternative to second-look surgery, potentially reducing healthcare costs and complications.

Limitations

- Smaller lesions may be missed with DWI-MRI.
- MRI is expensive and time-consuming compared to HRCT.

Conclusion

DWI-MRI is a reliable and accurate method for diagnosing cholesteatoma, potentially eliminating the need for second-look surgery in many cases. Future research can explore

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optimal DWI protocols for smaller lesion detection and establish specific ADC cut-off values for definitive diagnosis.

1. Introduction

Cholesteatoma, a non-neoplastic lesion affecting the middle ear cleft and other pneumatized regions of the temporal bone, presents a unique diagnostic challenge due to its potential to manifest in various anatomical sites, such as the middle ear cavity, mastoid air cells, external auditory canal, and petrous apex. Distinguished by its epithelial-lined cyst containing desquamated debris, cholesteatoma can be either congenital or acquired [1].

Accurate diagnosis is crucial for appropriate management, and while computed tomography (CT) has traditionally played a pivotal role, certain limitations persist [2]. Despite providing excellent spatial resolution and aiding in the identification of lesion location and patterns of bone erosion, CT imaging struggles to differentiate soft tissue densities in the middle ear or mastoid air cells, leading to challenges in distinguishing cholesteatoma from other entities like granulation tissue or mucoid secretion [3].

In this context, the utility of magnetic resonance imaging (MRI) gains prominence, particularly with the advent of diffusion-weighted imaging (DWI). While conventional MRI was initially focused on detecting intracranial complications of cholesteatoma, such as subdural or epidural empyema, cerebritis, venous sinus thrombosis, meningitis, or abscess, DWI emerges as a valuable tool for directly assessing cholesteatoma itself. This is attributed to the ability of DWI to discern tissues based on their diffusion characteristics, making it particularly adept at identifying cholesteatoma due to its high keratin content [4].

Given the challenges posed by postoperative cases or instances of atypical cholesteatoma, where traditional CT signs may not be applicable due to surgical alterations of bony landmarks, the role of DWI becomes even more crucial. This modality not only aids in accurate detection but also has the potential to obviate the need for 'second-look surgery,' thus significantly impacting patient management [5,6].

The objectives of this study are twofold: first, to evaluate the diagnostic performance of DWI in the context of cholesteatoma, and second, to establish a correlation between the imaging findings obtained through DWI and the gold standard of histopathological examination. This research aims to shed light on the evolving role of DWI in the assessment of cholesteatoma, offering insights that may reshape diagnostic paradigms and enhance clinical decision-making.

2. Materials and Methods

Study Design: This study is designed as a prospective observational study conducted at the Department of Radiodiagnosis, Bangalore Medical College and Research Institute, and its affiliated hospitals.

Inclusion Criteria: Patients with clinical and otoscopically suspected cholesteatoma. Patients who have undergone previous surgery (canal wall up) for middle ear cholesteatoma. Patients willing to provide informed consent.

Exclusion Criteria: General contraindications to MRI such as pacemakers, cochlear implants, metallic implants, or metallic foreign bodies. Claustrophobic patients. Patients unwilling to provide informed consent.

Methodology for Data Collection: Patients clinically suspected of cholesteatoma will be referred to the Department of Radiodiagnosis for imaging studies. Relevant clinical data, including ear pain, discharge, and duration of symptoms, will be collected using a standardized proforma. Informed consent will be obtained, and patients will be screened for contraindications to MRI.

Imaging Techniques: HRCT Temporal Bone: Conducted on a 128-slice CT machine (PHILIPS). Parameters: Pitch factor of 0.426, reconstruction slice thickness of 0.67 mm, rotation time of 0.5 s, and an image matrix of 768 × 768. DWI MRI: Performed using a 1.5 T MRI machine (SIEMENS MAGNETOM AVANTO). Parameters: TR: 2,250 ms; TE: 63 ms; FOV: 200 mm; b factor 0 and 800 mm2/s.

Statistical Analysis: SPSS version 20 will be used for statistical analysis. Descriptive statistics (mean, standard deviation, frequency, and proportions) will be calculated for quantitative and qualitative variables. Inferential statistics, including the chi-square test and diagnostic accuracy test, will assess the performance of DWI compared to histopathological examination. The level of significance is set at 5%.

Sample Size Estimation: Source of data: Patients presenting to the Department of Radiodiagnosis at Bangalore Medical College and Research Institute and its affiliated hospitals. Study period: November 2019 to May 2021. Sample size calculation based on a previous study by Sanjay Vaid et al. Proportion of patients with confirmed cholesteatoma (p) = 61.29% Absolute precision (d) = 20% of p = 12.26% Standard table value for 95% confidence interval (z) = 1.96 Sample size (n) = [(1.96)^2 * 61.29 * 38.71] / (12.26)^2 = 65 cases

3. Results

Age Distribution: In our study, the mean age of the subjects was approximately 30 years among the total 65 patients. The age distribution showed a diverse range, with the majority falling within the age groups of 11 to 40 years, encompassing adolescents and middle-aged individuals.

Gender Distribution: Males and females were equally affected by cholesteatoma, with 64.6% being males and 35.4% females among the 65 patients. No significant gender predilection was observed in the occurrence of cholesteatoma. However, in our study males were affected more than females.

Previous Surgery: Out of the total 65 patients, 13.8% had a history of previous surgery for middle ear cholesteatoma, while 86.2% were primary cholesteatoma cases. The study included both primary and recurrent cholesteatoma cases to assess the efficacy of DWI in their evaluation.

HRCT Findings: Among the patients, 76.9% showed positive bone erosions on HRCT suggestive of cholesteatoma, while 23.1% had soft tissue suspicious of cholesteatoma without bone erosions.

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Lesion Dimensions: The mean maximum dimension of the cholesteatoma lesions among the 65 patients was approximately 7.86 mm, with the smallest lesion measuring 2.0 mm and the largest measuring 16 mm.

DWI MRI Findings: Among the 65 patients who underwent DWI MRI, 84.6% of middle ear lesions showed diffusion restriction, indicating cholesteatoma. The remaining 15.4% were not restricting lesions.

MRI Classification: Based on DWI findings, middle ear lesions were classified into cholesteatoma (84.6%) and other inflammatory or granulation tissue (15.4%).

Histopathological Diagnosis: Out of the 65 patients, 13.8% did not have histopathological confirmation due to various reasons, such as patient refusal, loss to follow-up, or transfer. Among the 56 patients with histopathological diagnosis, 80% were confirmed to have cholesteatoma.

ADC Levels: The mean ADC value of cholesteatoma was found to be 741 x 10^-6 mm^2/s, while granulation tissue and inflammatory tissue showed higher ADC values of 2142 x 10^-6 mm^2/s and 1900 x 10^-6 mm^2/s, respectively.

Comparison Between DWI and HPE: The cross-tabulation revealed a significant correlation between preoperative DWI diagnosis and postoperative HPE diagnosis (p value = 0.00). DWI MRI showed a sensitivity of 94.23%, specificity of 100%, positive predictive value of 100%, and negative predictive value of 57.14%.

Impact of Previous Surgery on DWI Diagnosis: In patients with previous surgery, DWI-MRI showed an accuracy of 87.5%, with sensitivity, specificity, positive predictive value, and negative predictive value of 80%, 100%, 100%, and 75%, respectively. For primary cholesteatoma, DWI-MRI demonstrated a diagnostic accuracy of 95.83%, with sensitivity and specificity of 95.74% and 100%, respectively.

Comparison Between HRCT and HPE: Cross-tabulation between HRCT and HPE findings revealed that HRCT detected 87.5% of primary cholesteatoma cases accurately, whereas DWI MRI identified 93.8%. For recurrent/residual cholesteatoma, HRCT accuracy was 25.0%, while DWI MRI achieved an 80% accuracy.

These findings highlight the effectiveness of DWI MRI in diagnosing cholesteatoma, particularly in cases with a history of previous surgery, and its superiority over HRCT in providing tissue-specific diagnosis.

Table 1 - Demographic characteristics

Characteristic	Frequency	Percent
Age Groups (years)		
11 to 20	18	27.7
21 to 30	10	15.4
31 to 40	17	26.2
41 to 50	10	I 15.4
6 to 10	I 4	6.2
> 50	I 6	9.2
Gender	-	
Females	I 23	I 35.4

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Males	I 42	64.6
Previous Surgery		
No	I 56	86.2 I
Yes	9	13.8 I
HRCT Findings		
Bone erosions negative	15	23.1 I
Bone erosions positive	I 50	76.9 I
Mean Maximum Dimension (mm)		7.86 I
DWI Findings		
Not Restricting (NR)	10	15.4
Restricting (R)	I 55	84.6 I
MRI Classification I		
Cholesteatoma (C)	I 55	84.6 I
Granulation Tissue/Inflammation (GT/I) I	10	15.4 I
HPE Diagnosis		
Cholesteatoma (C)	52	80.0 I
Granulation Tissue (GT)	3	4.6 I
Inflammation (I)	1	1.5 I
Lost to Follow Up (LFU)	19 I	13.8 I

Table 2 - Diagnostic Performance

Diagnostic Performance	Value	95% CI
Sensitivity (DWI vs. HPE)	94.23% I	84.05% to 98.79%
Specificity (DWI vs. HPE)	100% I	39.76% to 100%
Positive Predictive Value (DWI vs. HPE)	100% I	
Negative Predictive Value (DWI vs. HPE) I	57.14% I	.77% to 80%
Accuracy (DWI vs. HPE) I	94.64% I	85.13% to 98.88%

Table 3: Cross-tabulation of DWI and HPE (based on previous surgery)

Previous surgery	DWI		HPE		Total
			Absent	Present	
No	Absent	Count	1	2	3
		%	2.1%	4.2%	6.3%
	Present	Count	0	45	45
		%	0.0%	93.8%	93.8%
	Total	Count	1	47	48
		%	2.1%	97.9%	100.0%

Yes	Absent	Count	3	1	4
		%	37.5%	12.5%	50.0%
	Present	Count	0	4	4
		%	0.0%	50.0%	50.0%
	Total	Count	3	5	8
		%	37.5%	62.5%	100.0%

	Previous surgery			
	No		**Yes**	
Statistic	**Value**	**95% CI**	**Value**	**95% CI**
Sensitivity	95.74%	85.46% to 99.48%	80%	28.36% to 99.49%
Specificity	100%	2.5% to 100%	100%	29.24% to 100%
Positive Likelihood ratio	-	-	-	-
Negative Likelihood Ratio	0.04	0.01 to 0.17	0.2	0.03 to 1.15
Positive Predictive Value (PPV)	100%	-	100%	-
Negative Predictive Value (NPV)	33.33%	11.41% to 65.99%	75%	34.20% to 94.54%
Accuracy	95.83%	85.75% to 99.49%	87.5%	47.35% to 99.68%

Table 4: Cross-tabulation of HRCT and HPE (based on previous surgery)

PREVIOUS SURGERY	**HRCT**		**HPE**			**Total**
			C	**GT**	**I**	
No	S	Count	5		1	6
		%	10.4%		2.1%	12.5%
	S+E	Count	42		0	42
		%	87.5%		0.0%	87.5%
	Total	Count	47		1	48
		%	97.9%		2.1%	100.0%
Yes	S	Count	3	3		6
		%	37.5%	37.5%		75.0%
	S+E	Count	2	0		2
		%	25.0%	0.0%		25.0%
	Total	Count	5	3		8
		%	62.5%	37.5%		100.0%

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4. Discussion

This prospective observational study, conducted from November 2019 to May 2021, centered on evaluating the diagnostic prowess of Diffusion-Weighted Imaging Magnetic Resonance Imaging (DWI-MRI) in cases of cholesteatoma. The study, based in hospitals affiliated with Bangalore Medical College and Research Institute, enrolled 65 patients suspected of cholesteatoma, all of whom underwent DWI-MRI and High-Resolution Computed Tomography (HRCT) temporal bone scans. Postoperative histopathological examinations confirmed the diagnosis in 56 out of the 65 cases.
The study reported a mean patient age of 30 years, aligning with similar studies by Vaid et al.[7] and A Evlice et al.[8] Males were more commonly affected (64.6%), consistent with gender distribution trends observed in the study by Khemani S et al.1. HRCT, employed for its ability to identify middle ear soft tissue and ossicular chain erosion, faced limitations in distinguishing cholesteatoma from granulation tissue. In contrast, DWI-MRI, specifically utilizing the echo-planar DW sequence, demonstrated robust diagnostic accuracy with a sensitivity of 94.23% and specificity of 100%.
Comparisons with existing literature showcased a parallel age distribution and gender ratio. Notably, the study's DWI-MRI sensitivity and specificity surpassed or equaled those reported in previous research, underscoring its effectiveness across primary and recurrent/residual cholesteatoma cases.
The study delved into the measurement of mean Apparent Diffusion Coefficient (ADC) values for cholesteatoma, granulation tissue, and inflammatory tissue. The obtained ADC values closely mirrored those reported in studies by Ravi K Lingam et al.[9] and Camilla Russo et al.[10], suggesting a consistent pattern across different patient cohorts.
In primary cholesteatoma cases, DWI-MRI outperformed HRCT, detecting 93.8% of cases compared to HRCT's 87.5%. Even in recurrent/residual cases, where HRCT accuracy faltered at 25.0%, DWI-MRI maintained superior performance with an 80% detection rate. These findings reiterated the diagnostic edge of DWI-MRI over HRCT in cholesteatoma cases.
Acknowledging study limitations, such as cases lost to follow-up during the COVID-19 pandemic, the discussion emphasized the impact of lesion size on sensitivity. Notably, smaller lesions posed challenges for detection using DWI-MRI.
The study provided a comprehensive discussion by comparing various imaging modalities, including studies leveraging echo-planar diffusion-weighted MRI and non-echo-planar techniques. Sensitivity variations across studies were attributed to differences in imaging protocols. The use of HRCT temporal bone for the evaluation of cholesteatoma has drastically improved the outcome in the management. Although HRCT provides an excellent spatial resolution and detects bone erosions, it cannot accurately differentiate soft tissue content into cholesteatoma or granulation tissue/ Inflammation. Diffusion-weighted imaging can give a tissue-specific diagnosis due to the high keratin content of cholesteatomas. Newer advances allow detection of smaller lesions and may be sufficient to replace second-look surgery in patients with prior cholesteatoma resection. [11]
Residual/ recurrent cholesteatoma is one of the most common complications after surgery. The decision regarding the second look surgery depends on the accurate diagnosis of the

cholesteatoma preoperatively. DWI MRI can be used as a screening modality to check for residual/ recurrent cholesteatoma and provide a non-invasive tissue-specific diagnosis.
There are many disadvantages to second-look operations, including higher costs, a greater risk of complications and the need for a second anaesthetic. Therefore, it would be beneficial if non-invasive pre-operative imaging could detect residual or recurrent cholesteatoma, in order to prevent unnecessary second-look surgery in patients without cholesteatoma.
A more appropriate approach for patients with smaller lesions maybe follow up with repeated Echoplanar diffusion-weighted MRI, rather than second-look surgery, as cholesteatomas smaller than 5 mm have little effect on the short-term prognosis.
Specific ADC cut off values are also being studied for accurate diagnosis of cholesteatoma.
DWI-MRI is superior to HRCT temporal bone in accurate diagnosis of Cholesteatoma.
Drawbacks of our study: MRI can be time-consuming, costly and warrants the patient to be still. Paediatric patients require sedation. Very small postoperative recurrent/residual cholesteatomas can be missed as we have used Echo planar diffusion-weighted imaging in our study. However, Non-echo-planar imaging modalities have promising results.

5. Conclusion

In conclusion, Diffusion weighted imaging is a valuable technique for the detection of primary and recurrent acquired cholesteatoma with high sensitivity and specificity. DWI MRI modality can be used instead of the ‘second-look’ surgery, with high sensitivity and specificity. Early detection avoids unnecessary complications associated with the second look surgery. HRCT temporal bone used in conjuction with DWI MRI can be a very good tool to diagnose Cholesteatoma as MRI gives a tissue specific diagnosis. Cholesteatomas smaller than 5 mm have little effect on the short-term prognosis, small cholesteatomas which are missed on the initial DWI can be re-evaluated on repeat scans.

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