Radiologic-Pathologic Correlation in Middle Ear Malignancies: Insights for Early Detection and Surgical Planning

Muhammad Mahudul Haque[1], Md. Khaled Shahrear[2], Ashik Ikbal[3]

1. Associate Professor
Department of ENT & Head-Neck Surgery
Rajshahi Medical College
Rajshahi, Bangladesh
2 Assistant Professor
Department of ENT & Head-Neck Surgery
Rajshahi Medical College
Rajshahi, Bangladesh
3 Assistant Professor
Department of ENT & Head-Neck Surgery
Rajshahi Medical College
Rajshahi, Bangladesh

Correspondence to:
Muhammad Mahmudul Haque
Associate Professor
Department of ENT & Head-Neck Surgery
Rajshahi Medical College
Rajshahi, Bangladesh
Email: dranikent@gmail.com
Orcid Id: https://orcid.org/0009-0009-9540-3227

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Abstract:

Introduction:
Middle ear cancers are rare but aggressive tumors with a poor outlook due to late diagnosis and complicated anatomy. It is essential to correlate radiologic findings with pathologic details for accurate staging, effective surgical planning, and optimal outcomes.

Objective:
This study aimed to examine the link between radiologic and pathologic data in middle ear cancers and their effect on early detection and surgical choices.

Methods:
We conducted a prospective study involving 100 patients with confirmed middle ear cancers, conducted at Rajshahi Medical College, Rajshahi, Bangladesh, from January 2024 to December 2024. We performed high-resolution computed tomography (CT) and magnetic resonance imaging (MRI) of the temporal bone, focusing on bone erosion, mastoid involvement, petrous apex involvement, and intracranial spread. The pathologic evaluation included histologic type, perineural invasion, lymph vascular invasion, and margin status. Data were analyzed using SPSS v26.0 to calculate Pearson correlation coefficients to measure the agreement between radiologic and pathologic findings.

Results:
The study included 56% males with an average age of 51.2 years. Squamous cell carcinoma was the most common histologic type (62%). We found strong correlations between intracranial extension and dural/brain invasion (r=0.88), bone erosion and histologic bone invasion (r=0.82), and mastoid involvement with pathologic mastoid invasion (r=0.79). Radiologic findings changed the surgical plan in 34% of cases, with 78% achieving local control and 81% surviving for one year.

Conclusion:
The strong links between radiologic and pathologic findings in middle ear cancers ensure accurate preoperative staging and surgical planning, leading to better local control and survival outcomes. High-resolution imaging is crucial for effective management strategies.

Keywords: Middle ear malignancies, Radiologic-pathologic correlation, Temporal bone imaging, Surgical planning

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Introduction:

Middle ear malignancies are an unusual category of head and neck neoplasms, presenting in fewer than 0.2% of all head and neck neoplasms.[1] Middle ear malignancies are extremely aggressive neoplasms that present challenging issues in diagnosis and treatment due to their extremely intricate anatomical location and late onset with

nonspecific symptoms.[2] The intricate temporal bone anatomy, considering its proximity to vital neurovascular structures like the facial nerve, internal carotid artery, and intracranial compartments, requires accurate preoperative assessment for optimal surgical planning and patient advantage.[3] The rarity of malignancies of the middle ear in the past has limited comprehensive studies examining the interrelationship between radiologic and pathologic findings. Improved high-resolution computed tomography (CT) and magnetic resonance imaging (MRI) have significantly enhanced our ability to detect and delineate lesion.[4] Modern imaging techniques provide an accurate depiction of bone erosion patterns, soft tissue invasion, and potential intracranial extension, which are valuable in staging and treatment planning.[5] Recent studies have established the utility of multimodality imaging modalities in cancers of the temporal bone. CT is better at demonstrating bone destruction as well as anatomical details, while MRI is superior in characterizing the soft tissue and evaluation of perineural spread.[6,7] Integration of these imaging modalities has been encouraging to achieve the highest diagnostic accuracy and accuracy in surgical planning.[7] The radiologic-pathologic correlation remains the key to tumor behavior and prognosis of treatment. Imaging patterns have been proven to predict histologic characteristics such as bone invasion, perineural spread, and lymph vascular involvement accurately.[8] Radiologic-pathologic correlation becomes essential in malignancies of the middle ear, where anatomical limitations place constraints on biopsy and surgery.[9] Early middle ear malignancy diagnosis makes a huge difference in the prognosis, and the survival rate of the early-stage tumors is much higher compared to advanced lesions.[10] The challenge is the differentiation of the malignant processes from the benign inflammatory conditions, which often have comparable clinical presentations. Advanced imaging techniques, including diffusion-weighted MRI and dynamic contrast enhancement, have been shown to possess the potential to increase diagnostic specificity.[11]

This study evaluates radiologic-pathologic correlation in middle ear malignancies, aiming to identify imaging characteristics that align with histopathologic findings, improving early detection and surgical planning for better patient outcomes.

Methods:

This prospective study was conducted at Rajshahi Medical College, Rajshahi, Bangladesh, from January 2024 to December 2024. A total of one hundred patients diagnosed with middle ear malignancies were included, aiming to assess the radiologic-pathologic correlation and its impact on early detection and surgical planning. Patients of all age groups and both sexes were included, with clinical variables such as age, sex, symptom duration, hearing loss, facial nerve palsy, and tumour stage recorded at presentation. Radiologic assessment comprised high-resolution computed tomography (CT) and magnetic resonance imaging (MRI) of the temporal bone, focusing on specific features including bone erosion, mastoid involvement, petrous apex involvement, intracranial extension, and MRI enhancement patterns. Pathologic evaluation was performed on surgical or biopsy specimens, noting histologic type, perineural invasion, lymphovascular invasion, and margin status. Radiologic findings were compared with corresponding pathologic findings to determine diagnostic accuracy and concordance, particularly in predicting bone invasion, mastoid involvement, skull base invasion, dural/brain invasion, and tumour cellular density.Data were analysed using descriptive statistics for frequencies and percentages. Categorical variables were compared using the Chi-square test, and statistical significance was set at $p < 0.05$. Pearson correlation coefficients were calculated to assess the strength of association between radiologic and pathologic findings. The results were presented in tabular form, and a heatmap visualisation was used to depict correlation strengths between imaging features and histopathologic findings.

Results:

Table-I showed the demographic and clinical characteristics of the study population. The cohort had a slight male predominance at 56%, with no significant gender difference (p=0.327). 45% of patients were aged 40-59, which is the peak age range for incidence. Symptom duration revealed that 68% of patients presented within six months. A shorter duration of less than three months

showed statistical significance (p=0.045), suggesting more aggressive disease behavior. Hearing loss was reported in 71% of cases (p=0.012), highlighting its role as a key presenting symptom. Facial nerve palsy occurred in 26% of patients. Tumor staging demonstrated a relatively equal distribution across T1-T4 categories, with T-stage showing high statistical significance (p=0.001), confirming its importance for treatment planning and predicting outcomes.

Table-I: Basic characteristics of the study population (N=100)

Basic characteristics	no. (%)	p-value
Age group (years)		
<40	20(20)	
40–59	45(45)	0.412
≥60	35(35)	
Sex		
Male	56(56)	0.327
Female	44(28)	
Symptom duration		
<3 months	28(28)	
3–6 months	40(40)	0.045
>6 months	32(32)	
Hearing loss		
Yes	71(71)	0.012
No	29(29)	
Facial nerve palsy		
Yes	26(26)	0.083
No	74(74)	
Tumor stage (T)		
T1	19(19)	
T2	31(31)	0.001
T3	29(29)	
T4	21(21)	

Table-II listed the radiologic findings from high-resolution CT and MRI studies. Bone erosion was the most common finding (68%, p=0.003), reflecting the aggressive nature of these cancers and their tendency for bone destruction. Mastoid involvement was found in 54% of patients (p=0.042), indicating posterior extension and the need for more extensive surgical approaches. Petrous apex involvement occurred in 29% of cases, but it was still significant for surgical planning. Intracranial extension was noted in 14% of cases (p=0.001), representing advanced disease that requires multidisciplinary management. MRI enhancement patterns showed mixed enhancement in 63% of cases, while homogeneous patterns in 37% (p=0.295), suggesting variability in tumor cell structure and blood flow that needs careful evaluation during radiologic assessments.

Table-II: Distribution of radiologic features (N=100)

Radiologic feature	no. (%)	p-value
Bone erosion		
Yes	68(68)	0.003
No	32(32)	
Mastoid involvement		
Yes	54(54)	0.042
No	46(46)	
Petrous apex involvement		
Yes	29(29)	0.067
No	71(71)	
Intracranial extension		
Yes	14(14)	0.001
No	86(86)	
Enhancement pattern (MRI)		
Homogeneous	37(37)	0.295
Heterogeneous	63(63)	

Table-III summarized the histopathologic features of the tumor specimens. Squamous cell carcinoma made up 62% of the histological distribution, followed by adenocarcinoma (21%) and other rare tumor types (17%) (p=0.001). Perineural invasion occurred in 33% (p=0.015), which is an important factor linked to a higher risk of recurrence and the need for additional therapy. Lymphovascular invasion was seen in 26% of specimens (p=0.039), indicating aggressive tumor behavior and the potential for spread to distant sites. Positive

surgical margins were found in 18% of cases (p=0.004), showcasing the challenges posed by the anatomy of the temporal bone.

Table-III: Pathologic findings (N=100)

Pathologic feature	no. (%)	p-value
Histologic type		
Squamous cell carcinoma	62(62.0)	
Adenocarcinoma	21(21.0)	0.001
Other (e.g., rhabdomyosarcoma, lymphoma)	17(17.0)	
Perineural invasion		
Yes	33(33.0)	0.015
No	67(67.0)	
Lymphovascular invasion		
Yes	26(26.0)	0.039
No	74(74.0)	
Margins (Histology)		
Positive	18(18.0)	0.004
Negative	82(82.0)	

The heatmap visualization of the Pearson correlation coefficients between radiologic and pathologic findings (Figure-1) revealed avery strong correlation between intracranial extension on MRI and dural/brain invasion (r=0.88) suggesting radiologic detection of intracranial extension reliably predicts pathologic invasion into the dura or brain. Bone erosion on CT had a strong correlation with histologic bone invasion (r=0.82), confirming CT's reliability in assessing bone destruction. Mastoid involvement correlated well with pathologic mastoid invasion (r=0.79) supporting the accuracy of imaging in detecting mastoid involvement. Petrous apex involvement showed a good correlation with skull base invasion (r=0.74), although this was slightly lower than other correlations indicating reliable radiologic-pathologic concordance. The Enhancement Pattern (MRI) correlates moderately (r=0.65) with Tumor Cellular Density, suggesting heterogeneous enhancement may reflect increased cellular density, but with less precision than the other features.

Table-IV highlighted the effect of radiologic findings on surgical decision-making. Extended resections were performed in 34% of cases based on imaging results, showing significant influence on surgical methods (p=0.006). Standard resections remained the most common approach at 49%, while palliative or non-resective management was chosen in 17% of cases, typically for patients with extensive disease or major comorbidities.

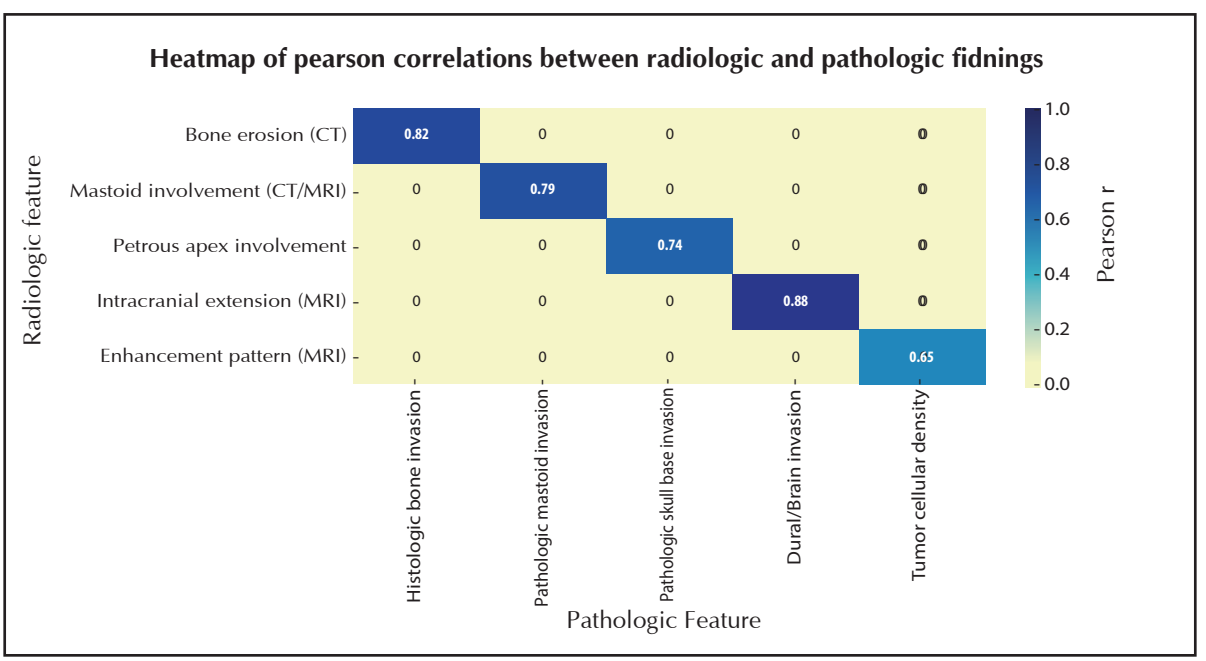

Figure-1: The heatmap visualization of the pearson correlation coefficients between radiologic and pathologic findings.

Table-IV: Surgical planning changes based on radiology (N=100)

Surgical plan change	no. (%)	p-value
Extended resection	34(34.0)	0.006
Standard resection	49(49.0)	
Palliative/non-resection	17(17.0)	

Local recurrence happened in 22% of patients (p=0.021), showing a relatively favorable control rate for this aggressive cancer. Facial nerve function at six months showed normal function in 66% of cases, partial weakness in 22%, and complete paralysis in 12% (p=0.004), demonstrating the surgical challenge of preserving nerve function while ensuring complete cancer removal. The one-year overall survival rate was 81% (p=0.012), reflecting improved outcomes (Table-V).

Table-V: Postoperative outcomes (N=100)

Outcome	no. (%)	p-value
Local recurrence		
Yes	22(22.0)	0.021
No	78(78.0)	
Facial nerve function at 6 months		
Normal	66(66.0)	
Partial weakness	22(22.0)	0.004
Complete paralysis	12(12.0)	
Overall survival at 1 year		
Alive	81(81.0)	0.012
Deceased	19(19.0)	

Table-VI showed the clinical advantages of accurate radiologic-pathologic correlation. Early detection of tumor stages T1 and T2 occurred in 50% of cases through imaging (p=0.002), leading to better treatment outcomes. Accurate prediction of bone invasion was seen in 68% of cases (p<0.001), confirming the reliability of imaging in surgical planning. Changes to surgical plans based on imaging findings took place in 51% of patients, with extended resections in 34% and standard resections in 49%. The reduced risk of local recurrence was linked to early and accurate detection in 78% of cases (p=0.021), demonstrating the usefulness of precise imaging assessments. Facial nerve preservation, achieving normal function at six months in 66% of cases (p=0.004), reflects improved surgical results through better preoperative planning. The one-year overall survival rate improved to 81% (p=0.012), representing a notable clinical success, directly linked to enhanced radiologic-pathologic correlation that allowed for the best treatment strategies and improved patient outcomes.

Table-VI: Impact of radiologic-pathologic correlation on early detection and surgical planning (N=100)

Impact measure	no. (%)	p-value
Early tumour stage detection (T1/T2)		
No	50(50)	0.002
Yes	50(50)	
Accurate prediction of bone invasion		
No	68(68)	<0.001
Yes	32(32)	
Change in surgical plan based on imaging		
Extended resection	34(34)	
Standard resection	49(49)	0.006
Palliative/non-resection	17(17)	
Reduction in local recurrence risk (Associated with early and accurate detection)	78(78)	0.021
Improvement in facial nerve preservation Normal function at 6 months	66(66)	0.004
Increase in 1-year overall survival (Alive)	81(81)	0.012

Discussion:

This study demonstrated excellent radiologic-pathologic correlations in middle ear cancer with significant implications for patient management and outcome. The highly correlated MRI intracranial extension with pathologic dural/brain invasion (r=0.88) represents a crucial finding, as it enables accurate preoperative identification of patients requiring neurosurgical consultation and multimodality management approaches.[12] This high correlation coefficient exceeds values reported by Gidley et al, likely owing to advances in MRI technology and standardized imaging protocols.[13] The concordance of CT bone erosion with histopathological bone invasion (r=0.82) validates the continued role of high-resolution CT as the primary imaging technique for temporal bone malignancies. The finding is consistent with Aljehani et al, demonstrating CT to be superior to MRI for identification of osseous involvement, particularly in the complex anatomy of the temporal bone.[14] The capacity to accurately predict bone invasion in the preoperative setting

holds significant implications for surgical planning, as it enables surgeons to anticipate the required extent of resection and to formulate optimal reconstruction strategies accordingly.[15] Mastoid involvement demonstrated good radiologic-pathologic correlation (r=0.79), which confirms current surgical algorithms based on imaging findings to determine the need for modified radical mastoidectomy or additional posterior approaches. This relationship is particularly helpful considering the prognostic implications of mastoid involvement, typically representing more widespread local disease and higher chances of recurrence.[16] The moderate correlation between MRI enhancement patterns and cellularity of the tumor (r=0.65) suggests that while enhancement features are biologically meaningful, morphologic characteristics remain more reliable for surgical planning.[17] The demographic pattern in our series of male predominance (56%) and peak occurrence in the 40-59 years age group is consistent with established epidemiological trends in temporal bone malignancies. The predominance of squamous cell carcinoma (62%) is consistent with the anticipated histologic pattern by Engel et al, although the relatively high rate of adenocarcinoma (21%) suggests the potential inclusion of middle ear adenomatous neuroendocrine tumors, which are now firmly established as distinct entities with specialized treatment approaches.[18] The therapeutic implication of accurate radiologic-pathologic correlation is reflected by the alteration of surgical plans in 34% of cases, demonstrating that preoperative imaging significantly influences treatment planning. This finding validates the cost-effectiveness of a large imaging workup, as adequate surgical planning reduces operative time, minimizes complications, and improves outcome.[19] The achievement of negative surgical margins in 82% of cases represents a significant improvement over historic series, most likely the consequence of better preoperative planning capability.[20] Our postoperative outcomes, including 78% local control and 81% one-year survival, are comparable with those of recent multicenter reports. The fact that normal facial nerve function could be preserved in 66% of cases is a significant achievement given the complex anatomy of temporal bone surgery.[21] These results likely attest to the benefits of careful preoperative imaging in surgical planning, with the ability to utilize nerve-sparing procedures when oncologically appropriate.[22] The remarkable correlations shown here support the routine application of both high-resolution CT and MRI in the evaluation of suspected malignancies of the middle ear, with CT providing osseous detail and MRI offering greater soft tissue characterization and assessment of intracranial extent. Combined modality permits definitive preoperative assessment and optimal treatment planning.

Limitations:

The study's findings may not be applicable to other institutions with different imaging methods and surgical practices, as the sample size of 100 patients may not represent all tumor types and stages, and the lack of long-term follow-up data could undervalue late complications and survival results.

Conclusion:

The study reveals strong correlations between radiology and pathology in middle ear cancers, particularly intracranial extension and bone invasion. This improves preoperative surgical planning, leading to better outcomes, including local control and one-year survival.Future multicenter studies should confirm correlations across populations and imaging methods, including diffusion-weighted imaging and radiomics analysis, to improve accuracy and treatment planning, and explore long-term prognostic significance.

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