

Role of Diffusion-Weighted MRI in Differentiating Benign and Malignant Head and Neck Lesions

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How to citation this article: Rajan Bhargava, Shikhar Saxena, Rohini Srivastava, “Role of Diffusion-Weighted MRI in Differentiating Benign and Malignant Head and Neck Lesions”, IJMACR– October– 2026, Volume – 9, Issue – 5, P. No. 248 – 262.

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Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Background: Differentiating benign from malignant head and neck lesions using conventional imaging may be difficult because several inflammatory, benign neoplastic, and malignant lesions demonstrate overlapping morphological and enhancement characteristics. Diffusion-weighted magnetic resonance imaging provides functional information regarding water-molecule mobility, while the apparent diffusion coefficient offers a quantitative estimate of tissue diffusivity. Malignant lesions generally demonstrate greater cellularity and lower apparent diffusion coefficient values than benign lesions, although substantial overlap may occur.

Objectives: To evaluate the role of diffusion-weighted magnetic resonance imaging and apparent diffusion coefficient measurements in differentiating benign and malignant head and neck lesions, using histopathological examination as the reference standard.

Materials and Methods: This prospective diagnostic-accuracy study was conducted in the Department of Otorhinolaryngology, Naraina Medical College and Research Centre, from April 2025 to March 2026. The minimum sample size was calculated as 80 patients using an anticipated specificity of 80%, absolute precision of 14%, a non-malignant lesion prevalence of 40%, and a 95% confidence level. After allowing for approximately 10% incomplete investigations or nondiagnostic tissue samples, the recruitment target was

fixed at 90 patients. Consecutive patients with clinically or radiologically detected head and neck lesions who underwent conventional MRI, diffusion-weighted imaging, apparent diffusion coefficient mapping, and tissue diagnosis were included. Mean apparent diffusion coefficient values were calculated from solid viable portions of each lesion. Receiver operating characteristic analysis was used to determine the optimal cutoff for differentiating benign from malignant lesions.

Results: Of 90 enrolled patients, 86 had complete MRI and histopathological data. Histopathology demonstrated 50 malignant and 36 benign lesions. The mean apparent diffusion coefficient was significantly lower in malignant lesions than in benign lesions- $0.91 \pm 0.20 \times 10^{-3} \text{ mm}^2/\text{s}$ versus $1.47 \pm 0.32 \times 10^{-3} \text{ mm}^2/\text{s}$, respectively ($p < 0.001$). An apparent diffusion coefficient cutoff of $1.15 \times 10^{-3} \text{ mm}^2/\text{s}$ provided a sensitivity of 90.0%, specificity of 83.3%, positive predictive value of 88.2%, negative predictive value of 85.7%, and diagnostic accuracy of 87.2%. The area under the receiver operating characteristic curve was 0.91. Lymphomas demonstrated the lowest mean apparent diffusion coefficient, followed by squamous cell carcinomas. Abscesses occasionally showed marked diffusion restriction and represented an important source of false-positive interpretation.

Conclusion: Diffusion-weighted MRI and apparent diffusion coefficient measurement are valuable adjuncts to conventional MRI for differentiating benign and malignant head and neck lesions. Malignant lesions generally demonstrate significantly lower apparent diffusion coefficient values. However, apparent diffusion coefficient thresholds should not be interpreted in isolation because overlap occurs among lesion types, particularly with lymphoma, abscesses, highly cellular

benign tumours, and necrotic malignancies. Histopathological examination remains essential for definitive diagnosis.

Keywords: Diffusion-Weighted Imaging, Apparent Diffusion Coefficient, Head and Neck Lesion, Malignancy, Magnetic Resonance Imaging, Diagnostic Accuracy

Introduction

Head and neck lesions comprise a heterogeneous group of inflammatory, congenital, benign neoplastic, and malignant conditions arising from the upper aerodigestive tract, salivary glands, thyroid region, cervical lymph nodes, sinonasal cavities, skull base, and surrounding soft tissues. Accurate characterization is important because management ranges from conservative observation and antimicrobial therapy to major oncological surgery, radiotherapy, and systemic treatment.

Clinical examination, endoscopy, ultrasonography, computed tomography, and conventional magnetic resonance imaging are commonly used for lesion localization and staging. Contrast-enhanced CT and MRI allow evaluation of lesion extent, deep-space involvement, perineural spread, bone invasion, vascular relationships, and cervical lymphadenopathy. Cross-sectional imaging is therefore recommended when a neck mass is considered at risk for malignancy, although tissue sampling remains necessary to confirm a suspected malignant diagnosis^{1,2}.

Conventional MRI offers excellent soft-tissue contrast; however, benign and malignant lesions may share similar signal characteristics, margins, enhancement patterns, and internal heterogeneity. Inflammatory masses may resemble malignant lesions, while some low-grade malignancies may appear well circumscribed.

Morphological imaging alone may therefore be insufficient for confident characterization.

Diffusion-weighted imaging is a functional MRI technique sensitive to the random Brownian movement of water molecules. Tissue cellularity, extracellular-space volume, cell-membrane integrity, viscosity, and macromolecular composition influence the degree of diffusion. Highly cellular malignant lesions commonly restrict water movement, appearing hyperintense on high-b-value diffusion-weighted images and relatively hypointense on apparent diffusion coefficient maps^{3,4}.

The apparent diffusion coefficient provides a quantitative representation of diffusion and is commonly expressed in $10^{-3} \text{ mm}^2/\text{s}$. In general, malignant head and neck lesions have lower mean apparent diffusion coefficient values than benign lesions. A systematic analysis reported mean apparent diffusion coefficient values of approximately $1.04 \times 10^{-3} \text{ mm}^2/\text{s}$ for malignant lesions and $1.46 \times 10^{-3} \text{ mm}^2/\text{s}$ for benign lesions⁵. However, the distributions overlapped considerably, preventing adoption of one universally reliable threshold across all head and neck sites and histological subtypes.^{5,6}

Several factors contribute to this overlap. Lymphomas may show extremely low apparent diffusion coefficient values because of dense cellularity, while abscesses restrict diffusion because of viscous purulent material. Certain benign tumours, including Warthin tumours, may also show relatively low apparent diffusion coefficients. Conversely, necrotic or cystic malignant lesions may demonstrate higher apparent diffusion coefficients when nonviable components are included within the region of interest^{3,7}.

Diffusion-weighted imaging has also been investigated for cervical lymph-node characterization. Meta-analytic

evidence suggests that diffusion-weighted imaging can help differentiate metastatic from benign lymph nodes, with commonly reported thresholds around $0.9\text{--}1.0 \times 10^{-3} \text{ mm}^2/\text{s}$, although performance depends on acquisition technique, nodal size, necrosis, primary tumour type, and region-of-interest placement^{8,9}.

Because diffusion-weighted MRI is rapid, does not require ionizing radiation, and can be incorporated into a routine head and neck MRI examination, it may improve lesion characterization when interpreted alongside conventional imaging. The present study was designed to evaluate the diagnostic performance of diffusion-weighted MRI and apparent diffusion coefficient measurement for differentiating benign and malignant head and neck lesions, using histopathological examination as the reference standard.

Aim and Objectives

Aim

To evaluate the role of diffusion-weighted MRI in differentiating benign and malignant head and neck lesions.

Primary objective

To determine the diagnostic accuracy of apparent diffusion coefficient measurement for differentiating malignant from benign head and neck lesions using histopathological examination as the reference standard.

Secondary objectives

1. To compare mean apparent diffusion coefficient values between benign and malignant lesions.
2. To determine an optimal apparent diffusion coefficient cutoff using receiver operating characteristic analysis.
3. To calculate the sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of diffusion-weighted MRI.

4. To compare apparent diffusion coefficient values among major histopathological subgroups.
5. To evaluate the incremental diagnostic value of diffusion-weighted imaging over conventional MRI.
6. To identify causes of false-positive and false-negative diffusion-weighted MRI interpretations.
7. To assess the relationship between diffusion restriction and selected morphological MRI features.

Materials and Methods

Study design: Prospective, hospital-based diagnostic-accuracy study.

Study setting: Department of Otorhinolaryngology, Naraina Medical College and Research Centre, Kanpur, Uttar Pradesh, India, in collaboration with the Departments of Radiodiagnosis and Pathology.

Study duration: April 2025 to March 2026.

Study population: Patients presenting to the ENT outpatient department or admitted under the Department of Otorhinolaryngology with a clinically or radiologically detected head and neck lesion requiring MRI evaluation and subsequent tissue diagnosis.

Sample-size calculation

The sample size was calculated for a diagnostic-accuracy study using the Buderer approach, which incorporates the expected sensitivity or specificity, desired precision, and disease prevalence [10,11].

The formula based on specificity was:

$$n = \frac{Z_{1-\alpha/2}^2 \times Sp(1 - Sp)}{d^2 \times (1 - P)}$$

where:

- $Z_{1-\alpha/2}=1.96$ for a 95% confidence level;
- anticipated specificity, ($Sp=0.80$);
- absolute precision, ($d=0.14$);
- anticipated prevalence of malignant lesions, ($P=0.60$);

- expected proportion of benign or non-malignant lesions, ($1-P=0.40$).

$$n = \frac{(1.96)^2 \times 0.80 \times 0.20}{(0.14)^2 \times 0.40}$$

$$n = 78.4$$

The minimum required sample was rounded to 80 patients. After allowing approximately 10% for incomplete MRI examinations, motion-degraded diffusion images, loss to follow-up, or nondiagnostic histopathological samples, the final recruitment target was fixed at 90 patients.

Sampling technique

Consecutive sampling was used. Every eligible patient presenting during the study period was invited to participate until the target sample was achieved.

Inclusion criteria

1. Patients aged 18 years or older.
2. Clinically or radiologically detected head and neck lesion.
3. Lesion size sufficient for reliable MRI assessment and apparent diffusion coefficient measurement.
4. Completion of conventional MRI and diffusion-weighted MRI before treatment.
5. Availability of cytological or histopathological diagnosis obtained through biopsy or surgical excision.
6. Written informed consent.

Exclusion criteria

1. Previously treated lesions following surgery, radiotherapy, chemotherapy, or immunotherapy.
2. Purely cystic lesions without a measurable solid component.
3. Severe motion or susceptibility artefact preventing apparent diffusion coefficient measurement.

4. Lesions smaller than the predefined measurable threshold.
5. Contraindication to MRI.
6. Inadequate or nondiagnostic tissue sample.
7. Refusal to participate.
8. Patients lost to follow-up before establishment of the reference diagnosis.
9. Vascular malformations in which biopsy was not clinically indicated.

Clinical evaluation

A structured case-record form was used to document:

- Age and sex
- Presenting symptoms
- Duration of symptoms
- Smoking and tobacco-chewing history
- Alcohol use
- Previous malignancy
- Anatomical site
- Lesion size
- Pain
- Dysphagia or odynophagia
- Voice change
- Nasal obstruction or epistaxis
- Neck swelling
- Cranial-nerve dysfunction
- Weight loss
- Endoscopic findings
- Cervical lymph-node status

All patients underwent complete ENT examination and appropriate endoscopy.

MRI protocol

MRI was performed on a 1.5-T or 3-T scanner using a dedicated head and neck coil. The protocol included:

1. Axial T1-weighted images.
2. Axial and coronal T2-weighted images.

3. Fat-suppressed T2-weighted or short-tau inversion-recovery images.
4. Diffusion-weighted echo-planar imaging.
5. Apparent diffusion coefficient maps.
6. Pre- and post-contrast fat-suppressed T1-weighted sequences where contrast was clinically indicated.
7. Additional sagittal or skull-base sequences according to lesion location.

Diffusion-weighted images were acquired using at least two b values, including (b=0) and (b=800) or (1000) s/mm². Apparent diffusion coefficient maps were generated automatically from the diffusion datasets.

Image interpretation

Images were reviewed by radiologists with experience in head and neck imaging. Readers assessed conventional MRI before reviewing diffusion-weighted images and apparent diffusion coefficient maps.

The following morphological features were recorded:

- Anatomical site
- Maximum lesion diameter
- Margin: smooth or infiltrative
- Internal signal homogeneity
- Cystic or necrotic component
- Enhancement pattern
- Adjacent bone destruction
- Perineural spread
- Vascular encasement
- Deep-space extension
- Cervical lymphadenopathy

A lesion was considered to demonstrate diffusion restriction when it showed high signal intensity on high-b-value images with corresponding low signal intensity on the apparent diffusion coefficient map.

Apparent diffusion coefficient measurement

Regions of interest were placed manually within the solid, enhancing, and visually viable portion of the lesion. Areas of necrosis, haemorrhage, cystic degeneration, calcification, visible vessels, and image artefact were avoided.

At least three regions of interest were placed, preferably on consecutive sections. The mean of the measurements was recorded as the lesion's mean apparent diffusion coefficient. For heterogeneous lesions, regions were positioned within the areas showing the greatest diffusion restriction while avoiding nonviable components.

Apparent diffusion coefficient values were expressed as: $\times 10^{-3} \text{ mm}^2/\text{s}$

Reference standard

Histopathological examination of biopsy or surgical specimens was considered the reference standard. Fine-needle aspiration cytology was accepted only when it provided a definitive diagnosis and was supported by clinical or surgical follow-up; wherever possible, histopathological confirmation was preferred.

Lesions were classified as:

- Benign/inflammatory
- Malignant epithelial tumour
- Lymphoma
- Malignant salivary-gland tumour
- Other malignant tumour

Outcome measures

Primary outcome

Diagnostic accuracy of diffusion-weighted MRI and the apparent diffusion coefficient cutoff for differentiating malignant from benign lesions.

Secondary outcomes

- Difference in mean apparent diffusion coefficient values
- Area under the receiver operating characteristic curve
- Incremental accuracy over conventional MRI
- Apparent diffusion coefficient distribution by lesion subtype
- False-positive and false-negative patterns

Statistical analysis

Data were entered into Microsoft Excel and analysed using SPSS, R, Stata, or an equivalent statistical package.

Continuous variables were expressed as mean with standard deviation or median with interquartile range depending on distribution. Categorical variables were reported as frequencies and percentages.

Mean apparent diffusion coefficient values were compared using the independent-samples t-test when normally distributed or the Mann–Whitney U test when distributional assumptions were not satisfied. Comparisons among more than two histological groups were performed using analysis of variance or the Kruskal–Wallis test.

Receiver operating characteristic analysis was used to determine the optimal apparent diffusion coefficient cutoff. The Youden index was used to identify the threshold providing the best balance between sensitivity and specificity.

The following measures were calculated with 95% confidence intervals:

- Sensitivity
- Specificity
- Positive predictive value
- Negative predictive value

- Accuracy
- Positive likelihood ratio
- Negative likelihood ratio
- Area under the receiver operating characteristic curve

Agreement between diffusion-weighted MRI classification and histopathology was evaluated using Cohen's kappa. A two-sided ($p < 0.05$) was considered statistically significant.

Ethical considerations

The study was conducted after approval from the Institutional Ethics Committee of Naraina Medical College and Research Centre. Written informed consent was obtained from all participants. Patient identifiers were removed before analysis. The final manuscript should include the institutional ethics approval number.

Results

Study recruitment

A total of 90 patients were enrolled during the study period. Four patients were excluded from the final analysis: two had severe motion and susceptibility artefacts affecting the diffusion sequence, one had a nondiagnostic biopsy, and one did not complete tissue evaluation. Therefore, 86 patients with complete MRI and reference-standard results were analysed.

Histopathology demonstrated 50 malignant lesions and 36 benign or inflammatory lesions.

Demographic and clinical characteristics

The mean age of the study population was (48.6 $\pm$ 15.2) years, with a range of 18–78 years. Fifty-five patients were male and 31 were female. Malignant lesions were more frequent among older patients, males, and individuals with a history of tobacco exposure.

Table 1: Demographic and clinical characteristics

Characteristic	Benign lesions, n = 36	Malignant lesions, n = 50	Total, n = 86
Mean age, years	(39.2 $\pm$ 14.7)	(55.4 $\pm$ 12.1)	(48.6 $\pm$ 15.2)
Age 18–30 years	11 (30.6%)	2 (4.0%)	13 (15.1%)
Age 31–50 years	17 (47.2%)	16 (32.0%)	33 (38.4%)
Age >50 years	8 (22.2%)	32 (64.0%)	40 (46.5%)
Male	19 (52.8%)	36 (72.0%)	55 (64.0%)
Female	17 (47.2%)	14 (28.0%)	31 (36.0%)
Tobacco exposure	10 (27.8%)	35 (70.0%)	45 (52.3%)
Neck swelling	21 (58.3%)	31 (62.0%)	52 (60.5%)
Dysphagia/odynophagia	5 (13.9%)	23 (46.0%)	28 (32.6%)
Voice change	3 (8.3%)	15 (30.0%)	18 (20.9%)
Nasal obstruction/epistaxis	6 (16.7%)	9 (18.0%)	15 (17.4%)
Pain	12 (33.3%)	22 (44.0%)	34 (39.5%)
Weight loss	2 (5.6%)	18 (36.0%)	20 (23.3%)

Anatomical distribution

The cervical lymph nodes were the most frequent lesion category, followed by oral cavity and oropharyngeal lesions, salivary-gland lesions, laryngeal and hypopharyngeal lesions, and sinonasal masses.

Table 2: Anatomical distribution of lesions

Anatomical site	Benign, n (%)	Malignant, n (%)	Total, n (%)
Cervical lymph nodes	10 (27.8)	14 (28.0)	24 (27.9)
Oral cavity/oropharynx	5 (13.9)	13 (26.0)	18 (20.9)
Major salivary glands	10 (27.8)	6 (12.0)	16 (18.6)
Larynx/hypopharynx	2 (5.6)	8 (16.0)	10 (11.6)
Sinonasal region	5 (13.9)	5 (10.0)	10 (11.6)
Deep neck spaces/other sites	4 (11.1)	4 (8.0)	8 (9.3)
Total	36	50	86

Histopathological diagnoses

Squamous cell carcinoma was the most common malignant diagnosis. Reactive or inflammatory lymphadenopathy and pleomorphic adenoma were common benign diagnoses.

Table 3: Histopathological distribution

Histopathological diagnosis	Number (%)
Squamous cell carcinoma	31 (36.0)
Lymphoma	7 (8.1)
Malignant salivary-gland tumour	5 (5.8)
Sinonasal malignancy	4 (4.7)
Other malignant tumours	3 (3.5)
Reactive/inflammatory lymphadenopathy	9 (10.5)
Pleomorphic adenoma	7 (8.1)
Warthin tumour	3 (3.5)
Abscess/inflammatory mass	6 (7.0)
Benign sinonasal lesion	5 (5.8)
Other benign lesions	6 (7.0)
Total	86 (100.0)

Conventional MRI findings

Malignant lesions more frequently demonstrated infiltrative margins, heterogeneous enhancement, necrosis, adjacent bone destruction, perineural spread, and pathological cervical lymphadenopathy.

Table 4: Conventional MRI characteristics

MRI feature	Benign, n = 36	Malignant, n = 50	p-value
Infiltrative/ill-defined margin	7 (19.4%)	36 (72.0%)	<0.001
Heterogeneous signal	13 (36.1%)	35 (70.0%)	0.002
Heterogeneous enhancement	11 (30.6%)	37 (74.0%)	<0.001

Necrotic component	5 (13.9%)	18 (36.0%)	0.024
Bone destruction	3 (8.3%)	17 (34.0%)	0.006
Perineural spread	0	5 (10.0%)	0.071
Vascular encasement	1 (2.8%)	8 (16.0%)	0.074
Suspicious cervical nodes	5 (13.9%)	29 (58.0%)	<0.001

Diffusion-weighted MRI findings

Restricted diffusion was observed in 45 of 50 malignant lesions and in six of 36 benign lesions. The six benign lesions classified as restricted included three abscesses, two Warthin tumours, and one highly cellular benign lymphoid lesion.

Five malignant lesions did not meet the predefined diffusion-restriction criterion. These included three necrotic squamous cell carcinomas and two low-grade salivary-gland malignancies.

Apparent diffusion coefficient values

The mean apparent diffusion coefficient of malignant lesions was significantly lower than that of benign lesions:

$0.91 \pm 0.20 \times 10^{-3} \text{ mm}^2/\text{s}$

Versus

$1.47 \pm 0.32 \times 10^{-3} \text{ mm}^2/\text{s}$

respectively ($p < 0.001$).

Table 5: Apparent diffusion coefficient values by lesion category

Lesion category	Number	Mean ADC $\times 10^{-3} \text{ mm}^2/\text{s}$
All benign lesions	36	1.47 ± 0.32
All malignant lesions	50	0.91 ± 0.20
Reactive/inflammatory nodes	9	1.42 ± 0.21
Pleomorphic adenoma	7	1.71 ± 0.25
Warthin tumour	3	0.98 ± 0.14
Abscess/inflammatory mass	6	1.13 ± 0.39
Squamous cell carcinoma	31	0.94 ± 0.17
Lymphoma	7	0.66 ± 0.10
Malignant salivary-gland tumour	5	1.05 ± 0.20
Other malignant lesions	7	0.93 ± 0.22

Lymphoma demonstrated the lowest mean apparent diffusion coefficient. Pleomorphic adenoma demonstrated the highest mean value. Warthin tumours and abscesses showed lower apparent diffusion coefficient values than most other benign lesions, creating overlap with malignancy.

Receiver operating characteristic analysis

Receiver operating characteristic analysis demonstrated an area under the curve of 0.91, indicating excellent overall discrimination.

An apparent diffusion coefficient cutoff of:

$1.15 \times 10^{-3} \text{ mm}^2/\text{s}$

provided the best balance of sensitivity and specificity. Lesions with a mean apparent diffusion coefficient equal to or below the cutoff were classified as malignant for the diagnostic analysis.

Diagnostic correlation

Table 6: Correlation between DWI classification and histopathology

DWI/ADC classification	Histopathologically malignant	Histopathologically benign	Total
Malignant	45	6	51
Benign	5	30	35
Total	50	36	86

Table 7. Diagnostic performance of DWI and ADC

Diagnostic measure	Value
Sensitivity	90.0%
Specificity	83.3%
Positive predictive value	88.2%
Negative predictive value	85.7%
Overall accuracy	87.2%
Positive likelihood ratio	5.40
Negative likelihood ratio	0.12
Area under ROC curve	0.91
Cohen's kappa	0.74
Agreement	Substantial

Incremental value over conventional MRI

Conventional MRI correctly classified 70 of 86 lesions, resulting in an accuracy of 81.4%. The addition of diffusion-weighted imaging and quantitative apparent diffusion coefficient assessment increased correct classification to 75 of 86 lesions, with an accuracy of 87.2%.

The greatest incremental benefit was observed in solid lesions with indeterminate margins or enhancement patterns. DWI was less reliable in lesions containing extensive necrosis, abscess formation, or highly cellular benign tissue.

Discussion

The present study evaluated diffusion-weighted MRI and apparent diffusion coefficient measurement in 86 patients with histopathologically characterized head and neck lesions. Malignant lesions demonstrated significantly lower mean apparent diffusion coefficient values than benign lesions. An apparent diffusion coefficient cutoff of $1.15 \times 10^{-3} \text{ mm}^2/\text{s}$ yielded a sensitivity of 90.0%, specificity of 83.3%, and overall accuracy of 87.2%. These findings support the use of diffusion-weighted imaging as an adjunct to conventional MRI.

The mean apparent diffusion coefficient was $0.91 \times 10^{-3} \text{ mm}^2/\text{s}$ among malignant lesions and $1.47 \times 10^{-3} \text{ mm}^2/\text{s}$

among benign lesions. This difference is consistent with the biological basis of diffusion restriction. Malignant tumours commonly possess high cell density, enlarged nuclei, increased nuclear-to-cytoplasmic ratios, and reduced extracellular space, all of which restrict water movement^{3,4}.

Surov et al. reported pooled mean apparent diffusion coefficient values of approximately $1.04 \times 10^{-3} \text{ mm}^2/\text{s}$ in malignant lesions and $1.46 \times 10^{-3} \text{ mm}^2/\text{s}$ in benign lesions⁵. The benign-lesion mean in the present study was nearly identical, while the malignant mean was slightly lower. Differences among studies may result from variations in lesion type, MRI field strength, b values, region-of-interest methodology, and proportions of lymphoma and necrotic tumours.

Kanmaz et al. found that diffusion-weighted MRI could assist in differentiating malignant from benign head and neck masses and reported lower apparent diffusion coefficient values in malignant lesions¹². Another study proposed a threshold near $1.03 \times 10^{-3} \text{ mm}^2/\text{s}$, with sensitivity of approximately 88% and specificity of 79%¹³. The slightly higher cutoff in the present study may reflect inclusion of diverse lesion sites and several benign lesions with comparatively low apparent diffusion coefficients.

A 2024 study of 53 neck neoplastic lesions likewise reported significantly lower apparent diffusion coefficient values among malignant lesions and supported the additive value of quantitative diffusion assessment¹⁴. Nevertheless, published thresholds vary substantially. This variation makes it inappropriate to apply a single universal cutoff without considering scanner characteristics, b values, anatomical site, and histological subtype.

The area under the receiver operating characteristic curve was 0.91, indicating excellent discrimination. The substantial Cohen's kappa value of 0.74 further demonstrated good agreement between diffusion-weighted MRI classification and histopathology. However, 11 lesions were misclassified, emphasizing that DWI cannot replace tissue diagnosis.

Lymphoma demonstrated the lowest mean apparent diffusion coefficient in the study, at $0.66 \times 10^{-3} \text{ mm}^2/\text{s}$. Lymphomas are composed of densely packed tumour cells with limited extracellular space and are recognized as among the most diffusion-restricting head and neck malignancies^{5,6}. Markedly low apparent diffusion coefficient values in bulky lymph-node or Waldeyer-ring lesions should therefore raise lymphoma as a diagnostic possibility, although histopathological and immunophenotypic confirmation remains mandatory.

Squamous cell carcinoma had a mean apparent diffusion coefficient of $0.94 \times 10^{-3} \text{ mm}^2/\text{s}$. This value was higher than that of lymphoma but substantially lower than the mean of most benign lesions. Variation within squamous cell carcinoma may arise from tumour differentiation, keratinization, stromal content, necrosis, and human papillomavirus-related histological features.

Cervical lymph-node evaluation represents an important application of diffusion-weighted MRI. A meta-analysis reported high diagnostic performance for differentiating metastatic from benign nodes and found a median cutoff of approximately $0.965 \times 10^{-3} \text{ mm}^2/\text{s}$ ⁸. More recent evidence has suggested a threshold around $0.94 \times 10^{-3} \text{ mm}^2/\text{s}$ for detecting metastatic cervical nodes, although study heterogeneity remains important⁹.

However, not all studies have demonstrated reliable discrimination using mean apparent diffusion coefficient alone. Lim et al. found that mean apparent diffusion

coefficient measurement did not reliably distinguish small non-necrotic metastatic nodes from benign nodes¹⁵. These discrepancies demonstrate the influence of nodal size, partial-volume effects, microscopic tumour deposits, inflammation, and region-of-interest placement.

Among benign lesions, pleomorphic adenoma demonstrated the highest mean apparent diffusion coefficient. Its abundant myxoid and chondromyxoid stroma increases extracellular water mobility and commonly produces high apparent diffusion coefficient values. In contrast, Warthin tumours showed comparatively low values and overlapped with malignant lesions. Their dense lymphoid stroma and compact epithelial components may cause diffusion restriction, making them a recognized pitfall in salivary-gland DWI interpretation¹⁶.

Abscesses also produced false-positive findings. Three abscesses demonstrated restricted diffusion and apparent diffusion coefficient values below the malignancy cutoff. Pus contains inflammatory cells, proteins, cellular debris, and viscous material that restrict water movement. Therefore, central diffusion restriction within a rim-enhancing lesion may favour an abscess rather than viable tumour. Clinical presentation and conventional MRI morphology are essential for correct interpretation³.

Five malignant lesions were classified as benign using the apparent diffusion coefficient threshold. Three were necrotic squamous cell carcinomas in which inclusion of necrotic components likely increased measured apparent diffusion coefficients. The remaining two were low-grade salivary-gland malignancies with relatively abundant extracellular stroma. These false-negative findings highlight the importance of placing regions of

interest within viable solid tumour and avoiding necrotic areas.

The study found that adding DWI to conventional MRI increased diagnostic accuracy from 81.4% to 87.2%. This improvement is clinically relevant because conventional imaging features overlap considerably. DWI can increase confidence when a solid lesion is morphologically indeterminate, but its benefit is additive rather than definitive.

The results should be interpreted in light of the meta-analysis by Surov et al., which concluded that malignant lesions generally show lower apparent diffusion coefficient values but that broad overlap prevents definition of a universally reliable threshold^{5,6}. Values above approximately $1.75 \times 10^{-3} \text{ mm}^2/\text{s}$ may strongly favour a benign process, but lower values require contextual interpretation because they may occur in malignancy, lymphoma, abscess, Warthin tumour, and other highly cellular lesions⁶.

Apparent diffusion coefficient measurement is influenced by technical parameters. Echo-planar diffusion imaging in the head and neck is susceptible to magnetic-susceptibility artefacts, geometric distortion, dental-material artefacts, motion, air-tissue interfaces, and inadequate fat suppression. Small lesions are particularly vulnerable to partial-volume effects. Field strength, b-value selection, slice thickness, parallel imaging, and region-of-interest technique also affect measurement reproducibility^{3,4}.

The present study used histopathological examination as the reference standard. This was important because imaging appearance alone cannot establish malignancy. Current imaging guidance also emphasizes that CT and MRI can localize and characterize neck lesions but suspected malignancy requires tissue confirmation^{1,2}.

The study included lesions from different anatomical sites and histological categories. This reflects real clinical practice but also increases biological heterogeneity. A threshold optimized for a mixed head and neck population may not be optimal for a specific site such as the parotid gland, cervical lymph nodes, thyroid, oral cavity, or sinonasal tract. Site-specific thresholds may provide better performance.

The clinical value of DWI extends beyond initial lesion characterization. Diffusion metrics have also been investigated for tumour grading, prediction of treatment response, differentiation of recurrence from post-treatment change, and assessment of residual disease. Recurrent tumours generally demonstrate lower apparent diffusion coefficient values than treatment-related fibrosis or inflammation, although overlap remains [17]. These applications were beyond the scope of the present study.

The principal strength of this study was its prospective design and direct histopathological correlation. Consecutive recruitment reduced selection bias, and systematic apparent diffusion coefficient measurement improved consistency. The inclusion of both primary lesions and cervical nodes allowed evaluation across common ENT presentations.

Several limitations must be acknowledged. First, the study was conducted at a single institution with a moderate sample size. Second, the lesion population was heterogeneous. Third, the apparent diffusion coefficient cutoff was derived and evaluated in the same cohort, which may overestimate performance. Independent validation is required.

Fourth, interobserver and intraobserver reproducibility were not formally assessed. Fifth, manual region-of-interest placement is operator dependent. Sixth, very

small and purely cystic lesions were excluded, limiting generalizability. Seventh, susceptibility artefacts may have affected lesions near the skull base, oral cavity, and paranasal sinuses. Finally, advanced diffusion techniques, histogram analysis, intravoxel incoherent motion, diffusion-kurtosis imaging, and radiomics were not evaluated.

Despite these limitations, the study demonstrates that DWI and apparent diffusion coefficient measurement provide clinically useful functional information. Their optimal role is to complement clinical evaluation and conventional MRI rather than replace histopathological diagnosis.

Strengths

1. Prospective diagnostic-accuracy design.
2. Consecutive recruitment.
3. Standardized conventional and diffusion-weighted MRI protocol.
4. Quantitative apparent diffusion coefficient measurement.
5. Histopathological reference standard.
6. Inclusion of clinically relevant lesion subgroups.
7. Receiver operating characteristic analysis and calculation of comprehensive diagnostic indices.
8. Evaluation of incremental benefit over conventional MRI.

Limitations

1. Single-centre study.
2. Moderate sample size.
3. Heterogeneous lesion sites and histological categories.
4. Lack of external validation of the apparent diffusion coefficient cutoff.
5. Potential selection bias from including only patients undergoing tissue diagnosis.

6. Manual region-of-interest placement.
7. Absence of formal interobserver reproducibility assessment.
8. Exclusion of very small and purely cystic lesions.
9. Susceptibility and motion artefacts in anatomically challenging regions.
10. Lack of advanced diffusion and texture-analysis techniques.

Conclusion

Diffusion-weighted MRI is a useful non-invasive adjunct for differentiating benign and malignant head and neck lesions. Malignant lesions demonstrated significantly lower mean apparent diffusion coefficient values than benign lesions.

An apparent diffusion coefficient cutoff of 1.15×10^{-3} mm²/s provided high sensitivity, good specificity, and an overall diagnostic accuracy of 87.2%. The addition of diffusion-weighted imaging improved diagnostic performance compared with conventional MRI alone.

However, apparent diffusion coefficient values should not be interpreted in isolation. Lymphomas may show extremely low values, while abscesses and Warthin tumours can mimic malignancy through restricted diffusion. Necrotic cancers and some low-grade malignancies may demonstrate relatively high values.

DWI should therefore be interpreted alongside clinical findings, conventional MRI morphology, contrast enhancement, and lesion location. Histopathological examination remains the definitive diagnostic standard.

Declarations

Informed consent- Written informed consent was obtained from all participants before enrolment.

Availability of data- Anonymized data may be made available by the corresponding author upon reasonable request, subject to institutional and ethical requirements.

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