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(Research Article)

Multiparametric MRI approach to head and neck masses: Combined utility of DWI and DCE-MRI

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Abstract

Head and neck masses present significant diagnostic challenges, which necessitate the unequivocal differentiation between benign and malignant tumors. The sensitivity and specificity of conventional MR and CT imaging are lower, so diffusion-weighted imaging (DWI) and dynamic contrast-enhanced MRI (DCE-MRI) are ideal alternatives. For the discrimination of benign from malignant head and neck tumors, this study assesses the diagnostic accuracy of ADC values of DWI and the perfusion curve analysis of DCE-MRI.

This study included 100 patients prospectively examined with DWI (b-values of 600 and 800 s/mm^2) and analyzed with DCE-MRI time-intensity curve analysis. MRI findings were compared with the histopathological reports. Out of the 100 cases, 78 were malignant cases. Using DWI MRI, ADC (B:600) had 100% sensitivity and 77.2% specificity; ADC (B:800) had 100% sensitivity and 86.36% specificity. Differential curve types of DCE-MRI have significantly differed in malignancy detection ($p < 0.0001$). Functionally, DWI and DCE-MRI enhance diagnostic accuracy in evaluating head and neck tumors. While DWI offers rapid assessment devoid of contrast, DCE-MRI highly characterizes lesions. Integrating these sequences into routine imaging could significantly contribute to better diagnosis and planning for therapy.

Keywords: Diffusion-Weighted Imaging (DWI); Dynamic Contrast-Enhanced MRI (DCE-MRI); Apparent Diffusion Coefficient (ADC); Head and Neck Tumors; Magnetic Resonance Imaging (MRI); Benign vs. Malignant Lesions; Perfusion Curve Analysis; Nodal Staging in Head and Neck Cancer; Non-invasive Tumor Characterization; Quantitative Imaging Biomarkers

1. Introduction

Head and neck masses present a common clinical challenge across diverse age groups. The differential diagnoses span congenital, inflammatory, and neoplastic lesions, requiring precise diagnostic approaches for effective management (1). While conventional MRI and CT remain the primary imaging modalities for evaluating head and neck cancers, their reliance on volumetric and morphological criteria results in limited sensitivity and accuracy for definitive diagnosis (2,3).

Advanced MRI techniques, including Diffusion-Weighted Imaging (DWI) with apparent diffusion coefficient (ADC) measurements and Dynamic Contrast-Enhanced MRI (DCE-MRI), have emerged as promising tools for characterizing head and neck lesions. These techniques enable more reliable differentiation between benign and malignant tumors and provide valuable insights into tumor microenvironments (4).

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DWI has demonstrated considerable value in diagnosis, prognosis, and treatment response monitoring in head and neck tumors (5,6). By measuring the random Brownian motion of water molecules within tissues, DWI can distinguish between viable and necrotic portions of tumors. This technique proves especially beneficial in pediatric cases, where it allows for lesion characterization without contrast administration (7). The quantitative ADC values derived from DWI aid in cancer staging, detection of subcentimeter nodal metastases, and differentiation between carcinomas, lymphomas, benign lesions, and tumor necrosis from abscesses (8,9).

Moreover, DWI enables differentiation between various subtypes of squamous cell carcinoma (SCC) through ADC measurements (10). Malignant lesions with dense cellular packing typically exhibit restricted diffusion and consequently lower ADC values. Interestingly, lower pretreatment ADC values often predict favorable responses to chemoradiation therapy (6). As treatment progresses, the destruction of malignant cells increases water diffusion, resulting in higher ADC values—a valuable marker for monitoring therapeutic efficacy.

DWI has also proven to be perhaps the most effective imaging technique for nodal staging in the head and neck region, accurately differentiating benign from malignant lymph nodes (6).

DCE-MRI, meanwhile, evaluates the cancer microenvironment by assessing complex interrelated processes such as hypoxia and angiogenesis. Analysis typically involves drawing regions of interest (ROIs) and observing signal intensity variations over time. The resulting time-intensity curves provide useful parameters for differentiating head and neck tumors (11). While semi-quantitative evaluations are widely applied, they don't offer insights into the underlying pharmacokinetic properties of tissues. Furthermore, signal intensity analyses are significantly influenced by scan parameters and operator expertise (12). This limitation has driven the development of noninvasive quantitative methods that can measure contrast agent exchange between intravascular and interstitial spaces (13).

Aim and Objectives

This study aimed to evaluate the diagnostic accuracy of ADC value measurements and DCE-MRI in differentiating between benign and malignant head and neck tumors, comparing the specificity and sensitivity of both quantitative and semi-quantitative analytical methods.

Specifically, we sought to assess the diagnostic value of DWI at two different b-values (600 and 800 s/mm^2) with corresponding ADC values, and to characterize enhancement patterns using perfusion curve analysis for distinguishing between benign and malignant head and neck tumors.

2. Materials and Methods

2.1. Study Design and Patient Population

We conducted a prospective study evaluating 100 patients presenting with head and neck masses at the Radiodiagnosis Department of Ruby Hall Clinic between June 2017 and September 2017. Informed consent and relevant clinical history were obtained from all participants.

2.2. MRI Protocol

All patients underwent DWI and DCE-MRI examinations on a Philips Ingenia 3 Tesla scanner. DWI was performed with b-values of 600 and 800 s/mm^2 in each patient, and their ADC values and enhancement curve patterns were analyzed.

Diffusion-sensitizing gradients were applied in all three orthogonal planes (x, y, z). Images were obtained in the axial plane using a turbo spin echo sequence with a parallel imaging technique (generalized SENSE factor 2.5) for acceleration. The free-breathing DW-MRI technique was employed, and ADC values were automatically reconstructed using standard software on the main console.

Regions of interest (ROIs) of 15-30 mm^2 covering the solid components of masses and lymph nodes were placed on diffusion images with b=600 s/mm^2 or 800 s/mm^2 using the Advantage Windows Workstation. These ROIs were then copied to the corresponding ADC maps to measure ADC values. The average ADC values with standard deviations were calculated for each mass and lymph node (Fig 1).

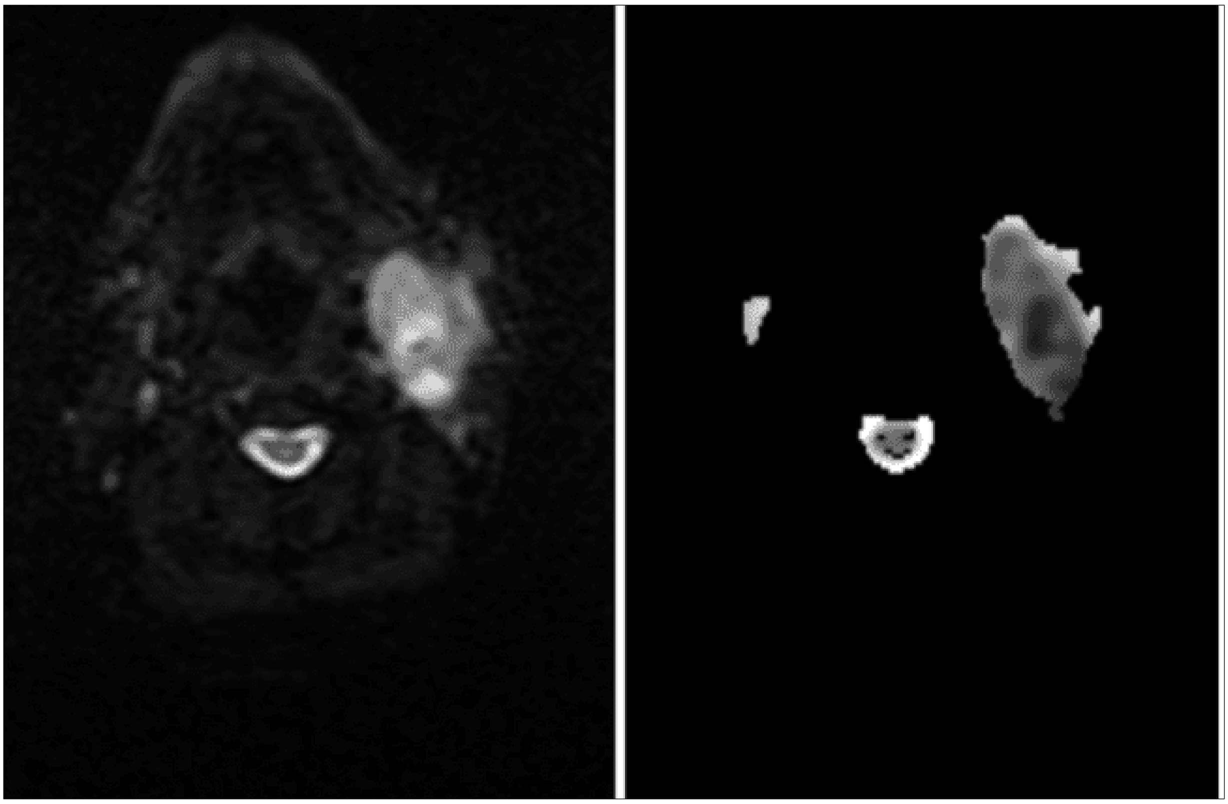

Figure 1 Diffusion restriction on diffusion-weighted images (b= 800 mm2/s) with corresponding area showing low on ADC image

For DCE-MRI, THRIVE dynamic sequence was used with a field of view of 200 × 200 mm and 3 mm slice thickness for 20 slices. Each dynamic scan lasted 10 seconds, with 25 dynamics acquired in total. ROIs were carefully placed in the solid parts of lesions to avoid bias from necrotic areas with low perfusion. From these ROIs, time-intensity curves and time-to-peak values were automatically generated.

Quantitative analysis of DCE-MRI data was performed using Philips IntelliSpace Portal version 8.0, generating color maps and values for wash-in and wash-out rates in the form of time-intensity curves.

2.3. Enhancement Pattern Classification

Four types of enhancement patterns were identified (Fig 2):

- **Type A curve (Progressive enhancement pattern)**: Shows continuous signal intensity increase throughout the acquisition period. Typically associated with benign lesions, with only about 9% of malignant lesions displaying this pattern.
- **Type B curve (Plateau pattern)**: Characterized by initial uptake followed by a plateau phase. Considered concerning for malignancy, though not definitive.
- **Type C curve (Washout pattern)**: Exhibits relatively rapid initial uptake followed by decreasing enhancement in later phases. Strongly suggestive of malignancy.
- **Type D curve (Flat pattern)**: Shows no significant enhancement, typically considered exclusively benign.

Both semi-quantitative (using time-intensity curves) and quantitative interpretations of DCE-MRI were performed. Observers were blinded to final pathological and clinical results during interpretation. MRI findings were correlated with histological findings whenever possible.

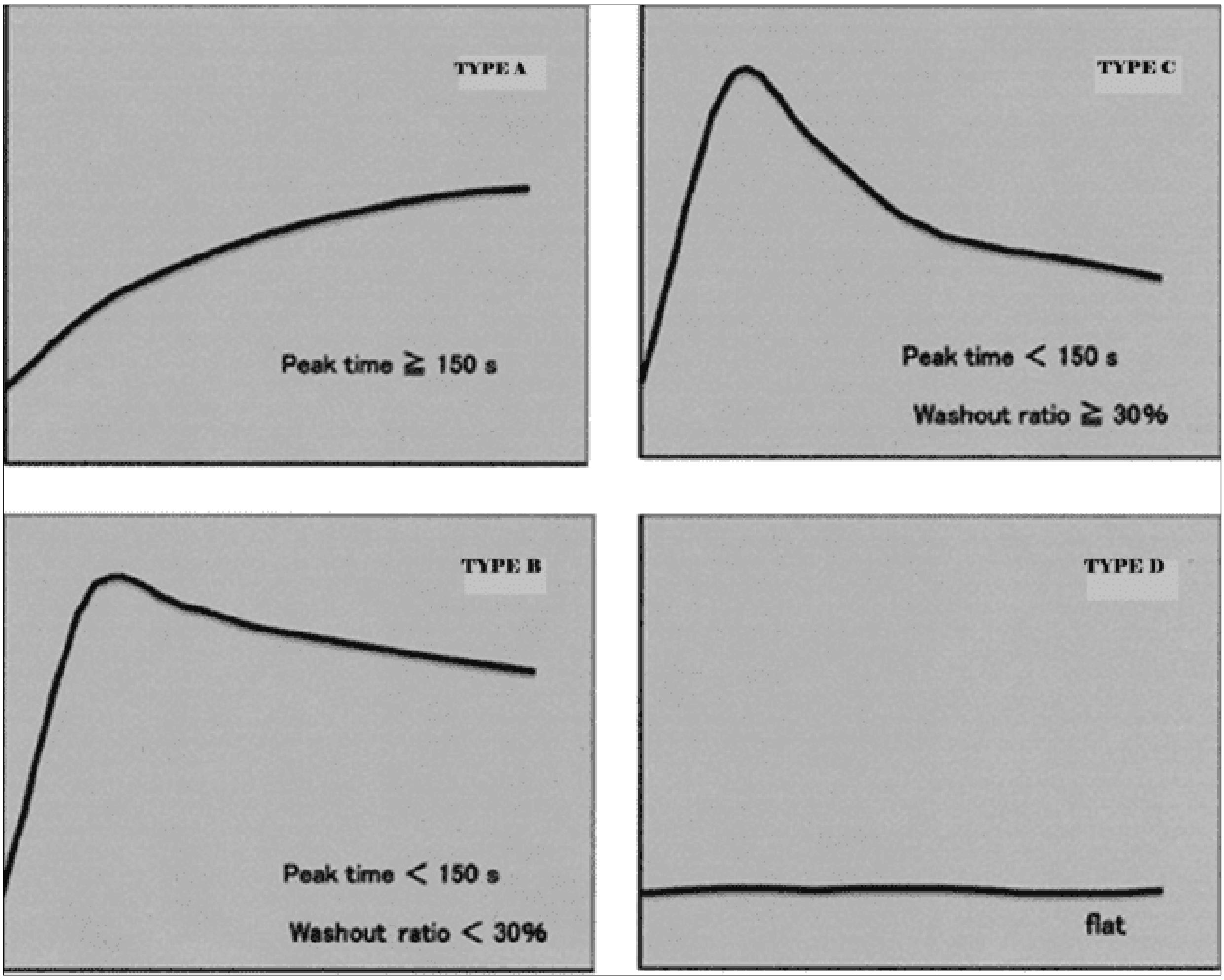

Figure 2 Types of time intensity curves

3. Results

Our study included 100 patients with head and neck masses—78 malignant and 22 benign cases—as confirmed by histopathological correlation. This substantial sample allowed for comprehensive analysis of DWI ADC values and DCE-MRI perfusion curve types in differentiating benign from malignant tumors.

Statistical analysis revealed a highly significant association ($p < 0.0001$) between DWI MRI ADC values (at both b=600 and b=800) and histopathological findings, confirming the diagnostic reliability of ADC measurements in distinguishing malignant from benign lesions.

For detecting malignant tumors, DWI MRI ADC at b=600 demonstrated 100% sensitivity, 77.2% specificity, 93.9% positive predictive value (PPV), and 100% negative predictive value (NPV). At b=800, sensitivity remained at 100%, while specificity improved to 86.36%, with a PPV of 96.3% and NPV of 100%. This indicates superior specificity at higher b-values (b=800) for differentiating malignant from benign lesions, reinforcing the reliability of ADC as a quantitative imaging biomarker.

DCE-MRI perfusion curve patterns provided additional support in distinguishing benign from malignant lesions. All benign tumors (100%) exhibited either Type A, B, or D curves, with a distribution of 59.1% Type A, 22.7% Type B, and 18.2% Type D. In contrast, 98.4% of malignant tumors showed Type B or C curves (42% Type B and 56.4% Type C).

These findings suggest that Type A and D curves strongly indicate benign tissue, while Type C curves highly suggest malignancy (Fig 3 , Fig 4 , Fig 5 , Fig 6).

Further statistical analysis demonstrated significant differences between Types A, B, and C curves ($p < 0.0001$), supporting their utility in distinguishing benign from malignant lesions. However, Type B curves showed no significant difference ($p = 0.097$) between benign and malignant cases, indicating that Type B curves alone cannot reliably differentiate between these groups.

All data were meticulously recorded and analyzed using Microsoft Office 2010, with results presented as percentages and proportions. Chi-square tests were applied where appropriate to determine statistical significance and reliability. Both ADC values and DCE-MRI perfusion curves demonstrated high sensitivity and specificity, expanding their potential for routine clinical applications in evaluating head and neck tumors.

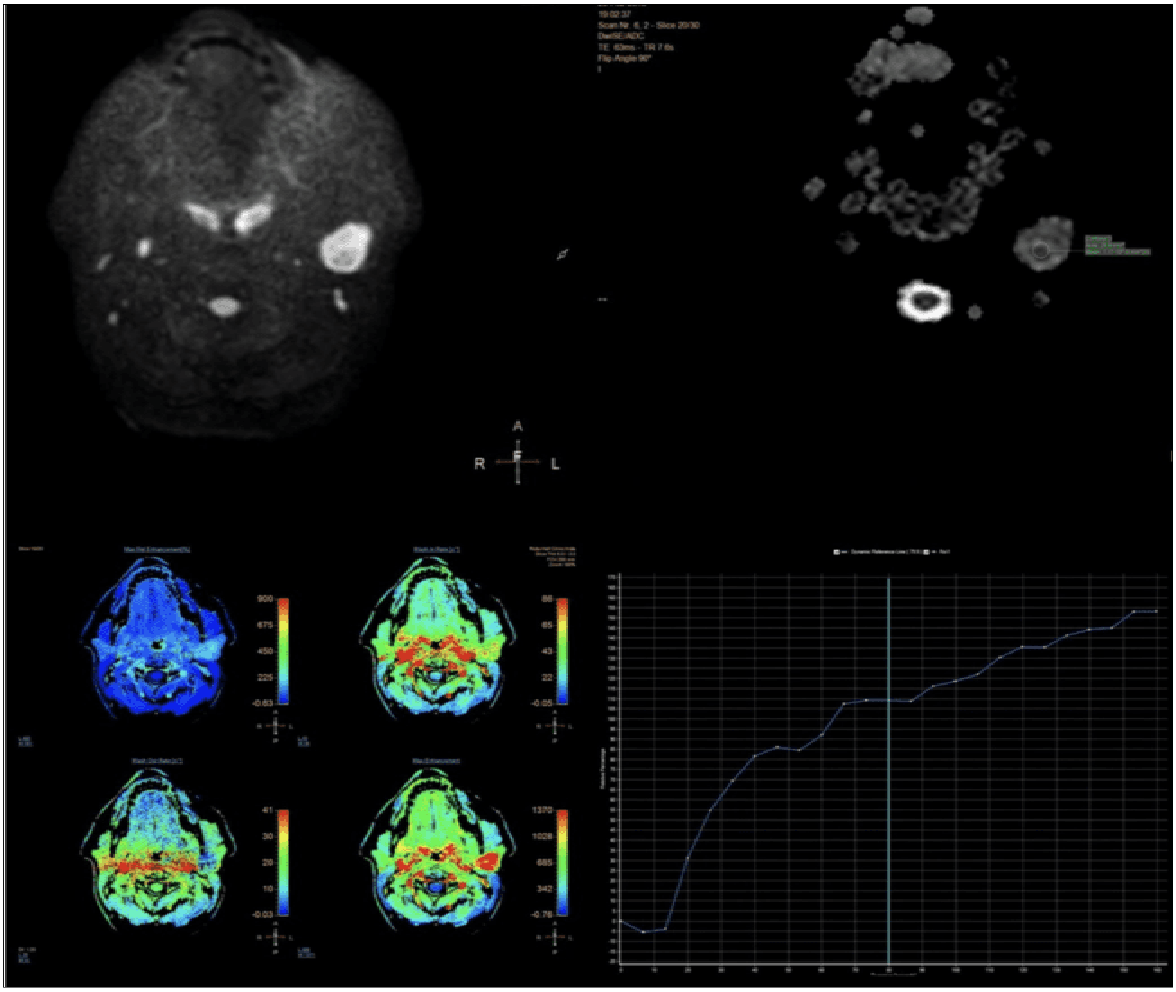

Figure 3 Case of Parotid adenoma. The upper row shows diffusion restriction on diffusion-weighted images (b=800 mm2/s), with the corresponding area showing low values for the ADC image. The ADC value of the lesion was measured as 1.1×10#3 mm2/s. The lower row DCE-MRI shows Type A TIC

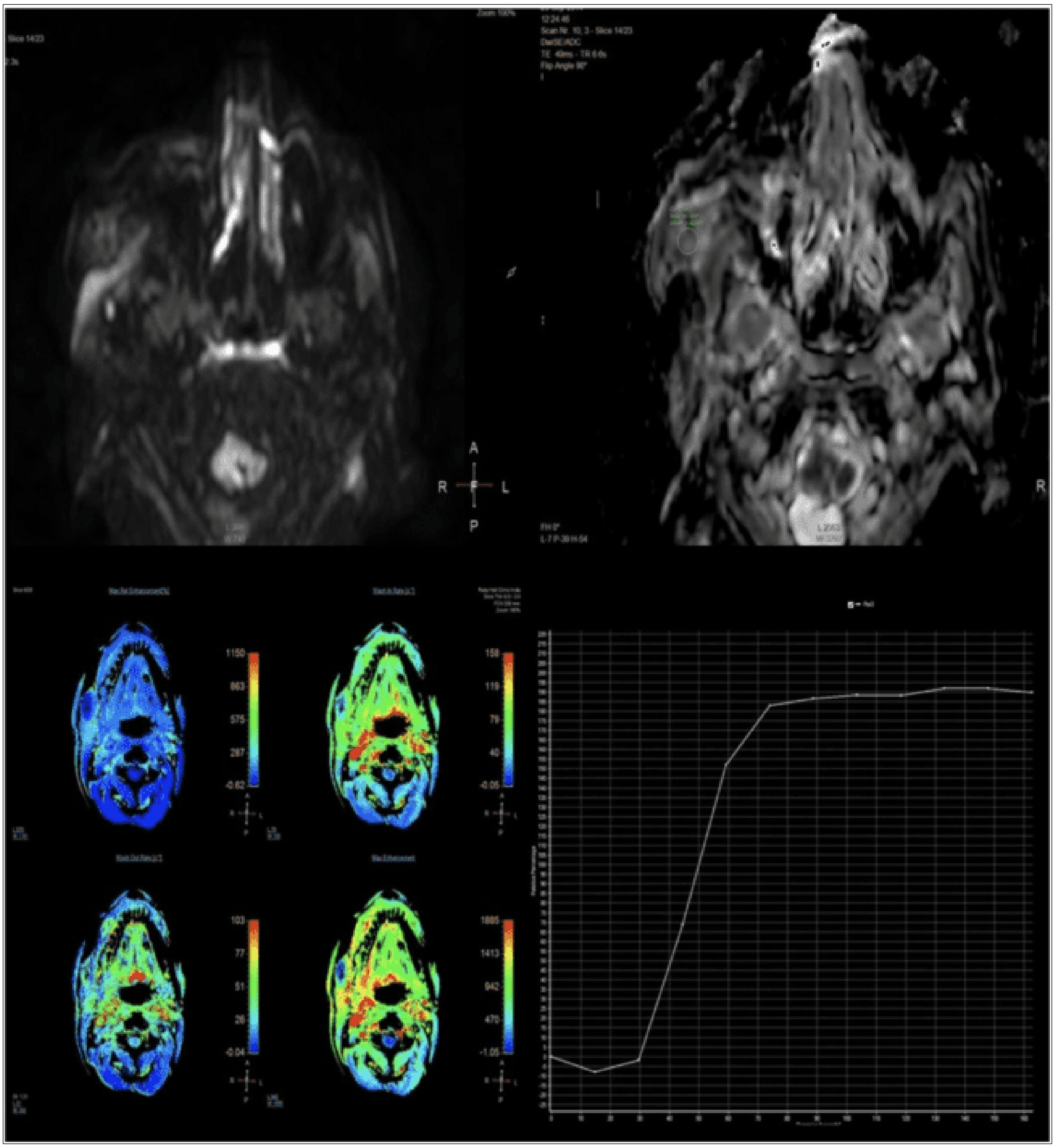

Figure 4 Case of Pleomorphic adenoma. The upper row shows diffusion restriction on diffusion-weighted images (b=800 mm2/s), with the corresponding area showing low values for the ADC image. The ADC value of the lesion was measured as 1.4×10#3 mm2/s. The lower row DCE-MRI shows Type B TIC

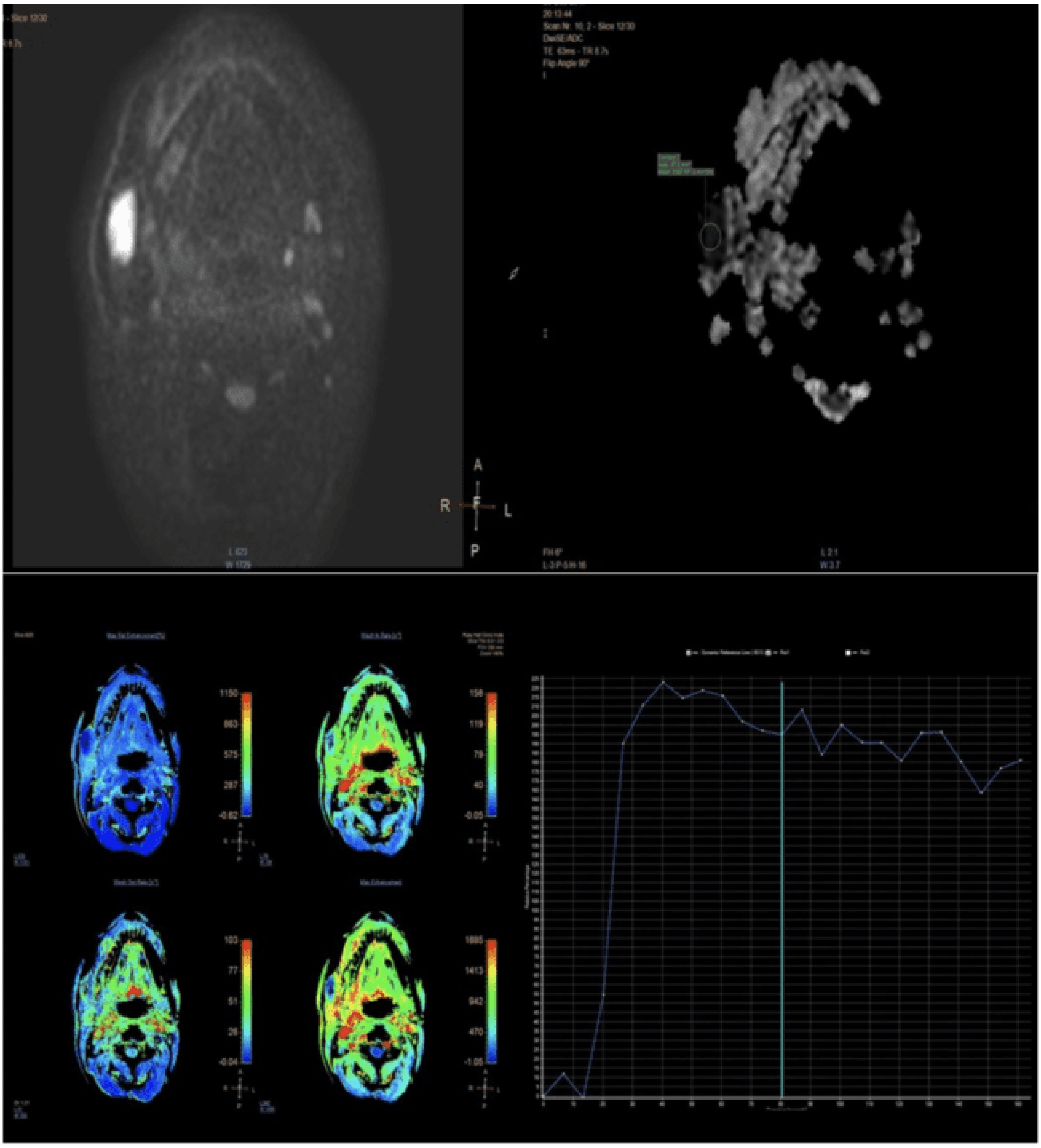

Figure 5 Case of carcinoma buccal mucosa. The upper row shows diffusion restriction on diffusion-weighted images (b=800 mm2/s), with the corresponding area showing low values for the ADC image. The ADC value of the lesion was measured as 0.83 ×10#3 mm2/s. The lower row DCE-MRI shows Type C TIC

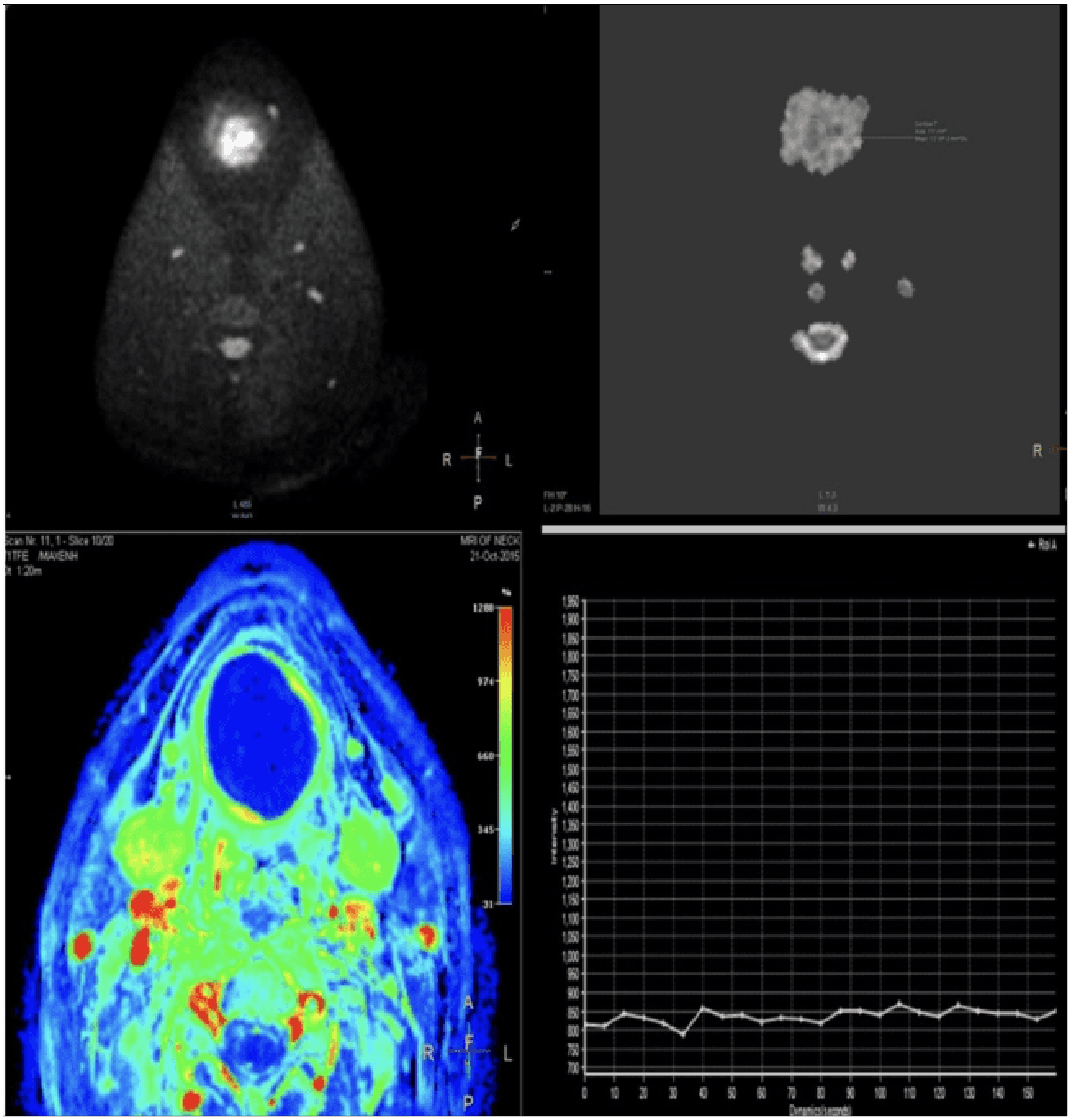

Figure 6 Case of Dermoid cyst . The upper row shows diffusion restriction on diffusion-weighted images (b=800 mm2/s), with the corresponding area showing low values for the ADC image. The ADC value of the lesion was measured as 1.2 ×10#3 mm2/s. The lower row DCE-MRI shows Type D TIC

4. Discussion

Our findings emphasize the significance of DWI and DCE-MRI in differentiating benign from malignant head and neck masses. The results establish ADC values and perfusion curve analysis as promising imaging biomarkers in clinical practice, with DWI ADC values at both b=600 and b=800 showing high sensitivity and specificity for diagnosing malignancy.

The diagnostic accuracy of ADC values observed in our study aligns with previous research highlighting DWI's excellence in tumor characterization. The high sensitivity (100%) and specificity (77.2% for b=600 and 86.36% for b=800) confirm that restricted diffusion in malignant lesions—due to increased cellular density—results in distinctly lower ADC values (14,16). Previous studies have similarly demonstrated that malignancies exhibit significantly lower

ADC values, while benign lesions present relatively higher values due to reduced cellularity and expanded extracellular space (17,18).

Notably, the higher specificity of b=800 compared to b=600 suggests enhanced ability to differentiate malignant from benign tumors at higher b-values. This finding corresponds with literature indicating that increased b-values confer better sensitivity for detecting malignancy with DWI (15).

Regarding DCE-MRI, our study confirms the value of perfusion curve patterns in lesion characterization. Type A and D curves predominantly appeared in benign lesions, while Type C curves strongly indicated malignancy. These findings align with previous reports that washout patterns (Type C) are characteristic of malignant tumors due to rapid neovascularization and increased vascular permeability (19,20). The observation that Type B curves appeared in both malignant (42%) and benign (22.7%) cases suggests that plateau enhancement is not exclusive to malignancy, corroborating earlier studies that identified intermediate perfusion behavior in certain tumor types (16,18).

Beyond ADC values, the highly significant diagnostic value ($p<0.0001$) of DCE-MRI perfusion curves in differentiating benign from malignant lesions underscores their clinical utility. These methods provide noninvasive, quantitative measures that may reduce unnecessary biopsies and facilitate treatment planning and prognostication. Multiple studies support incorporating DWI and DCE-MRI as complementary imaging modalities, particularly when histopathological confirmation presents challenges (14,17,19).

DWI carries particular value for patients with renal impairment or contrast allergies, as it provides rapid diagnostic information without contrast administration. Our study also supports previous findings that low pre-treatment ADC values correlate with better responses to chemoradiation therapy (15,20).

4.1. Clinical Implications and Future Recommendations

Our findings suggest that both DWI and DCE-MRI should be incorporated into core imaging protocols for evaluating head and neck tumors. DWI offers particular advantages in distinguishing tumor-free soft tissue and demonstrates high sensitivity for detecting malignancy. Meanwhile, DCE-MRI significantly enhances lesion characterization, especially regarding tumor vascularity, microenvironment, and treatment response (17).

Future research should include larger patient cohorts and multi-institutional validation to enhance the generalizability of these results. Implementing machine learning-based automated ADC thresholding and quantitative DCE-MRI pharmacokinetic modeling could further improve diagnostic accuracy and minimize observer variability (16,18).

5. Conclusion

This study highlights the valuable contributions of Diffusion-Weighted Imaging and Dynamic Contrast-Enhanced MRI in characterizing head and neck masses, with particular emphasis on differentiating benign from malignant lesions. These imaging techniques offer substantial clinical value for early diagnosis, staging, and follow-up of head and neck tumors, supported by their high sensitivity and specificity.

DWI serves as an excellent and reliable quantitative imaging modality for tumor differentiation based on ADC values. It enables noninvasive assessment without contrast agents, offering safety advantages and rapid acquisition compared to other imaging modalities. DWI effectively accounts for tumor-free soft tissue and cellular density while showing promise in predicting treatment response, as pre-treatment ADC values correlate with tumor responsiveness to chemoradiation therapy. However, larger studies and multi-center trials are needed to validate these findings and establish standardized ADC cut-off values for routine clinical use.

DCE-MRI provides critical assessment of tumor vascularity and perfusion dynamics. By offering functional imaging along with pharmacokinetic parameters such as wash-in and wash-out rates, it reliably differentiates benign from malignant lesions. The perfusion curve patterns serve as important biomarkers for tumor aggressiveness and prognosis, with wash-in rate emerging as a particularly promising quantitative parameter for malignancy detection. DCE-MRI thus plays a vital role in advanced tumor characterization and treatment planning.

In summary, routine application of DWI and DCE-MRI protocols significantly improves diagnosis and clinical management of head and neck malignancies. The combination of DWI's noninvasiveness with DCE-MRI's functional imaging capabilities greatly facilitates early detection, staging, treatment monitoring, and follow-up evaluation. Future research should focus on optimizing imaging protocols, refining ADC thresholds, and implementing artificial intelligence-based image analysis to enhance diagnostic accuracy and reduce observer variability. Standardizing these imaging methodologies will enable more personalized and precise evaluation of head and neck tumors, ultimately improving patient outcomes.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of ethical approval

Institutional Review Board approval was not required because - Our institutional review board (IRB) [or ethics committee] determined that, based on the retrospective, de-identified nature of the data and the minimal risk involved, formal IRB approval and individual informed consent were not required for this specific project.

Statement of informed consent

Written informed consent was not required for this study because - No direct patient contact was made during the study, and all data were collected retrospectively from the hospital's Picture Archiving and Communication System (PACS) and electronic health records (EHR). The data used for the analysis were de-identified according to [relevant guidelines, e.g., HIPAA Safe Harbor provisions] prior to analysis, ensuring patient anonymity.

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