Assessment of nasal and paranasal sinus masses by diffusion-weighted MR imaging

Étude des masses nasales et paranasales par IRM de diffusion

A.A.K.A. Razek*, S. Sieza, B. Maha

Diagnostic radiology department, Mansoura faculty of medicine, 62, ElNokrasi street, Meet Hadr, 53312 Mansoura, Egypt

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Nasal;
Tumor;
Sinus

Introduction

A wide spectrum of malignant tumors and benign lesions can be seen in the nasal cavity and paranasal sinuses.
High-resolution computed tomography (CT) scans help to reveal bony erosion in critical areas, and magnetic resolution imaging (MRI) studies provide excellent delineation of sinonasal tumor from surrounding inflamed soft tissue and secretions, making both of these technologies useful for disease staging and surgical planning. Differentiating malignant nasal and paranasal sinus tumors from benign lesions, characterizing malignant tumors and grading the malignancy are essential for treatment planning as well as determining the patient’s prognosis. However, the appearances of nasal masses on routine CT and MRI are not pathognomonic. Some malignant tumors may be as slow-growing as benign lesions, while some benign lesions extend into adjacent structures, mimicking malignancies. Also, routine imaging of nasal masses does not allow pathological grading or distinguish between the various pathological types of tumors [1–8].

Diffusion-weighted MRI imaging (DWI) offers better characterization of tissues and their physiological processes because it reflects the random motion of water protons, which is disturbed by the intracellular organelles and macromolecules located in tissues. Thus, the apparent diffusion coefficient (ADC) values of tissues vary according to their molecules located in tissues. Therefore, the apparent diffusion coefficient (ADC) values of tissues vary according to their histological results were correlated with the ADC values.

Statistical analyses were carried out using Microsoft Excel and Statistical Package for Social Science (SPSS) version 10 software.

Results

The histopathological findings of nasal and paranasal masses were malignant tumors (n = 38) and benign lesions (n = 12), and the sizes of the masses were 15–120 mm in diameter (mean: 71 mm). They were seen in one or more of the paranasal sinuses, and located in the nasal cavity (n = 22), maxillary sinus (n = 19), ethmoid sinus (n = 12) or frontal sinus (n = 7). The malignant tumors (n = 27) comprised squamous cell carcinoma (n = 20), undifferentiated carcinoma (n = 3), mucocoeplidmoid carcinoma (n = 3) and adenoid cystic carcinoma (n = 1), while sarcomas (n = 11) comprised non-Hodgkin’s lymphoma (n = 4), rhabdomyosarcoma (n = 3), olfactory neuroblastoma (n = 2), chondrosarcoma (n = 1) and osteosarcoma (n = 1). The malignant tumors were well differentiated (n = 13), or poorly differentiated or undifferentiated (n = 25). The benign tumors (n = 12) included juvenile angiofibroma (n = 4), inverted papilloma (n = 3), inflammatory polyps (n = 3), ossifying fibroma (n = 1) and aneurysmal bone cyst (n = 1).

The mean ADC value for malignant tumors was $1.10 \pm 0.25 \times 10^{-3} \text{mm}^2/\text{s}$ and, for benign lesions, $1.78 \pm 0.41 \times 10^{-3} \text{mm}^2/\text{s}$. There was a statistically significant
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Figure 1  Box and plot of the ADC value. A. The mean ADC value for malignant tumors (1.10 ± 0.25 × 10⁻³ mm²/s) is significantly lower (P=0.001) than that for benign lesions (1.78 ± 0.41 × 10⁻³ mm²/s). B. The mean ADC value for carcinoma (1.18 ± 0.24 × 10⁻³ mm²/s) is significantly different (P=0.01) from that for sarcoma (0.89 ± 0.18 × 10⁻³ mm²/s). C. The ADC value in low-grade malignancy (1.29 ± 0.29 × 10⁻³ mm²/s) is significantly different (P=0.005) from that in high-grade malignancy (1.00 ± 0.17 × 10⁻³ mm²/s).

The difference in ADC values between malignant tumors and benign lesions (P=0.001; Fig. 1; Table 1). Using an ADC value of 1.53 × 10⁻³ mm²/s as the threshold value for differentiating malignant from benign lesions gave the best results, with 94% sensitivity, 92% specificity, 93% accuracy, positive predictive value (PPV) of 92%, negative predictive value (NPV) of 94% and an area under the curve (AUC) of 0.89 (Fig. 2).

The mean ADC for sarcomas (0.89 ± 0.18 × 10⁻³ mm²/s) was significantly different (P=0.01) from that for carcinomas (1.18 ± 0.24 × 10⁻³ mm²/s; Fig. 1B). The mean ADC value was 1.15 ± 0.6 × 10⁻³ mm²/s (squamous cell carcinoma; Fig. 3). The highest ADC value (1.73 × 10⁻³ mm²/s) was seen in a patient with an adenoid cystic carcinoma that was mistaken for a benign lesion, whereas the lowest ADC value (0.72 × 10⁻³ mm²/s) was seen in non-Hodgkin's lymphoma (Fig. 4). There were non-significant differences in ADC values for the different types of sarcomas as well as the different types of carcinomas. The ADC used to differentiate carcinomas from sarcomas was 0.97 × 10⁻³ mm²/s, which had 92% sensitivity, 82% specificity, 87% accuracy, PPV of 84%, NPV of 91% and AUC of 0.83 (Fig. 2B).

The mean ADC value for well-to-moderately differentiated malignancies (1.29 ± 0.29 × 10⁻³ mm²/s) was significantly different (P=0.005) from that for poorly differentiated and undifferentiated malignancies (1.00 ± 0.17 × 10⁻³ mm²/s; Fig. 1C). The ADC value used to differentiate low- from high-grade malignancy was 1.16 × 10⁻³ mm²/s, which had 80% sensitivity, 77% specificity, 79% accuracy, PPV of 78%, NPV of 79% and AUC of 0.76 (Fig. 2C).

The mean ADC value for benign lesions was 1.78 ± 0.41 × 10⁻³ mm²/s. Benign vascular lesions such as juvenile angiofibroma had higher ADC values than that of the other benign solid tumors, including inverted papilloma and angiomatous polyps (Fig. 5). There was an insignificant difference in ADC value across the various benign lesions. The highest ADC value was seen in a patient with

Figure 2  Receiver operating characteristic (ROC) curve. A. The cutoff ADC value used to differentiate malignant from benign lesions was 1.53 × 10⁻³ mm²/s. The area under the curve (AUC) was 0.89 with 94% sensitivity, 92% specificity and 93% accuracy. B. The ADC value used to differentiate carcinoma from sarcoma was 0.97 × 10⁻³ mm²/s. The AUC was 0.83 with 92% sensitivity, 82% specificity and 87% accuracy. C. To separate high-grade from low-grade malignancy, the AUC was 0.76, with sensitivity of 80%, specificity of 77% and accuracy of 79%.
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Figure 3  Squamous cell carcinoma. A. Coronal contrast T1-weighted image shows a right nasal mass with marked contrast enhancement associated with retained secretions in the right maxillary sinus. B. Axial ADC map shows a low ADC value in the mass ($1.11 \times 10^{-3} \text{mm}^2/\text{s}$) with a high ADC value in the retained fluid ($2.2 \times 10^{-3} \text{mm}^2/\text{s}$).

Figure 4  Non-Hodgkin’s lymphoma. A. Axial T2-weighted image shows a mass with intermediate signal intensity in both maxillary antra and nasal cavities associated with retained secretions in the right maxillary antrum. B. Axial ADC map shows a low ADC value in the mass ($0.72 \times 10^{-3} \text{mm}^2/\text{s}$) and a high ADC value in the retained fluid ($1.98 \times 10^{-3} \text{mm}^2/\text{s}$).

Aneurysmal bone cyst ($2.278 \times 10^{-3} \text{mm}^2/\text{s}$). The lowest ADC value was seen in a patient with an ossifying fibroma ($0.57 \times 10^{-3} \text{mm}^2/\text{s}$) that was, from the ADC map, misdiagnosed as a malignant tumor.

Discussion

A variety of malignant tumors and benign lesions are seen in the sinonasal region, and distinguishing malignant
and head-and-neck tumors. Guo et al. [21] reported that separate benign from malignant lesions. That, to some extent, ADC analysis is promising in helping to lesion, the greater the likelihood that it is malignant, and lesions. They also added that the lower the ADC value of a P
nant sinonasal tumors was significantly lower (P < 0.001) of carcinomas
\[1—5,19\]. White et al. [19] found a statistically significant difference (P = 0.05) in the ADC values between benign and malignant lesions. They also added that the lower the ADC value of a lesion, the greater the likelihood that it is malignant, and that, to some extent, ADC analysis is promising in helping to separate benign from malignant lesions.

DWB has been used in the characterization of brain and head-and-neck tumors. Guo et al. [21] reported that ADC values were significantly lower in lymphomas than in high-grade gliomas, whereas cellularity was significantly greater in lymphomas than in high-grade gliomas. Maeda et al. [22] found a statistically significant difference in the ADC values (P < 0.001) of carcinomas vs lymphomas in the head and neck. Sumi et al. [23] reported that the ADC value of pharyngeal lymphoma was significantly lower than that of carcinoma, and King et al. [24] were able to differentiate metastatic from lymphomatous nodes in the head and neck using DWI. The present study findings suggest that ADC measurements can differentiate between carcinomas and sarcomas in the nasal and paranasal sinus masses. The mean ADC value for carcinoma is significantly higher than that for lymphoma, which may be attributable to the small foci of necrosis in carcinoma (not identifiable on MRI). In addition, lymphoma cells have relatively high nuclear-to-cytoplasm ratios and are densely packed [10,21—23]. The grade of a malignant tumor gives an idea of the tumor’s prognosis [1—4]. Sumi et al. [23] reported that the ADCs of poorly differentiated and undifferentiated carcinomas (0.691 ± 0.149 × 10^{-3} mm^2/s) were significantly lower than those of moderately differentiated and well-differentiated carcinomas (0.971 ± 0.221 × 10^{-3} mm^2/s) of the pharynx. Abdel Razek et al. [18] reported that the mean ADC value of poorly differentiated malignant tumors was lower than that of well-differentiated malignant pediatric head-and-neck tumors (P < 0.03). In the present study, poorly differentiated and undifferentiated malignant tumors had significantly lower ADC values (P = 0.01) than those in well-differentiated malignant lesions. This is explained by the fact that poorly and undifferentiated tumors show greater cellularity and, subsequently, restricted diffusion. In poorly differentiated or undifferentiated carcinomas, the tumor cells often appear to be overlapping. In the highly and moderately differentiated subtypes, tumor cells are often smaller and the nuclear-to-cytoplasm ratio is lower. Highly differentiated tumor cells often exhibit a plexiform pattern of growth that is associated with richly stromal areas, tissue components that are considered to have better water-diffusing characteristics [9,10,22].

The present study also shows that benign vascular lesions, such as juvenile angiofibroma, have higher ADC values than other benign solid tumors, such as inverted papilloma. This is due to the excess extracellular spaces and free diffusion within vascular lesions [18]. In addition, the perfusion of blood flow and susceptibility effects brought about by hemosiderin deposition may also affect ADC values [25].

In our study, there was overlapping of ADC values between benign and malignant lesions. Indeed, one benign fibroma exhibiting a low ADC value on ADC mapping was misdiagnosed as a malignant tumor. This was attributed to the excess fibrous tissue, typical of fibroma, leading to subsequent restriction of diffusion [26]. Also, one patient with adenoid cystic carcinoma showed a high ADC value. This can be explained by the prominent myxoid stroma in such carcinomas that offers fewer impediments to the movement of water molecules, thus giving rise to higher ADC values [19].

With EPI, a pulse sequence is the sequence of choice for a quantitative study of diffusion, as the diffusion and relaxation effects contribute separately to the MRI signal intensity and, so, are easily separated. Furthermore, EPI is a very fast technique that allows data acquisition with different b values within a reasonably short period of time [18]. However, DWI of the nasal cavity, the paranasal sinuses are prone to susceptibility artifacts, which are considerably minimized when the tumors are greater than 3 cm in size [19]. Diffusion-weighted spin-echo sequences such as split acquisition of fast spin-echo signals (SPLICE), line scans and fast asymmetrical spin-echo (FASE) have been used in the evaluation of head-and-neck lesions, but they all have long

<table>
<thead>
<tr>
<th>Pathology</th>
<th>ADC value (minimum—maximum)</th>
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<tbody>
<tr>
<td>Squamous cell carcinoma (n = 20)</td>
<td>1.15 ± 0.6 (1.01—1.27)</td>
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<tr>
<td>Adenoid cystic carcinoma (n = 1)</td>
<td>1.73</td>
</tr>
<tr>
<td>Mucoepidermoid carcinoma (n = 3)</td>
<td>1.35 ± 0.58 (1.13—1.42)</td>
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<tr>
<td>Undifferentiated carcinoma (n = 3)</td>
<td>1.35 ± 0.05 (1.01—1.99)</td>
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<tr>
<td>Non-Hodgkin’s lymphoma (n = 4)</td>
<td>0.72 ± 0.66 (0.67—0.82)</td>
</tr>
<tr>
<td>Rhabdomyosarcoma (n = 3)</td>
<td>0.85 ± 0.60 (0.78—0.89)</td>
</tr>
<tr>
<td>Olfactory neuroblastoma (n = 2)</td>
<td>0.92 ± 0.14 (0.91—0.93)</td>
</tr>
<tr>
<td>Osteosarcoma (n = 1)</td>
<td>0.78</td>
</tr>
<tr>
<td>Chondrosarcoma (n = 1)</td>
<td>0.93</td>
</tr>
<tr>
<td>Juvenile angiofibroma (n = 4)</td>
<td>1.88 ± 0.86 (1.77—1.97)</td>
</tr>
<tr>
<td>Inverted papilloma (n = 3)</td>
<td>1.72 ± 0.70 (1.65—1.79)</td>
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<tr>
<td>Inflammatory polyps (n = 3)</td>
<td>1.95 ± 0.01 (1.83—2.03)</td>
</tr>
<tr>
<td>Ossifying fibroma (n = 1)</td>
<td>0.57</td>
</tr>
<tr>
<td>Aneurysmal bone cyst (n = 1)</td>
<td>2.27</td>
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examination times, albeit with fewer susceptibility artifacts [25,27]. As echoplanar DWI is limited by notable susceptibility artifacts in the head and neck due to the presence of dental work as well as the adjacent air and bone, it may be of interest to use PROPELLER EPI and parallel imaging to improve image quality [28,29].

The present study has a few limitations, including the heterogeneity and small number of pathological types of lesions. Further studies of squamous cell carcinoma are recommended, as this is the most common type of tumor seen in the nasal cavity, and larger studies are required to confirm the results, given the wide variety of benign and malignant tumors observed in the sinonasal region. In addition, the ROI for measuring ADC values could not be correlated with histological specimens on a site-to-site basis, and there was no correlation between the ADC value and tumor cellularity. Finally, there was no comparison between the ADC value and standard MRI in the differentiation of malignant and benign sinonasal tumors. Further studies comparing the ADC value in sinonasal squamous cell carcinoma with standard MRI findings are recommended.

We conclude that the ADC value is a quantitative parameter that provides useful information for the differentiation of malignant and benign nasal and paranasal sinus tumors. It may also help in the differentiation of carcinoma from sarcoma as well as in the grading of malignant tumors. For this reason, it is recommended that diffusion-weighted MRI be added to routine MRI studies in patients with nasal and paranasal sinus tumors.

References