Role of MRI Diffusion in Assessment of Malignant Mediastinal Masses

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Abstract

Background: Diffusion MR imaging is a non-invasive functional imaging technique that can be incorporated into routine morphological MR examination to provide functional assessments of mediastinal lesions. It can be used for assessment of malignant mediastinal masses, differentiating benign from malignant masses as well as staging of central bronchogenic carcinoma. This method is an excellent alternative to PET/CT in the assessment of malignant mediastinal masses.

Patients and Methods: This study included 23 patients; 13 males and 10 females in the period from June 2013 to July 2014. The mean age was 53.3 ± 16.7 (range: 22-82 years). Cases were referred from the Chest and Oncology Departments to Radiology Department in Kasr El-Aini Hospital for MRI assessment. The complaints varied between dyspnea, chest pain, cough, hemoptysis, fatigue and loss of weight. A superconducting 1.5 T MRI machine with a four-channel body phased-array coil was used for the examination. Biopsy and histopathological assessment was done after that.

Results: MRI examination with diffusion weighted imaging was able to detect malignant mediastinal masses. The all showed restricted diffusion with the mean ADC for untreated bronchogenic carcinoma was 0.9 ± 0.44 X 10^-3 mm^2/s, for lymphoma was 1.22 ± 0.23 X 10^-3 mm^2/s, for thymoma was 1.24 ± 0.2 X 10^-3 mm^2/s. DWI was able to stage central bronchogenic carcinoma and differentiate the central mass from the post obstructive collapse where the central mass showed lower ADC value than the post obstructive collapse. The untreated cases of bronchogenic carcinoma showed more diffusion restriction and lower ADC value than the treated cases.

Conclusion: MRI with diffusion weighted images can detect malignant mediastinal masses, detect and stage lung cancer as well as differentiate central bronchogenic carcinoma from post obstructive collapse.

Key Words: Magnetic resonance imaging – Diffusion – Bronchogenic carcinoma – Lymphoma – Thymoma – Angiosarcoma.

Introduction

DIFFUSION weighted imaging MRI is emerging as a valuable chest imaging modality offering a unique combination of morphological and functional information in a single examination without any radiation burden to the patient. Experience with thoracic applications of Diffusion Weighted Imaging (DWI) techniques is still growing, and preliminary studies have reported promising results [1]. MRI DWI depends on the magnetic resonance signal related to random thermal motion (Brownian motion) or the “diffusion” of water protons in tissue [2].

In solid malignant lesions, the extravascular extracellular space is relatively diminished compared with the intracellular space due to an increased number of tightly packed cells, cellular pleomorphism, large cell volume and neoangiogenic vessels. This increased microstructural density will restrict random water molecule movement [3].

The evaluation of the data provided by DWI can be either qualitative or quantitative. Malignant lesions, in general, show restricted diffusion in the form of bright signal on diffusion-weighted images acquired using a high b-value and dark signal on the ADC map (lower ADC values) as compared with benign lesions [4].

MRI can detect and stage central lung cancer, and this method could be an excellent alternative to PET/CT in the investigation of lung malignancies and other diseases [5].

In the assessment of central lung cancer, diffusion MR imaging can be used for differentiating lung cancer from benign lung masses, differentiating central mass from post obstructive collapse as well as the assessment of associated lymph nodes and distant metastases [3].

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Central bronchogenic tumors often cause postobstructive pneumonia resulting in lung volume loss that can induce atelectasis. Atelectasis and tumors both appear as solid dense shadows on standard radiography, so differentiation can be difficult [6]. However, accurate characterization of the tumor is important for clinical staging, and differentiation of the tumor mass from atelectasis is important for CT-guided biopsy, setting of the radiation field for radiotherapy, and evaluation of therapeutic results [7].

MRI DWI can discriminate the cancer limits from the obstructive atelectasis, according to differences in signal intensity in DWI acquisitions with high b values. It was found that central bronchogenic carcinomas will show higher signal intensity and lower ADC values than benign obstructive atelectasis, according to differences in cellularity and grade of occupancy of the interstitium [8].

Diffusion MR imaging can be used for the diagnosis of metastatic lymph nodes with a high degree of accuracy. The mean ADC value in metastatic lymph nodes is less than that in nodes without metastases and similar to that in primary lesions [9].

Applications of DWI in malignancies include monitoring the treatment response after chemotherapy or radiation, discriminating post-therapeutic changes from residual tumors, and detecting recurrent cancer [2].

**Patients and Methods**

This study included 23 patients; 13 males and 10 females in the period from June 2013 to July 2014. The mean age was 53.3 ± 16.7 (range: 22-82 years).

Cases were referred from the Chest and Oncology Departments to Radiology Department in Kasr El-Aini Hospital for MRI assessment.

The complaints varied between dyspnea, chest pain, cough, hemoptysis, fatigue and loss of weight.

**Inclusion criteria included:** Patients with malignant mediastinal masses diagnosed by computed tomography.

**Exclusion criteria included:** Patients with pacemaker, cochlear implants, cerebral aneurysm clips, ocular metallic foreign body, bullets or gunshots near great vessels or vital organs.

All cases were subjected to the following:

- Proper clinical evaluation for all patients with relevant laboratory investigations including: CBC, random blood sugar, liver functions and kidney functions.
- Computed tomography of the chest.
- Magnetic resonance imaging using a 1.5-T superconducting imager using a four-channel body phased-array coil.

**MRI protocol:** Respiratory gating has been used. The MR scanning sequences were T1W1, T2WI, T2 STIR & DWI, quantitative DWI analysis (ADC measurement).

- T1WI was obtained with the spin echo sequence with the following parameters: Repetition time/echo time: 10ms/5ms; number of excitations: 2; direction of frequency encoding: R/L; section thickness: 8mm; gap: 0.5mm; field of view: 36-40cm; matrix: 288 X 224.
- T2WI was obtained with the following parameters: Repetition time/echo time, 664ms/80ms; number of excitations, 3; direction of frequency encoding: R/L; section thickness, 8mm; gap, 1.5mm; field of view, 36~40cm; matrix, 288 X 224.
- T2 STIR was obtained with the following parameters: Repetition time/echo time, 1.6ms/20ms; number of excitations, 3; direction of frequency encoding: R/L; section thickness, 10mm; gap, 1mm; field of view, 36~40cm; matrix, 288 X 224.
- DWI is typically acquired in a transverse plane, using at least two b-values; low (0-50s/mm²) and intermediate-to-high b-values (500-1000s/mm²). The typical slice thickness is 4-9mm with an interslice gap of 0-1.5mm, and the number of excitations ranges from 1 to 10.
- Quantitative DWI analysis (ADC measurement).
- Biopsy and histopathological assessment was done after that.

**MR imaging analysis:**

- Each lesion was first evaluated on conventional images for location, size and the presence of cystic-necrotic parts.

**Quantitative analysis:**

ADCs were calculated from the ADC maps which were constructed from $b=0$ and $b=1000$ sec/mm² values. A ROI was drawn centrally, and the size of ROI was kept as large as possible on
the ADC map avoiding the macroscopic necrosis and major blood vessel in the light of the conventional images. The average of three measurements was recorded as the final result.

- Presence of hilar or mediastinal lymphadenopathy.
- Presence of central bronchial obstruction and post obstructive collapse.
- Presence of pulmonary nodules.
- Pleural or pericardial collections.
- Presence of upper abdominal lesions (e.g. hepatic, splenic or suprarenal lesions).

**Statistical analysis:**

ADC was statistically described in terms of mean ± standard deviation (±SD), median and range. All statistical calculations were done using computer program SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA) release 15 for Microsoft Windows (2006).

**Results**

This study included 23 patients; 13 males and 10 females (mean age 53.3 ± 16.7) which were pathologically diagnosed as summarized in the following table (Table 1).

**MRI findings in patients with pathologically proven bronchogenic carcinoma:**

This group included 10 patients diagnosed as central bronchogenic carcinoma. Nine males and one female patient with mean age 59.4 ± 11.4 years (range: 36-76 years).

Three out of ten cases (30%) were under treatment.

Nine cases showed soft tissue mass lesions with restricted diffusion and low ADC values, whereas one treated case showed no sizable residual mass lesions.

The untreated cases showed lower ADC values ranging from 0.6 up to 1.2 (mean 0.9 ±0.44) X 10⁻³ mm²/s, whereas the treated cases showed relatively higher ADC values 1.6 & 1.35 (mean 1.48 ±0.18) X 10⁻³ mm²/s (Chart 1).

**Central mass with post obstructive collapse:**

4 cases (40%) showed central mass with post obstructive collapse; conventional T2 WI was able to differentiate the central mass from the post obstructive collapse in only two out of the four cases where the collapsed lung showed higher T2 signal intensity compared to the central mass.

Diffusion weighted imaging was able to differentiate central mass from post obstructive collapse in three cases where the central mass showed higher signal intensity in diffusion WI and lower ADC value than the benign post obstructive atelectasis Fig. (1). In one case both the central mass and post obstructive collapse showed similar ADC values denoting tumoral infiltration of the collapsed lung segment (Table 2).

The mean ADC value for the masses of central lung carcinoma with post obstructive collapse was 1.15±0.06 X 10⁻³ mm²/s and for consolidation was 1.9±0.5 X 10⁻³ mm²/s. ADC of central carcinoma masses was significantly lower than that of post obstructive collapse.

**Associated mediastinal/hilar lymphadenopathy:**

Quantitative analysis has also been used to assess associated mediastinal/hilar lymph nodes. Only lymph nodes appropriate to criteria were measured (number of total lymph nodes measured= 14 lymph nodes).

Lymph nodes were localized and defined as follows; 5 right paratracheal, 3 prevascular, 2 subcarinal, 2 hilar, 1 aorto-pulmonary and 1 cardio-phrenic lymph node.

Among the 14 nodes measured: 12 showed restricted diffusion with mean ADC value (1.067 ± 0.33) X 10⁻³ mm²/s (range 0.6-1.5), whereas 2 lymph nodes showed facilitated diffusion and were hyperintense on the calculated ADC map Fig. (2).

**Other associated findings:**

Associated MRI findings that were encountered (Table 3) included:

- Pulmonary nodules in 4 cases; (ADC value=1.63 ±0.6) X 10⁻³ mm²/s.
- Metastatic suprarrenal masses in 2 cases; (ADC value=1.4) X 10⁻³ mm²/s.
- Pleural effusion in 2 cases; which showed areas of low T2 signal intensity with (ADC value=1.8 in 1 case and 2.5 in the other case with average of 2.15±0.49) X 10⁻³ mm²/s.
- Pericardial effusion in 1 case.
- Multiple liver deposits in 1 case.
- Metastatic left supra-clavicular and bilateral axillary lymph node enlargement (ADC value= 0.95±0.07) X 10⁻³mm²/s.
MRI findings in patients with pathologically proven lymphoma:

Our study involved the evaluation of 7 patients (4 males and 3 females) with lymphoma.

The mean age of patients with lymphoma was 35.9±13.9 years (range: 22-60 years).

Number of total lymph nodes measured=17.

Lymph nodes localized and defined as follows: 2 amalgamated anterior mediastinal mass, 6 retrocaval paratracheal, 5 prevascular, 2 hilar, 1 aortopulmonary and 1 posterior mediastinal.

ADC analysis: The mean ADC for lymphoma was (1.22±0.23) X 10⁻³ mm²/s Fig. (3).

Associated findings in patients with lymphoma:
- Vertebral osseous lesions in 1 case.
- Splenic mass in 1 case.
- Pleural effusion in 1 case.
- Liver deposits in 1 case.

MRI findings in patients with pathologically proven malignant thymoma:

Five cases were diagnosed as thymoma (16.6%), one male and four females with mean age 67.2 ± 9.4 years (range: 58-82 years). On ADC analysis all thymoma cases presented with anterior mediastinal mass lesion with mean ADC (1.24±0.2) X 10⁻³ mm²/s (range 0.9-1.35) Fig. (4).

Other cases:

One female patient was diagnosed as angiosarcoma presenting with posterior mediastinal mass lesion with ADC value measuring 1 X 10⁻³ mm²/s. Associated findings included retrocaval lymph nodes with facilitated diffusion and hepatic focal lesion, with restricted diffusion (ADC=0.77 X 10⁻³ mm²/s) (Table 4).

### Table (1): Summary of patients' diagnosis.

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bronchogenic carcinoma</td>
<td>10</td>
</tr>
<tr>
<td>lymphoma</td>
<td>7</td>
</tr>
<tr>
<td>Thymoma</td>
<td>5</td>
</tr>
<tr>
<td>Angiosarcoma</td>
<td>1</td>
</tr>
</tbody>
</table>

### Table (2): ADC values in cases of central mass with post obstructive collapse.

<table>
<thead>
<tr>
<th></th>
<th>ADC value of central mass (X 10⁻³ mm²/s)</th>
<th>ADC value of post obstructive collapse (X 10⁻³ mm²/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>1.1</td>
<td>2</td>
</tr>
<tr>
<td>Case 2</td>
<td>1.1</td>
<td>2</td>
</tr>
<tr>
<td>Case 3</td>
<td>1.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Case 4</td>
<td>1.2</td>
<td>1.2</td>
</tr>
</tbody>
</table>

### Table (3): Associated MRI findings in patients with bronchogenic carcinoma.

<table>
<thead>
<tr>
<th>MRI associated findings</th>
<th>No of patients</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulmonary nodules.</td>
<td>4</td>
<td>40%</td>
</tr>
<tr>
<td>Suprarenal masses.</td>
<td>2</td>
<td>20%</td>
</tr>
<tr>
<td>Pleural effusion.</td>
<td>2</td>
<td>20%</td>
</tr>
<tr>
<td>Pericardial effusion.</td>
<td>1</td>
<td>10%</td>
</tr>
<tr>
<td>Liver deposits.</td>
<td>1</td>
<td>10%</td>
</tr>
<tr>
<td>Left supra-clavicular and bilateral axillary lymph nodes.</td>
<td>1</td>
<td>10%</td>
</tr>
</tbody>
</table>

### Table (4): ADC measurements in thymoma and angiosarcoma.

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Thymoma (n=5)</th>
<th>Angiosarcoma (n=1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC (X 10⁻³ mm²/s)</td>
<td>1.24±0.2</td>
<td>1</td>
</tr>
</tbody>
</table>

Fig. (1): A 70-year-old male presenting with hemoptysis (A) Coronal MR T2WI, (B) Axial DWI, (C) ADC map, showing left central bronchogenic carcinoma with post obstructive total lung collapse and left pleural effusion. The mass showed lower T2WI signal intensity, higher DWI signal and lower ADC value than the post obstructive collapse. The mean ADC for the mass was 1.2 X 10⁻³ mm²/s and for the collapse was 2.4 X 10⁻³ mm²/s.
Fig. (2): A 61 year old male presenting with hemoptysis (A) Coronal T2WI, (B) Axial T2WI, (C) Diffusion weighted MRI image (D) ADC map showing right hilar soft tissue mass lesion/bronchogenic carcinoma attenuating the right main bronchus and the right pulmonary artery being hypointense on T2WI, showing restricted diffusion with low ADC value; mean ADC value of 0.64 X 10^{-3} \text{mm}^2/\text{s}. It is seen merging with mediastinal prevascular, retrosternal and right paratracheal infiltrative mass lesion with restricted diffusion (ADC=0.6) consistent with nodal metastasis.

Fig. (3): A 40 year old female presenting with dyspnea (A) Axial T2 weighted MRI image, (B) Diffusion weighted MRI image (C) Inverted grey scale high $b$-value PET like images (D) ADC map; showing anterior mediastinal soft tissue mass lesion diagnosed as lymphoma. It elicits heterogenous T2 signal intensity with hyperintense central areas of breaking down, high signal intensity on DWI and low signal on ADC map with mean ADC value of 1.2 X 10^{-3}\text{mm}^2/\text{s}.
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Fig. (4): A 60 year old male presenting with chest pain and dyspnea (A) Axial T2 weighted MRI image, (B) Diffusion weighted MRI image (C) ADC map; showing anterior mediastinal soft tissue mass lesion diagnosed as malignant thymoma. It elicits heterogenous T2 signal intensity with hyperintense central areas of breaking down, high signal intensity on DWI and low signal on ADC map with mean ADC value of $1 \times 10^{-3} \text{mm}^2/\text{s}$.

![Chart showing ADC values for treated and untreated cases of bronchogenic carcinoma. The mean ADC value for treated cases was relatively higher.](chart)

Discussion

This study included evaluation of 23 patients with mediastinal mass lesions by MRI chest with diffusion weighted images; 13 males and 10 females with mean age of $53.3 \pm 16.7$ (range: 22-82 years).

Cases were referred from the Chest and Oncology Departments to Radiology Department in Kasr El-Aini Hospital for MRI assessment.

Our study included 10 cases with bronchogenic carcinoma, 7 cases with lymphoma, 5 cases with thymoma, one case of angiosarcoma.

Among the 10 cases of central bronchogenic carcinoma; it was found that the mean ADC value for untreated bronchogenic carcinoma was $(0.9 \pm 0.44) \times 10^{-3} \text{mm}^2/\text{s}$ (range from 0.6 to 1.2).

This is consistent with Liu et al., [10] who reported that the mean ADC value of benign lesions was greater than that of malignant tumors and that the optimal threshold ADC value for the differentiation of malignant tumors from benign lesions was $1.4 \times 10^{-3} \text{mm}^2/\text{s}$.

Tondo et al., [11] used an ADC value of $1.25 \times 10^{-3} \text{mm}^2/\text{s}$ as a threshold to differentiate malignant from benign lesions.

In our study, four cases showed central mass with post obstructive lung collapse. T2WI was able to differentiate the mass from the collapse in two cases whereas diffusion WI and ADC values could differentiate the mass from the collapse in three cases and in one case both the central mass and post obstructive collapse showed similar ADC values denoting tumoral infiltration of the collapsed lung segment.

Qi et al., [12] reported that using a combination of T2-weighted images and diffusion-weighted images was superior to bolus CT or T2-weighted imaging alone for differentiating lung cancer from post-obstructive collapse, with a sensitivity of 88%.

In our study we found that the mean ADC value for the central lung masses was significantly lower than post obstructive collapse; the mean ADC for the central mass was $(1.15 \pm 0.06) \times 10^{-3} \text{mm}^2/\text{s}$ and for collapse was $(1.9 \pm 0.5) \times 10^{-3} \text{mm}^2/\text{s}$.

Whereas Yang et al., [7] reported that the mean ADC for the central lung carcinoma was significantly less than that of the atelectasis $(1.83 \pm 0.58)$ vs. $(2.90 \pm 0.26) \times 10^{-3} \text{mm}^2/\text{s}$.

Mediastinal lymphadenopathy was detected in our cases of central bronchogenic carcinoma, most of which showed restricted diffusion with mean ADC value $(1.067 \pm 0.33) \times 10^{-3} \text{mm}^2/\text{s}$ (range 0.6-1.5), whereas only 2 lymph nodes showed facili-
tated diffusion and were hyperintense on the calculated ADC map.

In their study Hasegawa et al., [13] found that diffusion MR imaging can be used for the diagnosis of metastatic lymph nodes in patients with NSCLC with a high degree of accuracy (95%).

Kosucu et al., [14] found that the ADC value is significantly lower in metastatic nodes (1.01 ± 0.02) X 10^{-3} mm²/s than in benign lymph nodes (1.51 ± 0.07) X 10^{-3} mm²/s.

Whereas Nomori et al., [9] reported that the cut-off ADC value used to differentiate metastatic from non-metastatic lymph nodes in patients with NSCLC is 1.63 X 10^{-3} mm²/s, with an accuracy of 89%.

Associated pleural effusion was found in 2 cases; which showed areas of low T2 signal intensity with ADC value 1.8 in 1 case and 2.5 in the other case (average of 2.15±0.49) X 10^{-3} mm²/s.

İnan et al., [15] reported that the ADCs of the exudative effusions were significantly lower than those of transudative effusions, mean ADC was (3.3±0.7) X 10^{-3} mm²/s for exudative effusions and (3.7±0.3) X 10^{-3} mm²/s for transudative effusions. According to İnanc et al., setting the cutoff value at 3.6 X 10^{-3} mm²/s, ADC had a sensitivity of 71% and a specificity of 63% for differentiating transudative from exudative effusions.

Our study involved the evaluation of 7 patients with lymphoma; Number of total lymph nodes measured was 17.

In our study the mean ADC for lymphoma was (1.22±0.23) X 10^{-3} mm²/s, whereas Gümüştaş et al., [16] reported that the mean ADC for lymphoma was (1.3±0.581) X 10^{-3} mm²/s.

Our study involved 5 thymoma cases presented with anterior mediastinal mass lesion with an ADC value of (1.24±0.2) X 10^{-3} mm²/s which is consistent with Abdel Razek et al., [17] who found that the ADC value of malignant mediastinal tumors (1.09±0.25) X 10^{-3} mm²/s is significantly lower than that of benign tumors (2.38±0.6) X 10^{-3} mm²/s.

Conclusion:

MRI diffusion can detect malignant mediastinal masses which show more restricted diffusion and lower ADC value than benign lesions.

It can differentiate central mass of lung cancer from post obstructive collapse or consolidation (even better than PET CT) thus aids in guiding biopsy and sparing of the normal structures in radiotherapy.

Moreover it can stage central lung cancer by the assessment of associated lymph nodes and distant metastases.

References


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