Role of Functional MRI (Dynamic contrast enhanced study & DWI) in diagnosis of chest masses

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Abstract

Purpose: to evaluate the role of measurement of ADC value & Dynamic contrast enhanced study in the differentiation between benign and malignant mediastinal lesions. Patients and methods: This study included 70 patients ranging in age from 22 to 82 years with mean age 49.3 +/- 16.85. They were 40 males and 20 females. 40 patients had mediastinal lesions, 20 had lung lesions and 10 had chest wall and pleural lesions. Conclusion: Diffusion weighted MRI and measurement of ADC value are very helpful in the differentiation between benign and malignant mediastinal lesions.

Keywords: Functional MRI, Diffusion weighted imaging (DWI), Chest masses.

1. Introduction

Chest tumors represent wide diversity of disease states. Most common lesions in chest seen in mediastinum Although more than two thirds of mediastinal tumors are benign, masses in the anterior compartment are more likely to be malignant (Duwe Beau V et al. & Strollo DC et al.) [6, 16]. In the study by Davis et al. of 400 patients with mediastinal masses, malignancy was seen in 59%, 29%, and 16% respectively of anterior, middle and posterior mediastinal masses. Despite being the most common modality used for imaging the mediastinum, computed tomography (CT) cannot be used to reliably differentiate benign from malignant lesions (Whitten CR et al.) [19]. With the advent of the echo-planar magnetic resonance imaging (MRI) technique, diffusion weighted-magnetic resonance imaging (DW-MRI) of the abdomen and thoracic cavity has become possible with fast imaging time that minimizes the effect of gross physiological motion from respiration and cardiac movement (Koh DM et al) [11]. There is growing interest in the application of diffusion weighted imaging (DWI) in the evaluation of patients with cancer. The ADC is inversely correlated with tissue cellularity. The motion of water molecules is more restricted in tissues with a high cellular density associated with numerous intact cell membranes. The ADC value is estimated to be lower in viable tumor tissue with densely packed diffusion-hindering obstacles than in tissue with less densely packed obstacles such as tumor necrosis and benign tissue (Guo Y. et al. & Hemeth AM. et al.) [9, 10].

2. Patients and methods

This study included 70 patients ranging in age from 22 to 82 years with mean age 49.3 +/- 16.85. They were 40 males and 20 females. 40 patients had mediastinal lesions, 20 had lung lesions and 10 had chest wall and pleural lesions. They underwent diffusion weighted MRI with b values of 1000 and 0 s/mm2. ADC value measurement and histopathological diagnosis were done for most lesions. Correlation between ADC value and histopathology was done through statistical analysis.

2.1. MRI protocol

All MR studies were performed with a 1.5-T imager (Signa Twinspeed HD; GE Healthcare, Waukesha, Wis) using a phased-array body coil (Eight-Channel Body Array Coil; GE Healthcare). Patients were imaged in the supine position. Prior to diffusion weighted MRI, axial T1 weighted images and coronal T2-weighted images with and without fat saturation were obtained from each patient. Diffusion weighted MRI was performed in the axial plane on the basis of T1- and T2-weighted images. It was obtained during quiet breathing with a motion-probing gradient (MPG) of b values of 1000 and 0 s/mm2 in all x, y, and z directions, using the following parameters: spin-echo-based echo-planar imaging; 4100–5100/49.8; receiver bandwidth 250 kHz; section thickness, 3 mm (gapless); field of view 40–48 cm; echo space 396–420s; echo train length 96–128; and real spatial resolution in the phase encoding direction 2.08–2.50 mm. Apparent diffusion coefficient (ADC) maps were reconstructed in all cases by using a software on the basis of the images obtained with a b factor of 1000 s/mm2 and 0 s/mm2. ADC was calculated on these maps by drawing elliptical regions of interest (ROI). We used the same method of Gumustas et al. (8) The size of the ROI was kept as large as possible covering at least two thirds of the lesion yet avoiding interference from surrounding lung tissue, major blood vessels and necrotic parts. This procedure was done three times and the average of these measurements was recorded as the final mean ADC value. The final diagnosis was made by biopsy with histopathological examination. The biopsy was CT guided core biopsy in 28 patients, bronchoscopic in 8 and open surgery in 6 patients.

3. Results

40 malignant mediastinal lesions in 24 patients and 20 benign mediastinal lesions in 16 patients. The

mean ADC value for malignant lesions was 0.91 ± 0.23 x 10_3 mm2/s while for the benign lesions it was 1.80 ± 0.55 x 10_3 mm2/s. The cutoff point of the ADC value differentiating malignant from benign mediastinal lesions was 1.15 x 10 _3 mm2/s with sensitivity of 95%, specificity of 93.8%, positive predictive value of 90.5%, and negative predictive value of 96.8% and accuracy of 94.4%. The mean ADC value for the malignant lesions was significantly lower than the mean ADC value for benign lesions (P value <0.001). The number and mean ADC value of different histo-pathological types of the benign and malignant mediastinal lesions table (1).

Dynamic contrast MRI was done 30 cases of anterior mediastinum masses. The time intensity curve (TIC) was persistent (Type I) in 4 lesions, plateau (Type II) in 19 lesions and washout (Type III) in 7 lesions. There was significant association between the type of the time intensity curve and the histopathological type of the mass lesion. Type III washout curve was seen only in thymic epithelial tumors table (2)

20 pulmonary lesions were 14 malignant lesions and 6 benign lesions. The mean ADC value of malignant lesions was 1.264±0.23x10-3 mm2/sec and mean ADC value for benign lesions was 1.482±0.52x10-3 mm2/sec. There was significant difference between mean ADC value of malignant and benign pulmonary lesion with P-value=0.003 .

The mean lesion to cord ratio (LCR) was 1.315±0.423 for malignant lung lesions and 0.741±0.421 for benign ones. The difference between mean LCR of malignant and benign pulmonary lesions was highly significant (p<0.001).

Using a cutoff value of 1.027x10-3 mm2/sec, the ADC showed a positive predictive value of 85%, a negative predictive value of 68%, and an accuracy of 78 % in the detection of cancer lesions. However, by using a cutoff value of 0.971, the LCR had a positive predictive value of 93%, a nega¬tive predictive value of 76%, and an accuracy of 85 % for the detection of lung malignancies.

10 chest wall and pleural lesions were 6 benign and 4 malignant. The mean ADC value for benign lesions was 1.65 ±0.17x 10_3 mm2/s and mean ADC value for the malignant lesion was 1.23 ±0.19x 10_3 mm2/s. The mean ADC value of the malignant lesions was significantly different from mean ADC value of benign lesion with p < 0.001.

Table (1) number and mean ADC value of various benign and malignant mediastinal lesions.

Pathology	No.	% of total	(%) Mean ADC value
Thymoma	7	43.75	1.35±0.32 x 10_3 mm2/s
Goiter	3	18.75	0.70±0.23 x 10_3 mm2/s
Schwannoma	2	12.5	1.81±0.51 x 10_3 mm2/s
Thymic hyperplasia	3	18.75	2.1±0.0 x 10_3 mm2/s
Enlarged LNs	4	25	0.74±0.29 x 10_3 mm2/s
Sarcoidosis	1	6.25	1.61±0.41 x 10_3 mm2/s
Lymphoma	16	66.66	0.96±0.16 x 10_3 mm2/s
Malignant germ cell tumor	5	20.8	1.058±0.921 x 10_3 mm2/s
Invasive thymoma	2	8.33	0.95±0.17 x 10_3 mm2/s
Neuroblastoma	1	4.16	0.77±0.18 x 10_3 mm2/s

Table (2) DCE MRI of mediastinal lesions & correlation with TIC.

Histopathological diagnosis	Time intensity curve (TIC)		
	Persistent (type I)	Plateau (type II)	Washout (type III)
Thymic epithelial tumor:	**1**	**14**	**23**
Low-risk thymoma	-	(7)	(16)
High-risk thymoma	-	(4)	(5)
Thymic carcinoma	(1)	(3)	(2)
Malignant lymphoma & germ cell tumor:	**3**	**7**	**-**
Malignant lymphoma	(2)	(5)	-
Malignant germ cell tumor	(1)	(2)	-

4. Discussion
I-Mediastinal lesions

The mean ADC value for the malignant lesions was $0.91 \pm 0.23 \times 10^{-3}$ mm2/s while the mean ADC value for the benign lesions was $1.80 \pm 0.55 \times 10^{-3}$ mm2/s. Comparison between the mean ADC value of the benign and malignant mediastinal lesions was highly significant with P value <0.001.

This result agrees with the results of Nasr A. et al. (13), who reported that the mean ADC value for the malignant lesions was $0.91 \pm 0.23 \times 10^{-3}$ mm2/s while the mean ADC value for the benign lesions was $1.80 \pm 0.55 \times 10^{-3}$ mm2/s. This study results are also consistent with the results of El-Nahas M. et al. (7), Dawood H.A., and Salah-Eldin M. (5), Abdel Razek A. (1), and Gümüştaş S. et al. (8).

In agreement with the results of Abdel Razek et al. and Gumustas et al. (1 & 8), the results of our study demonstrated that the mean ADC value of malignant mediastinal lesions was significantly lower than the mean ADC value of benign mediastinal lesions (Fig. 1). We did not find significant difference in the mean ADC value between lymphoma and other malignant tumors encountered in this study. This is concordant with other results (Abdel Razek et al. and Gumustas et al.) (1 & 8) and discordant with results of (Sumi et al.) (17) who found significant difference in the mean ADC value between lymphoma and carcinoma.

Also Raafat et al. (14); Cutoff threshold of ADC value for the differentiation between malignant and benign lesion was 1.11×10^{-3} mm2/s, with an area under ROC curve of 0.93. The sensitivity and specificity of our cutoff ADC values were 90.9% and 100%, with 100% positive predictive value and 76.9% negative predictive value.

However, Abdel Razek A. (1), Gümüştaş et al. (8), and Sabri Y. et al. (15) reported higher cutoff ADC values of 1.56×10^{-3} mm2/s, 1.39×10^{-3} mm2/s, and 1.4×10^{-3} mm2/s, respectively, for the discrimination between malignant and benign mediastinal lesions. This variation of cutoff ADC values is likely attributed to the discrepancy in the sample size and the MRI technique specially the use of different b-values.
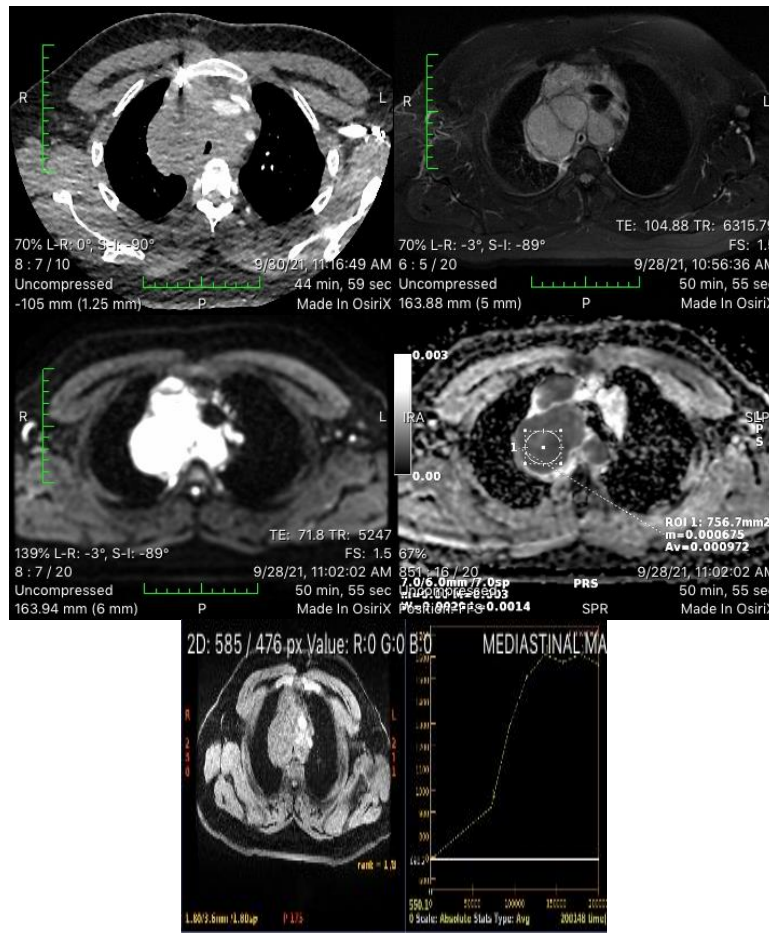
Fig. (1) Mediastinal lymph nodes in a 26 y old male patient with lymphoma (a) CT scan guided biopsy of the chest mediastinal window shows enhanced soft tissue mass lesion in the upper mediastinum. (b) Axial T2 WI with fat saturation shows the mass exerting hyperintense signal (c) On axial diffusion weighted imaging using b value 800 s/mm2 the mass exerts bright hyperintense signal. (d) On ADC mapping the mass has low signal intensity lesion with very low ADC value measuring 0.675 x 10_3 mm2/s. (e) Post IV contrast shows persistent curve type I.

II-Pulmonary lesions

The twenty pulmonary lesions were 14 malignant lesions and 6 benign lesions.

DWI grading as a qualitative, ADC as a quantitative, and LCR as a semi-quantitative evaluation showed reasonable accuracies in differentiating the lesions. There were significant differences between benign and malignant lesions in values of ADC, LCR, and DWI grading (Masoud et al.) (12).

In our study the mean ADC value of malignant lesions was $1.264 \pm 0.23 \times 10^{-3}$ mm2/sec and mean ADC value for benign lesions was $1.482 \pm 0.52 \times 10^{-3}$ mm2/sec. There was significant difference between mean ADC value of malignant and benign pulmonary lesion with p value=0.003. The mean lesion to cord ratio (LCR) was 1.315 ± 0.423 for malignant lung lesions and 0.741 ± 0.421 for benign ones. The difference between mean LCR of malignant and benign pulmonary lesions was highly significant (p<0.001).

Using a cutoff value of 1.027×10^{-3} mm2/sec, the ADC showed a positive predictive value of 85%, a negative predictive value of 68%, and an accuracy of 78 % in the detection of cancer lesions. However, by using a cutoff value of 0.971, the LCR had a positive predictive value of 93%, a negative predictive value of 76%, and an accuracy of 85 % for the detection of lung malignancies.

Cakmak et al. (2) conducted a study, which demonstrates that the LCR and ADC have good predictor values in the diagnosis of malignant and benign pulmonary lesions with the accuracy of 74% and 89%, respectively.

III-Pleura & chest wall lesions

The 10 chest wall and pleural lesions were 6 benign and 4 malignant. The benign lesions were 2 pleural fibromas, 2 chest wall infections, one chest wall lipoma and one hemangioma. The malignant lesions were one malignant pleural mesothelioma, one pleural sarcoma, one pleural metastasis from cancer colon and one chondrosarcoma of the sternum.

The mean ADC value for benign lesions was $1.65 \pm 0.17 \times 10_3$ mm2/s and mean ADC value for the malignant lesion was $1.23 \pm 0.19 \times 10_3$ mm2/s. The mean ADC value of the malignant lesions was significantly different from mean ADC value of benign lesion with p < 0.001.
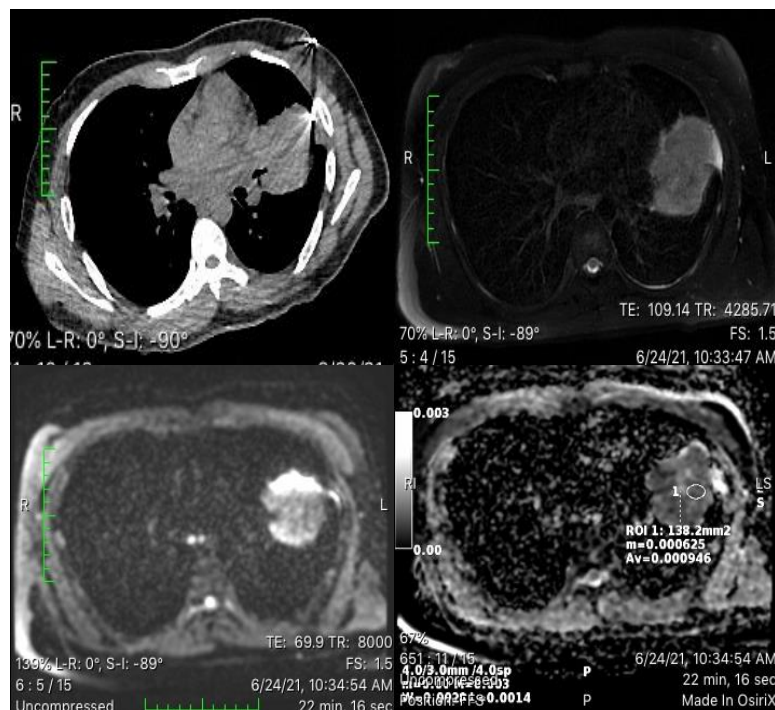
fig. (2) left central pulmonary mass in a 37 y old male patient with bronchogenic Ca. (a) CT scan guided biopsy of the mass (b) Axial T2 WI with fat saturation shows the mass exerting hyperintense signal (c) On axial diffusion weighted imaging using b value 800 s/mm2 the mass exerts bright hyperintense signal. (d) On ADC mapping the mass has low signal intensity lesion with very low ADC value measuring 0.675 x 10_3 mm2/s.

5. Summary

10 cases were diagnosed as central bronchogenic carcinoma; four cases showed central mass with post obstructive collapse. Magnetic resonance DWI could differentiate the mass from post obstructive collapse in 3 cases and in the fourth case both the central mass and post obstructive collapse showed similar ADC values denoting tumoral infiltration of the collapsed lung segment.

DWI was able to detect associated metastatic mediastinal lymphadenopathy in 8 cases, pleural effusion in 2 cases, pulmonary nodules in 4 cases, suprarenal masses in 2 cases, pericardial effusion in 1 case and multiple hepatic deposits in 1 case.

13 patients presented with mediastinal/hilar lymphadenopathy; 6 patients pathologically proven as sarcoidosis and 7 patients as lymphoma.

Diffusion MR imaging can be useful for differentiating lung cancer from benign mediastinal masses, differentiating central mass from post obstructive collapse as well as the assessment of associated lymph nodes, pulmonary, osseous, hepatic and suprarenal metastasis.

Diffusion-weighted imaging may be useful in differentiating lymphoma from sarcoidosis in mediastinal and hilar lymphadenopathy.

6. Conclusion

MRI with diffusion weighted images can detect and stage lung cancer, differentiate benign from malignant mediastinal masses and differentiate lymphoma from sarcoidosis in mediastinal/ hilar lymphadenopathy.

7. Recommendation
- Diffusion MR imaging should be incorporated into routine MRI examination in assessment of mediastinal mass lesions.
- Further studies can be done on larger number of patients and targeted to specific mediastinal pathologies.

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