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Evaluation of mediastinal lymphadenopathy by diffusion weighted MRI; correlation with histopathological results

Abstract

Introduction: Diffusion weighted imaging (DWI) has shown its potential as a reliable noninvasive technique for tissue characterization. DWI reflects the tissue specific diffusion capacity which can be used for tissue characterization. Hypercellular tissue (e.g; malignant tumors) had restricted diffusion capacity with increased signals on DWI and low ADC values. Non-tumoral tissues show low cellularity, and diffusion capacity is not restricted resulting in signal loss on DWI and high apparent diffusion coefficient (ADC). Differential diagnosis of mediastinal lymphadenopathy is an issue of debate, especially in malignant benign differentiation. Diffusion weighted imaging with magnetic resonance could improve the diagnostic accuracy in differentiation between benign and malignant mediastinal nodes.
Objectives: to determine the efficacy of diffusion weighted MRI in evaluation of mediastinal lymphadenopathy with histopathological correlation to differentiate benign from malignant lymph nodes.
Material and methods: 30 patients with mediastinal lymphadenopathy underwent diffusion weighted MRI. ADCs of lymph nodes were derived and constructed from b = 0 and b = 1000 sec/mm^2 values by drawing regions of interests (ROI). Consequently, mediastinal nodes were studied, biopsies and histopathological analysis were done after MRI examination.
Results: The best cutoff point of ADC to differentiate benign from malignant lesions was 1.15 mm/sec (sensitivity 77%, specificity 92% and AUC 81.4%). Significant negative correlation of ADC by DW MRI and the size of the LNs. The mean ADC values in the lymphoma group was lower than in the sarcoidosis group, and the difference was statistically significant.
Conclusion: The study supports that MRI with diffusion weighted images can differentiate benign from malignant mediastinal lymphadenopathy and differentiate lymphoma from sarcoidosis non-invasively.

Key words: mediastinal lymphadenopathy, diffusion weighted MRI, apparent diffusion coefficient (ADC)

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Introduction

Lymphadenopathy means abnormal increase in size and/or altered consistency of the lymph nodes. It is important to differentiate benign from malignant lymph nodes [1]. Computed tomography (CT) is the standard imaging tool for evaluation of enlarged mediastinal lymph nodes, but it has its limitations, and it makes lymph node sampling by mediastinoscopy or thoracotomy necessary to detect metastases [2].

Diffusion weighted magnetic resonance imaging (DW-MRI) has the potential to be reliable noninvasive imaging for tissue characterization. Hypercellular tissue like malignant lesions have decreased mobility of water protons and consequently, restricted diffusion capacity. Thus, tumors present with increased signals on DWI and low apparent diffusion coefficient (ADC) values. Non-tumoral tissues show low cellularity, and consequently, diffusion capacity is not restricted with resulting high ADC [3]. An inverse correlation between the ADC value and tumor cellularity has been shown [4].

MRI is an ideal tool to evaluate lymph nodes of the mediastinum due to its excellent soft tissue contrast [5]. Mean ADC for malignant mediastinal lesions could be lower than that for benign entities [6]. DW-MRI could improve the diagnostic accuracy in differentiation between benign and malignant mediastinal lymph nodes [4]. Differentiation of treatment-induced tissue changes, after chemotherapy and radiotherapy is another area in which DW-MRI may be helpful. A further

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possible application could be monitoring of tumor response during radiotherapy [7].

The study investigated the efficacy of diffusion weighted MRI in evaluation and characterization of mediastinal lymphadenopathy with histopathological correlation as a reference standard to differentiate benign from malignant lymph nodes.

Material and methods

This prospective study included 30 patients with mediastinal lymphadenopathy, it has been conducted in the Chest Department in collaboration with the Diagnostic Radiology Department, Faculty of Medicine, Cairo University Hospitals. Research ethics committee, the Faculty of Medicine, Cairo University approved the study. All patients above 18 years, whether smoker or not, with no sex predilection, presenting with enlarged mediastinal lymph nodes of different etiologies were included. Subjects with refractory hypoxia, unfit for bronchoscopy or tissue biopsy, coagulopathy, severe claustrophobia, cardiac pacemakers, metallic splinters were excluded. Patients were subjected to history taking, clinical examination and laboratory investigations, e.g.; complete blood picture, coagulation profile, renal and liver function tests, radiological assessment, including CT chest to detect mediastinal lymph node enlargement and diffusion weighted MRI using 1.5 Tesla Philips Achieva Medical Systems, Best; The Netherlands, Release 3.2.3.4, SRN: 33078, with a 30 mT/m maximum gradient capability.

MRI protocol and technique

MRI scanning protocol used was the following: T1WI, T2WI & T2 STIR, DWI & quantitative DWI analysis (ADC measurement). DWI is typically acquired in transverse plane, using at least two b values; low (0−50 s/mm^2) and intermediate to high b values (400−1000 s/mm^2). Typical slice thickness is 4−9 mm with interslice gap of 0−1.5 mm and a number of excitations ranges from 1−10. All DWI data were transferred to computer workstation for determination of signal intensity and ADC. ADC map was automatically reconstructed by standard software imager. ADC was measured by manually placing regions of interest on the ADC map. Necrotic areas were excluded from analysis. We used ADC b value (the diffusion gradient strength) 0−1000 values to achieve high accuracy in the detection of the nature of mediastinal lymph nodes, mainly by improving detection of subcentimeteric ones. Data from DW-MRI were assessed. In qualitative assessment, each lesion was evaluated on conventional images for location, size and presence of cystic necrotic parts. Each lesion signal intensity was evaluated in all pulse sequences T1WI, T2WI, STIR WI and its signal in DWI and ADC map were compared. In quantitative assessment, ADC value is calculated for each pixel of the image and is displayed as parametric map. ADCs of different tissues were constructed from b = 0 and b = 1000 sec/mm^2 values by drawing regions of interests on these maps using round or elliptical region of interest (ROI). ROI was drawn centrally and its size was kept as large as possible on ADC map covering at least two thirds of the lesion avoiding macroscopic necrosis and major blood vessel in the light of the conventional images, i.e. for entirely solid lymph nodes, regions of interest were placed over the entire lymph node. None of patients were under treatment when MRI was performed [8].

When evaluating diffusion weighted images, some investigators used multiple ROI measurements with minimum pixels and averaged the results (ADCavg) on ADC maps, while others have placed the ROI on hyperintense areas of the b1000 diffusion images and copied this ROI into the ADC map [9]. De Bondt *et al.* [10] suggested that if ADCavg values are to be used, necrotic areas of lymph nodes on conventional images should be excluded. Measurements were based on minimum ADC values, since using average ADC values would require multiple measurements to exclude necrotic areas, and it would conflict with the goal to search for parameters easy to use. Also, using multiple ROIs could decrease sensitivity for detecting small lymph nodes.

Lymph nodes biopsies were obtained either by EBUS-guided transbronchial needle aspiration, ultrasound or CT guided tru-cut needle biopsy, lymph no de excisional biopsy from peripherally enlarged lymph nodes in cases of generalized lymphadenopathy. Finally, DW-MRI ADC values were compared to histopathological results as a reference standard.

Statistical analysis

Data were collected, tabulated and statistically analyzed, using SPSS 22.0 for windows (SPSS Inc., Chicago, IL, USA). All tests were two-sided. A p-value < 0.05 was considered significant. Continuous variables were expressed as mean, and standard deviation (SD) and categorical variables were expressed as a number (percentage). Continuous variables were checked for normality by using the Shapiro–Wilk test. Independent samples Student's t-test was used to compare

Table 1. Comparison between the malignant and benign study groups

Variables	Group		P value
	Malignant (N = 17)	Benign (N = 13)	
Age (median)	52	50	> 0.05$^{\$\$}$
Sex distribution (N&%)			
Male	12 (40%)	1 (3.3%)	< 0.001$^{\#}$
Female	5 (16.7)	12 (40%)	
Smoking status			
Ex-smoker	1 (3.3%)	2 (3.3%)	< 0.001$^{\#}$
Smoker	11 (36.7%)	0 (0%)	
Non-smoker	5 (16.7)	12 (40%)	
No of total LN in CT (mean ± SD)	3.29 ± 1.69	3 ± 1.29	5$^{\wedge}$
Size of LN in CT			
Station 4R (median)	2.25	2	< 0.05$^{\$\$}$
Station 7 (mean ± SD)	3.57 ± 1.09	2.87 ± 0.96	> 0.05$^{\wedge}$
Station 10 (mean ± SD)	2.65 ± 1.043	2.32 ± 0.598	> 0.05$^{\wedge}$
Total size (median)	2.25	1.83	> 0.05$^{\$\$}$
No of total LN in DW-MRI (mean ± SD)	2.71 ± 1.047	2.62 ± 1.044	> 0.05$^{\wedge}$
ADC of LN in DW-MRI			
ADC Station 4R (mean ± SD)	0.89 ± 0.246	1.44 ± 0.494	< 0.001$^{\wedge}$
ADC Station 7 (median)	1.07	1.76	< 0.01$^{\$\$}$
ADC Station 10 (mean ± SD)	1.12 ± 0.275	1.34 ± 0.323	> 0.05$^{\wedge}$
Total ADC (mean ± SD)	1.02 ± 0.318	1.43 ± 0.340	< 0.01$^{\wedge}$
Size of LN in DW-MRI			
Station4R (median)	2.91	2.09	< 0.05$^{\$\$}$
Station 7 (mean ± SD)	4.223 ± 1.422	3.547 ± 0.881	> 0.05$^{\wedge}$
Station 10 (median)	2.995	2.755	> 0.05$^{\$\$}$
Total size (median)	3.24	2.93	> 0.05$^{\$\$}$

$^{\$\$}$Mann-Whitney U test; $^{\#}$Pearson Chi-Square; $^{\wedge}$Student's t-test; P considered significant if < 0.05.
Station 4R: Rt lower paratracheal lymph nodes, Station 7: Subcarinal lymph nodes, Station 10: Hilar lymph nodes.
NB: In Station 2R (Rt upper Paratracheal lymph nodes), Station 5 (Aortopulmonary lymph nodes) and Station 6 (Para-aortic lymph nodes) the comparisons were invalid duo to presence of lesion in one group rather than the other

between two groups of normally distributed data while the Mann–Whitney U test was applied for nonnormally distributed data. Anova test was used to compare between more than two groups of normally distributed data while Kraskall Wallis H test was used to compare between more than two groups of nonnormally distributed data. The percent of categorical variables were compared using Pearson's Chi-square test or Fisher's exact test, when appropriate. Pearson's correlation was calculated to assess the correlations between various study parameters. (+) sign indicate positive correlation and (-) sign indicate negative correlation. Receiver operating characteristic (ROC) curve analysis was used to identify optimal cutoff values of ADC with maximum sensitivity and specificity for prediction of malignancy. Area under the curve (AUC) was also calculated, > 0.60−0.70 was considered acceptable.

Results

Thirty patients with mediastinal lymphadenopathy were enrolled in the study. Their mean age was 46.6 years. Males constituted 43.33% while females — 56.67%. The majority of patients were nonsmokers (56.67%). 14 subjects (46.67%) were diagnosed by EBUS-guided TBNA and another 14 patients (46.67%) were diagnosed by image-guided tru-cut needle core biopsy and 2 individuals (6.67%) were diagnosed by excisional LN biopsy. Final histopathological diagnoses included 17 malignant (56.7%) and 13 benign cases (43.3%). Moreover, malignant cases consisted of lymphoma (7 cases, 23.3%) and metastatic lymph nodes (10 cases, 33.3%). Benign diagnoses comprised sarcoidosis (10, 33.3%) and tuberculous lymphadenitis (3, 10%).

Table 1 showed a comparison between benign and malignant cases regarding demographic data,

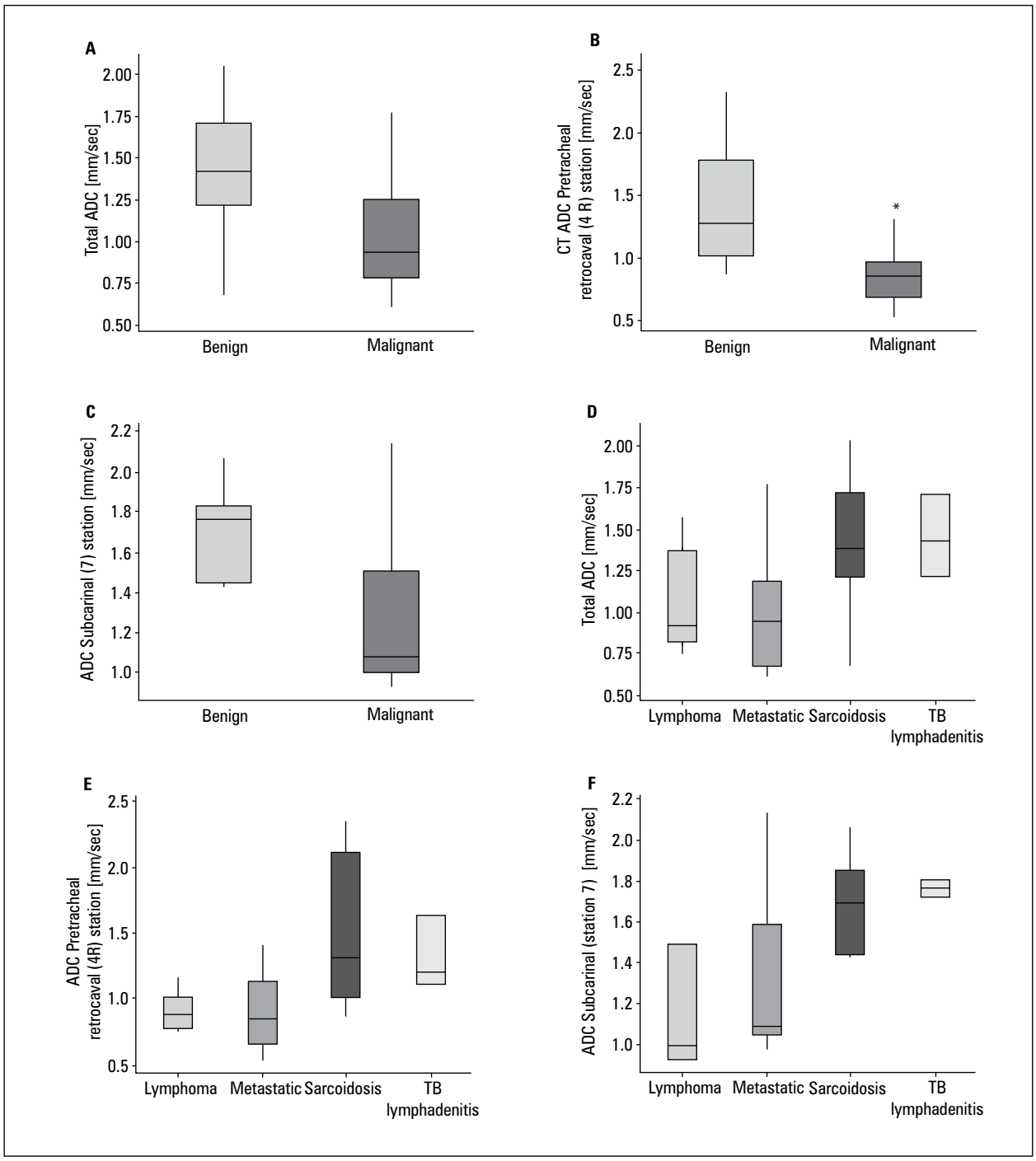

Figure 1. A. Total ADC value reported by DW-MRI; **B.** ADC value of station 4R (right lower paratracheal LN); **C.** ADC value of station 7 (subcarial LN); **D.** total ADC value of the 4 histopathological subgroups; **E.** ADC value of station 4R in the 4 histopathological subgroups; **F.** ADC value of station 7 in the 4 histopathological subgroups

CT and DW-MRI findings. Total mean ADC of LNs in the malignant group was 1.02 while in the benign group — 1.43 with significant statistical difference ($P < 0.01$) (Figure 1A). Station 4R and station 7 (Figure 1A, 1B) were sensitive in differentiation between benign and malignant lesion as regarding ADC. Station 4R LN size was significantly larger in malignant than the benign group ($P < 0.05$). Table 2 showed significant difference between various study histopathological subgroups regarding demographic data, total ADC in affected LNs and ADC value of 4R station (Figure 1D, 1E). But ADC of station 7 (Figure 1F) wasn't significantly different. Also, station 4R median size showed significant difference between the 4 subgroups.

Table 2. Comparison between the different histopathological subgroups of the study (Metastatic/Lymphoma/Sarcoidosis/ /Tuberculosis)

Variables	Groups				P value
	Metastatic (N = 10)	Lymphoma (N = 7)	Sarcoidosis (N = 10)	TB (N = 3)	
Age (mean ± SD)	58.3 ± 9.76	36.429 ± 16.4	46.7 ± 11.33	31 ± 22.6	< 0.01^^
Sex distribution (N&%)					
Male	10 (100%)	2 (28.6%)	1 (10%)	0	< 0.001#
Female	0	5 (71.4%)	9 (90%)	3 (100%)	
Smoking status (N&%)					
Ex-smoker	1 (10%)	0	1 (10%)	0	< 0.001#
Smoker	9 (90%)	2 (28.6%)	0	0	
Non-smoker	0	5 (71.4%)	9 (90%)	3 (100%)	
		ADC of LN in DW-MRI			
ADC Station 4R (mean ± SD)	0.88 ± 0.3	0.91 ± 0.15	1.48 ± 0.57	1.32 ± 0.27	< 0.05^^
ADC Station 7 (median)	1.089	0.998	1.698	1.76	> 0.05$
ADC Station 10 (mean ± SD)	1.05 ± 0.21	1.23 ± 0.38	1.33 ± 0.34	1.45	> 0.05^^
Total ADC (mean ± SD)	1 ± 0.37	1.04 ± 0.26	1.42 ± 0.37	1.45 ± 0.25	< 0.05^^
		Size of LN in DW-MRI			
Station 4R (median)	2.83	3.185	1.995	3.19	< 0.01$
Station 7 (mean ± SD)	4.15 ± 1.2	4.39 ± 2.23	3.39 ± 0.91	4.18 ± 0.49	> 0.05^^
Station 10 (mean ± SD)	2.79 ± 0.88	3.69 ± 0.9	2.93 ± 0.8	2.02 ± 0	> 0.05^^
Total size of LN in DW MRI (median)	3.16	3.77	2.83	3.61	> 0.05$

$Kruskal–Wallis One Way Analysis of Variance on Ranks; #Pearson Chi-Square; ^^One-way ANOVA test, P considered significant if < 0.05.
Station 4R: Rt lower paratracheal lymph nodes, Station 7: Subcarinal lymph nodes, Station 10: Hilar lymph nodes.
NB: In Station 2R (Rt upper Paratracheal lymph nodes), Station 5 (Aortopulmonary lymph nodes) and Station 6 (Para-aortic lymph nodes) the comparisons were invalid duo to presence of lesion in one group rather than the others

Significant negative correlation between total ADC value and size of LN was reported by DW--MRI (r = -0.373, P < 0.05) (Figure 2A), while CT chest showed insignificant negative correlation (r = -0.232, P > 0.05) (Figure 2B). The best ADC cutoff point to differentiate malignant from benign lesion was 1.15 mm/sec with sensitivity 77%, specificity 92%, and area under the curve (AUC) was 81.4% (Figure 3A). Sensitivity, specificity, PPV, NPV and accuracy (ACC) of ADC for malignancy diagnosis at cutoff point ≤ 1.15 were 77%, 92%, 92.9%, 75% and 83.3%, respectively. The best ADC cutoff point to differentiate between sarcoidosis and other lesions was > 1.15 mm/sec with sensitivity 90%, specificity 65% and AUC was 75% (Figure 3B). Sensitivity, specificity, PPV, NPV and accuracy of ADC for sarcoidosis diagnosis at cutoff point > 1.15 were 90%, 65%, 56%, 93% and 73%, respectively.

Discussion

To date, diagnosis of lymph node metastases is based mainly on size criteria; however, non-enlarged nodes may harbor malignancy, whereas reactive nodes may be enlarged. SPECT (single photon emission CT) and PET (photon emission tomography) are image techniques which supply functional information but being expensive, they are not easily available, additionally, they involve exposure to radiation [4]. Promising results with DWI that help detect lymph node metastases and differentiate between benign and malignant enlarged nodes have been reported [11].

This work evaluated diagnostic accuracy of DW-MRI in discriminating benign and malignant lymph nodes — the issue, which is crucial in diagnosis and management of patients with mediastinal lymphadenopathy using histopathological results as standard reference.

In this study, malignant cases constituted 56.7% while benign cases — 43.3%. Malignant cases were further subdivided into lymphoma (7, 23.3%) (Figure 4) and metastatic lymph nodes (10, 33.3%). Benign cases included sarcoidosis (10, 33.3%) and tuberculous lymphadenitis (3, 10%). This was similar to Sabri *et al.* [12] study (included 13 patients

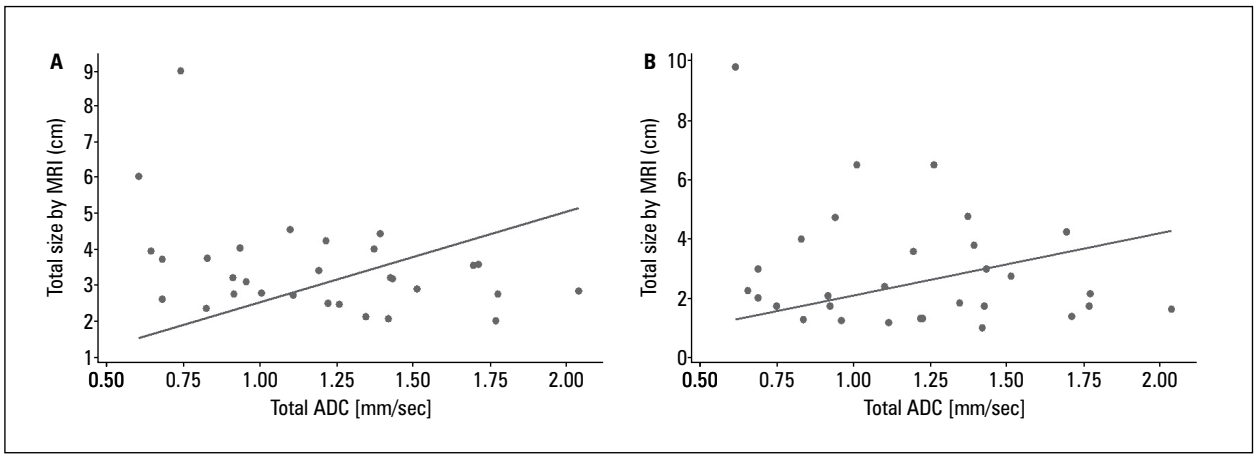

Figure 2. A. Correlation between the total ADC value and total size of LNs reported by DW-MRI (r = -0.373, P value 0.042); **B.** Correlation between the total ADC value and the total size of LNs reported by CT (r = -0.232 p value = 0.271)

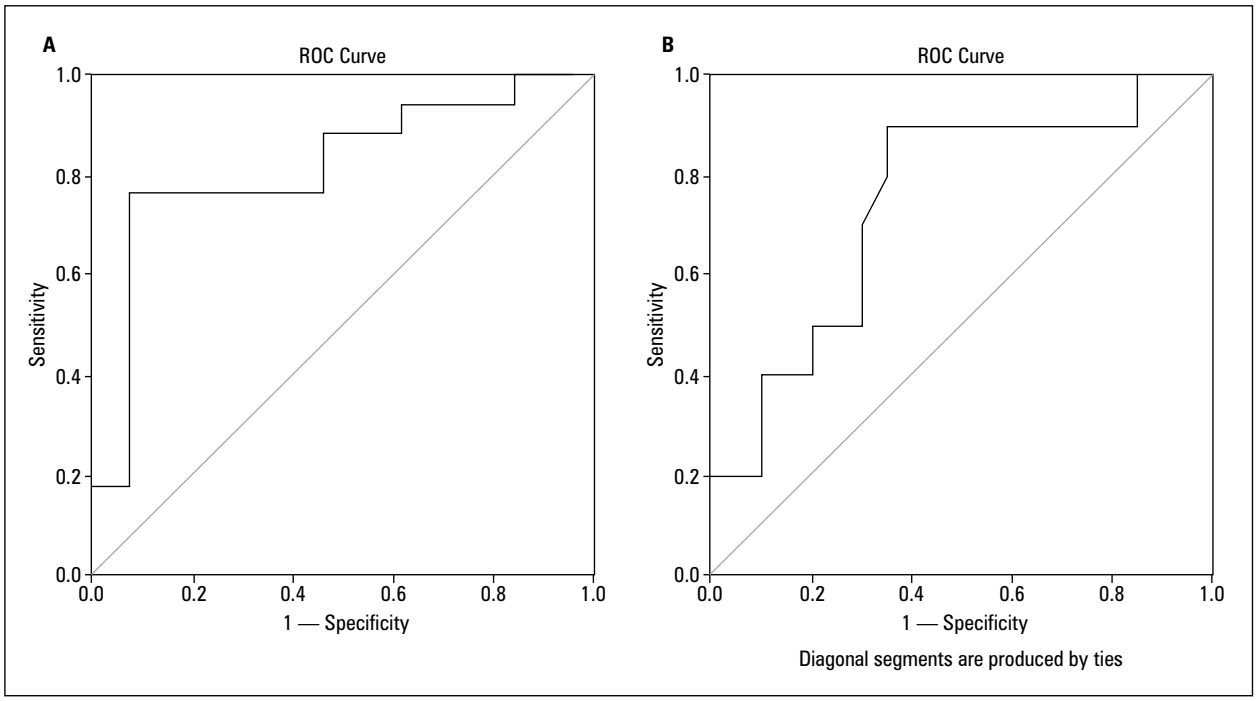

Figure 3. A. ROC curve of the total ADC values of malignant cases reported by DW-MRI (cutoff point ≤ 1.15 mm/sec, sensitivity 77%, specificity 92% and AUC 81.4%); **B.** ROC curve of the total ADC value of sarcoidosis cases reported by DW-MRI (cutoff point > 1.15 mm/sec, sensitivity 90%, specificity 65% and AUC 75%)

with mediastinal lymphadenopathy; 6 pathologically proven as sarcoidosis and 7 as lymphoma).

There was a significant difference between the 4 histopathological subgroups regarding age and sex. Also, smoking was significantly associated with the metastatic group. Median size of LNs reported by DW-MRI in the malignant group was 3.24 cm opposite to 2.93 cm in the benign one with no significant difference. This confirms the fact that size of LNs doesn't matter in differentiating benign from malignant nodes. ADC values in stations 4R and 7 were sensitive in differentiating benign and malignant lesions (Figure 1). Mean ADC value of LNs in the malignant group was 1.02 ± 0.32 while in the benign, it was 1.43 ± 0.34 with a significant difference in-between ($P < 0.01$). This agreed with Vandecaveye *et al.* [13] who correlated histopathologic and radiologic findings for lymph nodes (ADC value was 1.19 ± 0.22 for benign LNs and 0.85 ± 0.27 for malignant LNs; $P < 0.001$). Also, Seber and his colleagues [14] illustrated that mean ADC value

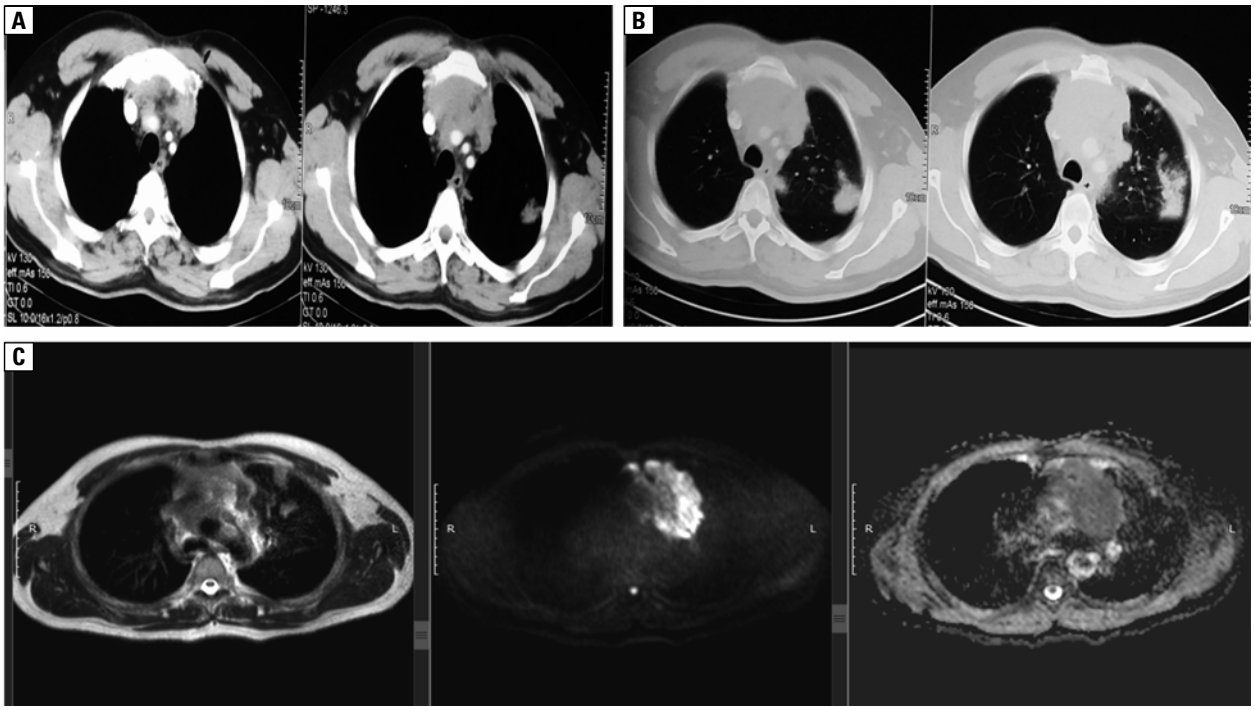

Figure 4. A. Axial contrast CT chest mediastinal window showing amalgamated nodal masses encasing main branches of aortic arch and SVC; **B.** Axial CT chest; pulmonary window showing a dense nodule at apicoposterior of the left upper lobe; **C.** DW MRI; Axial MR T2WI, axial DWI and ADC map, respectively showing low T2 signal intensity with restricted diffusion higher DWI signal and lower ADC value. The mean ADC for the amalgamated nodal mass was 0.984 × 10−3 mm^2/s. Restricted diffusion suggest malignant nature, mostly lymphoma. Tru-Cut needle biopsy obtained from this amalgamated nodal mass and histopathology revealed large cell type malignant lymphoma.

for benign LNs was 0.97 and for malignant LNs was 0.76 ($P < 0.001$).

There was a significant statistical difference between the 4 histopathological subgroups regarding ADC value in station 4R and ADC of all affected LNs. It was higher in TB and sarcoidosis (ADC; 1.45 ± 0.25 and 1.42 ± 0.37, respectively) than in the metastatic and lymphoma groups (ADC; 1 ± 0.37 and 1.04 ± 0.26, respectively). The same was reported by Gümüştaş *et al.* [15] who stated that ADC value for lymphoma was 1.130 ± 0.581 and for sarcoidosis was 2.065 ± 0.518. Also, Sabri *et al.* [12] showed that ADC for lymphoma (1.22 ± 0.23) was lower than that of sarcoidosis (1.9±0.28), and the difference was statistically significant. Vandecaveye *et al.* [13] again, reported that metastatic and lymphomatous nodes present reduction of diffusivity, which can be attributed to hypercellularity, cellular pleomorphism, increased mitosis and nuclear-to-cytoplasmatic ratio. Similarly, Kosucu *et al.* [16] found that ADC value is significantly lower in metastatic (1.01 ± 0.02) than in benign nodes (1.51 ± 0.07).

This study attempted to differentiate metastatic carcinoma and lymphoma on basis of their ADC values, but ADC value of lymphoma (1.04 ± 0.26) was not significantly different from that of metastatic carcinoma (1 ± 0.37). In contrast, statistically significant results were illustrated by King and colleagues [17] between ADC of metastatic nodes (1.057) and lymphoma (0.664) ($P < 0.01$). Differences in restriction of diffusion may be attributed to differences in cellularity, necrosis and perfusion. Greater cellularity and less extracellular space may lead to restriction of diffusion in lymphoma rather than in carcinomas**.** Again, Sumi and colleagues [18] reported that ADC of metastatic nodes was significantly higher (1.167 ± 0.4) than benign lymphadenopathies (0.652 ± 0.10) and lymphomatous ones (0.601 ± 0.427). These differences in the results may be due to the choice of the b values (lower b values increase signal-to-noise ratio but may worsen the sensitivity to diffusion ratio), the selection of the region of interest on ADC maps and the use of sequences which reduce artifacts in order to make more precise measurement of the area of interest. This was described by Wang and colleagues [19] who stated that in benign LNs, a false decrease in ADC may correlate with the presence of nodal reactive changes that manifest as multiple germinal centers and fibrotic stroma, which act as microstructural barriers. Also, Choi and colleagues [20] stated that false-positive readings

may be caused by restricted diffusion in recent hemorrhage or hematoma. Therefore, DWI should not be performed directly after biopsy.

This study showed significant negative correlation between ADC value and size of LNs reported by DW-MRI. While with CT chest, correlation was insignificantly negative. The best cutoff point of ADC value to differentiate between malignant and benign nodes was 1.15 mm/sec with sensitivity 77%, specificity 92%, and AUC 81.4%. PPV, NPV, and ACC of this ADC value in diagnosis of malignancy were 92.9%, 75% and 83.3%, respectively. Also, the best cutoff point of ADC value to differentiate between sarcoidosis and other lesions was > 1.15 with sensitivity 90%, specificity 65%, and AUC 75%. PPV, NPV and ACC of this ADC value in diagnosis of sarcoidosis were 56%, 93% and 73%, respectively. Vandecaveye *et al.* [13] showed that with an optimal ADC threshold of 0.94, sensitivity, specificity and accuracy for differentiation of malignant versus benign lymph nodes were 84%, 94% and 91%, respectively. Also, Tondo *et al.* [21] used ADC value of 1.25 as threshold to differentiate malignant from benign lesions with a 91% diagnostic accuracy, 90% sensitivity, 100% PPV and 57% NPV. Seber and colleagues [14] showed that in ROC analysis, the cutoff ADC value for malignant versus benign LNs differentiation was 0.8. Using an ADC value of 0.8, the sensitivity, specificity, PPV, NPV and accuracy for differentiating between benign and malignant LNs were 76.4%, 85.7%, 86.6%, 75%, and 80.6%, respectively. Also, Ragheb and colleagues [22] stated that optimal ADC cutoff value for differentiating benign and malignant LNs was 0.61 with accuracy 96.7%, sensitivity 100%, specificity 88.9%, PPV 95.4% and NPV 100%. Again, Holzapfel and colleagues [23] reported an accuracy of 94% in characterizing metastatic LNs when using threshold of 1.02. However, Abdel Razek and colleagues [24] reported slightly higher threshold (ADC:1.38) for characterizing suspected LNs with accuracy of 96%. Although both authors used similar MR sequence, the difference in ADC values may be due to the fact that Holzapfel and colleagues [23] calculated their ADC maps from 3 different b-values. Also, Perronea *et al.* [4] reported that ADC value for malignant lesions was 0.85, which is lower than benign LNs (ADC;1.448), and the best ADC threshold value for distinguishing benign from malignant nodes was 1.03 with sensitivity 100% and specificity 92.9%.

This study has some limitations such as a small study cohort in a single center. However, statistical tests were performed on the number of involved nodes (about 95 nodes) rather than the number of the patients. Finally, we can conclude that DW-MRI can noninvasively differentiate benign from malignant mediastinal lymphadenopathy and differentiate lymphoma from sarcoidosis. When compared to PET/CT, there is no exposure to ionizing radiation, no need for administration of external tracer and moreover, this technique is less expensive. DW-MRI offers unique combination of morphological and functional information in a single examination without radiation burden.

Conflict of interest and funding

The authors declare no conflict of interest.

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