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RESEARCH

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The dilemma of mediastinal lymphadenopathy between invasive and non-invasive procedures: ROC analysis of T2WI and DWI-MRI advanced parameters correlated with PET-CT and biopsy

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Abstract

Background The characterization of pathologically enlarged mediastinal lymph nodes is clinically essential for effective disease management and accurate prognosis. Malignancy (metastases and lymphoma) and granulomatous conditions (sarcoidosis and tuberculosis) are the most common causes. Magnetic resonance imaging (MRI) is a good modality to characterize the mediastinal pathologically enlarged lymph nodes based on the excellent soft tissue contrast. It can save high-risk patients from radiation exposure and hazards of intervention such as general anesthesia and biopsy.

Aim of the work To estimate the accuracy of different advanced MRI quantitative parameters in the differentiation between benign and malignant mediastinal lymphadenopathy. This would involve the lesion-to-cord signal intensity ratio (SIR) in the T2-WI and diffusion weighted image (DWI), the lesion-to-chest wall muscle SIR in T2-WI and DWI, and the mean apparent diffusion coefficient (ADC) values. These values would be correlated with the prospective pathological data and the results of the positron emission tomography (PET-CT).

Results Prospectively, the study was conducted during the period between June 2022 and September 2023 on 45 patients with indeterminate or suspicious mediastinal lymphadenopathy identified by CT. MRI examination, PET-CT, and biopsy were applied for all patients. The intra-class correlation coefficient ranged between 0.89 and 0.95. (A) The lesion-to-cord SIR in T2-WI in the malignant group (1.49 ± 0.30) was higher than that in the benign group (0.83 ± 0.24) with $P < 0.001$. The statistically calculated cutoff value (> 1.2) estimated 90% sensitivity, 100% specificity, with AUC = 0.989. (B) The lesion-to-chest wall muscle SIR in T2-WI in malignant nodes (3.13 ± 0.84) was significantly higher than that in the benign nodes (1.90 ± 0.80) with $P < 0.001$. The statistically calculated cutoff value (> 2.4) estimated 86.67% sensitivity, 86.67% specificity, with AUC = 0.88. (C) The lesion-to-cord signal SIR in b500-DWI in the malignant node (1.80 ± 0.54) was higher than that in the benign group (0.75 ± 0.29) with $P < 0.001$. The statistically calculated cutoff value (> 1.2) estimated 100% sensitivity and specificity with AUC = 1.00. (D) The lesion-to-chest wall SIR in b500-DWI in the malignant node (6.43 ± 1.28) was higher than that in the benign node (2.63 ± 0.94) with $P < 0.001$. The statistically calculated cutoff value (> 4.1) estimated 96.67% sensitivity, 100% specificity,

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with AUC = 0.997. € The mean ADC values in the malignant nodes ($0.83 \pm 0.20 \times 10^{-3}$ mm^2/s) were significantly lower than that in the benign nodes ($1.85 \pm 0.19 \times 10^{-3}$ mm^2/s) with $P < 0.001$. The statistically calculated cutoff value (≤ 1.2) estimated 100% sensitivity and specificity with AUC = 1.00.

Conclusions Biopsy remains the main diagnostic modality for the characterization of mediastinal lymphadenopathy despite its hazards and limitations. This study proved that MRI could be accepted as an alternative non-invasive imaging tool that can overcome the PET-CT limitations. The lesion signal-to-cord and to-muscle ratios in both T2-WI and DWI-MRI side by side with the mean ADC value showed high statistical accuracy.

Keywords DWI, MRI, PET/CT, Mediastinal lymphadenopathy

Background

The characterization of pathologically enlarged mediastinal lymph nodes is crucial for adequate management of underlying diseases. These would include variable inflammatory, malignant, and infectious pathologies. Malignancy (metastases from Lung cancer or extra-thoracic cancer and lymphoma) and granulomatous conditions (sarcoidosis and tuberculosis) are the most common causes [1]. The accurate initial lymph node staging with a noninvasive procedure of high diagnostic accuracy would be extremely useful [2].

Computed tomography (CT) imaging is the primary technique for evaluation of the thoracic diseases including mediastinal lymphadenopathy. It depends on morphological characteristics such as the distribution, size, and post-contrast enhancement of the lymph nodes. Overall, the use of CT imaging might be limited in differentiation between benign and malignant pathologically enlarged lymph nodes [3, 4].

Although positron emission tomography (PET-CT) is reliable to detect malignant pathologies, it has some limitations when it comes to the high cost, low accessibility, and also low specificity as in some types of lymphoma [5].

Diffusion-weighted magnetic resonance imaging (DW-MRI) could also be considered as a reliable noninvasive tool to diagnose malignancy by high DWI-signal and low apparent diffusion coefficient (ADC) values [6].

As compared to the 18F-FDG-PET/CT, the utilization of DWI has similar merits and additionally, it produces lower false-positive results [7]. 18F-FDG PET/CT might show false-positive results in some acutely inflamed nodes, and false-negative results in some malignant nodes with low percentage of tumor cells [8].

Aim of the work

To estimate the accuracy of different advanced MRI quantitative parameters in the differentiation between benign and malignant benign mediastinal lymphadenopathy. This would involve the lesion-to-cord signal intensity ratio (SIR) in the T2-WI and DWI, the lesion-to-chest wall muscle SIR in T2-WI and DWI, in addition to the mean ADC values. These values would be correlated with the prospective pathological and PET-CT data.

Methods

Prospectively, the study was conducted during the period between June 2022 and September 2023 on 45 patients with progressive dyspnea and indeterminate or suspicious mediastinal lymphadenopathy identified by CT, before any clinical intervention.

MRI was applied to all patients then PET-CT and biopsy. The MRI results were statistically correlated with PET-CT results and finally with the pathological results. The MRI-cutoff values were statistically calculated, then the statistical tests of accuracy were performed and ROC analyses were estimated.

The inclusion criteria involved patients with CT findings of indeterminate or suspicious mediastinal lymphadenopathy including one or more of the following criteria: (1) Short axis diameter of more than 1 cm, (2) Anterior and posterior mediastinal involvement, (3) hilar involvement or extra-thoracic involvement if present, (4) Necrosis or heterogeneous post-contrast enhancement if present [3].

The exclusion criteria were as follows: (1) Degraded images due to uncontrolled dyspnea or patient movement. (2) Patients with a contraindication to do an MRI examination such as patients with metallic implants, surgical clips that are incompatible with an MRI, or cardiac pacemakers. (3) Person who rejected giving an ethical consent.

The "Institutional Ethics Committee" approved this study. Every patient provided a written informed consent. This manuscript has no overlap with previously published researches.

Four expert consulting radiologists effectively worked in this study (with variable experience ranging between 9 and 30 years) in addition to a single expert pulmonologist and a single expert oncologist (having 25 and 15 years of experience respectively). The radiologists worked independently in a blinded way from the clinical info. Inter-observer agreement was statistically evaluated.

MRI scanning and sequences

The MRI examinations were conducted on closed 1.5 T PHILIPS Achieva (Netherlands) scanner using respiratory-gated technique. MRI spin echo sequences were implemented, as follows:

1. Axial T2-WI: with 665/80 ms repetition time/echo time, 5 mm slice thickness, 1.5 mm gap, 35–40 cm field of view.
2. Axial DWI with b values (0, 500, 800 and1000 s/mm^2) applying slice thickness (4–9 mm) and inter-slice gapping (0.5–1.5 mm).
3. ADC mapping was generated by the software.

Imaging processing

The radiologists used "OsiriX MD 11.0" software (Pixmeo SARL, Geneva, Switzerland) for processing MRI sequences side by side with the "Radiant" dicom-image viewer.

The radiologists initially performed a *qualitative assessment* of the lymph nodes was in the T2-WI, DWI, and also in the ADC mapping sequence. The T2 signal was considered high if the signal of the lesion was brighter than that of the chest wall muscles at the same level. The restricted diffusion was traditionally depicted by the high DWI signal and the corresponding low ADC signal.

The *quantitative advanced MRI parameters* included:

(1) *The lesion-to-cord SIR in T2-WI*: Two regions of interest (ROIs) were applied: the first ROI was inserted at the central zone of the targeted lymph node as possible (distant from the necrotic changes or calcifications), meanwhile the other ROI was inserted at the same level in the spinal cord.

(2) *The lesion-to-chest wall muscle SIR in T2-WI*: Two regions of interest (ROIs) were applied: the first ROI was inserted at the central zone of the targeted lymph node as possible (distant from the necrotic changes or calcifications), meanwhile the other ROI was inserted at the same level in the chest wall muscle.

(3) *The signal-to-noise ratio (SNR)*: calculated by detecting the attenuation value of the nodes at b500, b800, and b1000 DWI and detecting the attenuation in the background away from the imaged subject in the same slice by two ROIs and calculating their standard deviation (SNR = Signal intensity of the lymph node /SD of the background signal).

(4) *The lesion-to-cord SIR in b500-DWI*: Similarly, but in b500-DWI, two regions of interest (ROIs) were applied: the first ROI was inserted at the central zone of the targeted lymph node as possible (distant from the necrotic changes or calcifications), meanwhile the other ROI was inserted at the same level in the spinal cord.

(5) *The lesion-to-chest wall SIR in b500-DWI and the relative contrast ratio (rCR)*: Similarly, but in b500-DWI, two regions of interest (ROIs) were applied: the first ROI was inserted at the central zone of the targeted lymph node as possible (distant from the necrotic changes or calcifications), meanwhile the other ROI was inserted at the same level in the chest wall muscle. Then rCR was calculated (SI lymph node-SI muscle)/ SI muscle.

(6) *The mean ADC value* was estimated by inserting a ROI in the central zone of the targeted lymph node as possible which exhibited the most restricted diffusion distant from necrotic changes and calcifications.

Statistical analyses

(1) *The inter-rater reliability* was calculated online on "https://www.raterreliability.com/" and estimated the intra-class correlation coefficient (ICC).

(2) *IBM SPSS software package version 20.0* (Armonk, NY: IBM Corp) was applied. It demonstrated the results utilizing the range (minimum and maximum). It estimated the mean and median value. It calculated the standard deviation. The Chi-square test at P-value < 0.05 was utilized to test the significance of the provided results.

(3) *Mann–Whitney U test* evaluated the T2-WI lesion-to-cord SIR, T2-WI lesion-to-muscle SI ratio, DWI lesion-to-cord SIR, relative contrast ratio, and the mean ADC. The cutoff value was estimated according to the Youden index.

(4) *Accuracy tests* were applied. They sensitivity and the specificity were estimated. The positive predictive value (PPV) and the negative predictive values (NPV) were calculated.

(5) *"QI Macros" system* performed ROC analyses to evaluate the diagnostic role of both T2-WI and DWI.

Results

Demographic data

The study included 45 patients; 29 males (64.4%) and 16 females (35.6%). Their age ranged between 21 and 73 years with the mean age being 49.09 ± 15.19 years. All patients complained of dyspnea, 27/45 (60%) patients complained of weight loss, 22/45 (49%) patients complained of chest pain, and a single patient (2%) complained of night fever and sweating.

Final pathologic diagnosis (Table 1)

Malignancy was pathologically proven in 30/45 (67.7%) patients; 24 patients among them had metastatic nodes, while the other six patients had lymphoma (two of Hodgkin type and four of non-Hodgkin type).

Table 1 MRI parameters in each group of mediastinal lymphadenopathy with final diagnosis

	Final diagnosis				
	Metastatic nodes (n = 24)	**Lymphoma (n = 6)**	**Sarcoidosis (n = 11)**	**Reactive nodes (n = 3)**	**Pulmonary TB (n = 1)**
T2 signal to cord ratio					
Mean ± SD	1.53 ± 0.32	1.37 ± 0.14	0.85 ± 0.25	0.67 ± 0.12	0.9
Median (Min.–Max.)	1.40 (1.10–2.50)	1.35 (1.20–1.60)	0.90 (0.50–1.20)	0.60 (0.60–0.80)	
T2 signal to muscle ratio					
Mean ± SD	3.19 ± 0.91	2.87 ± 0.41	1.82 ± 0.58	2.23 ± 1.62	1.70
Median (Min.–Max.)	2.90 (1.70–5.30)	2.95 (2.30–3.40)	1.60 (1.10–2.90)	1.40 (1.20–4.10)	
Relative contrast ratio					
Mean ± SD	6.43 ± 1.32	6.45 ± 1.23	2.50 ± 0.88	2.70 ± 1.22	3.50
Median (Min.–Max.)	6.35 (4.0–9.10)	6.50 (4.60–8.30)	2.50 (1.10–4.0)	2.10 (1.90–4.10)	
Signal to cord ratio (diffusion) b500					
Mean ± SD	1.91 ± 0.55	1.37 ± 0.12	0.82 ± 0.29	0.62 ± 0.17	0.40
Median (Min.–Max.)	1.80 (1.30–3.20)	1.30 (1.30–1.60)	0.80 (0.40–1.20)	0.60 (0.46–0.80)	
Average ADC value					
Mean ± SD	0.86 ± 0.19	0.72 ± 0.22	1.85 ± 0.22	1.80 ± 0.10	1.70
Median (Min.–Max.)	0.85 (0.50–1.20)	0.80 (0.40–0.90)	1.90 (1.60–2.20)	1.80 (1.70–1.90)	
Minimal ADC value					
Mean ± SD	0.75 ± 0.17	0.57 ± 0.15	1.63 ± 0.15	1.53 ± 0.23	1.60
Median (Min.–Max.)	0.70 (0.40–1.20)–	0.60 (0.40–0.70)	1.60 (1.40–1.90)	1.40 (1.40–1.80)	

Sarcoidosis was proven in 11/45 (24.4%) patients. Reactive non-specific nodes were found in 3/45 (6.7%) patients. TB was confirmed in a single (2.2%) patient.

Initial CT criteria

Retrospective review of the initial CT data revealed that all malignant mediastinal lymph nodes were globular in shape and their short axis diameter was 4.26 ± 1.92 cm. On the other hand, 46.7% of the benign nodes were oval and their short axis diameter was 1.97 ± 0.86 cm, which was statistically significant ($P < 0.05$).

Qualitative T2 parameters

All malignant nodes and 14/15 (93.3%) of benign nodes showed a T2 hyper-intense signal (non-significant relation with P-value = 0.6) while single patient (6.7%) with sarcoidosis showed a T2 hypo-intense signal. Internal necrosis was found in 8/30 (26.7%) of malignant nodes and 1/15 (6.7%) of benign nodes (non-significant relation with P-value = 0.113846).

Quantitative T2 parameters: [Table 1 and Fig. 1]

The lesion-to-cord SIR in T2-WI

It was significantly higher in malignant nodes. The estimated cutoff value that predicts malignancy was (> 1.2) with 90% sensitivity, 100% specificity, 100% PPV, 83.3% NPV, and AUC = 0.989.

The lesion-to-chest wall muscle signal intensity ratio in T2-WI

It was significantly higher in malignant nodes. The estimated cutoff value that predicts malignancy was (> 2.4) with 86.7% sensitivity, 100% specificity, 92.9% PPV, 76.5% NPV, and AUC = 0.88.

Quantitative diffusion-weighted image (DWI) and ADC parameters: [Table 1 and Fig. 2]

The SNR in patients with malignant lymphadenopathy was higher than benign lymphadenopathy at all b values. Still, the SNR at b500-DWI was significantly higher than at both b800-DWI and b1000-DWI ($P < 0.05$). Consequently, the b500-WI was selected for the assessment of the quantitative diffusion parameters.

The ADC value

It was significantly lower in the malignant nodes. The estimated ADC cutoff value that predicted malignancy was ($\leq 1.2 \times 10^{-3}$ mm^2/s) with 100% sensitivity, 100% specificity, 100% NPV, 100% PPV, and AUC = 1.0.

All malignant nodes showed positive diffusion restriction with a DWI bright signal and low ADC value. Meanwhile, 9/15 (60%) of benign nodes showed a bright DWI signal and high mean ADC value (means no restriction), also 6/15 (40%) of benign nodes showed

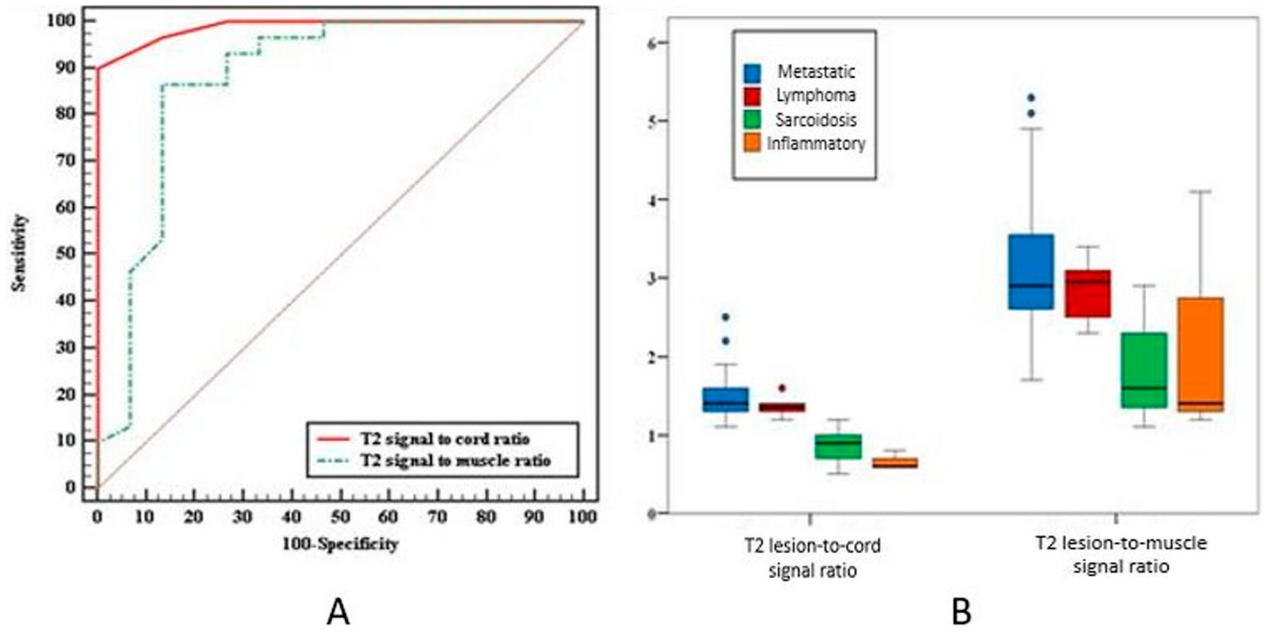

Fig. 1 **A** ROC curve for quantitative T2-WI parameters to predict malignancy. **B** Distribution of patients according to the T2 lesion-to-cord signal ratio and T2 lesions-to-muscle signal ratio in each final pathologic diagnosis (n = 45)

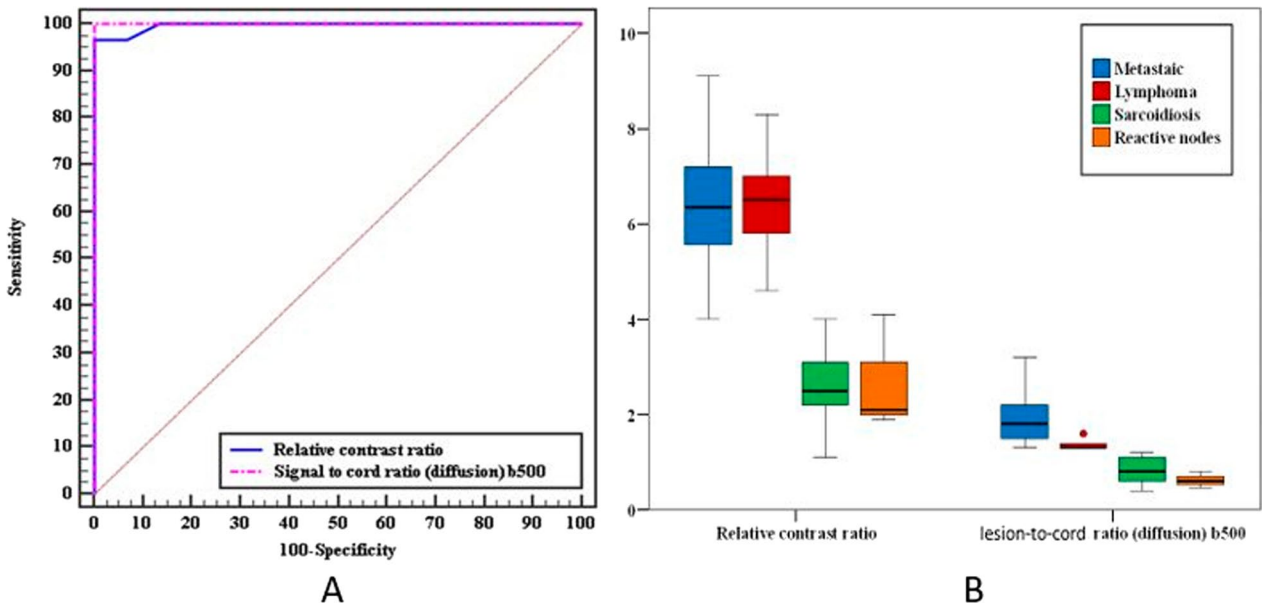

Fig. 2 **A** ROC curve for quantitative DWI parameters to predict malignancy. **B** Distribution of patients according to the relative Contrast Ratio (rCR) and Lesion-to-cord ratio in b500-DWI in each final pathologic diagnosis (n = 45)

a low DWI signal and high mean ADC value (no restriction).

The lesion-to-cord SIR in b500-DWI

It was significantly higher in malignant nodes. ROC calculated cutoff value that predicts malignancy was (> 1.2) with 100% sensitivity, 100% specificity, 100% NPV, 100% PPV, and AUC = 1.0.

The lesion-to-chest wall signal intensity ratio in b500-DWI and the relative contrast ratio (rCR)

It was significantly higher in malignant nodes. ROC calculated cutoff value that predicts malignancy was (> 4.1) with 96.67% sensitivity, 100% specificity, 100% PPV, 93.8% NPV, and AUC = 0.997.

PET-CT evaluation

All metastatic nodes expressed high FDG uptake. One patient with lymphoma showed false negative low FDG-uptake. Two patients with sarcoidosis showed false positive high FDG uptake.

At the commonly used SUV for predicting malignancy (> 2.5), the sensitivity was 82.2% and the specificity was 78.1%. On the other hand, the calculated cutoff value (> 4.5) gave higher sensitivity (90.1%) and specificity (87.3%).

The inter-rater reliability and intra-class correlation coefficient (ICC)

(a) Good to excellent inter-rater agreement regarding the lesion intensity to cord ratio and relative contrast ratio in T2-WI (ICC was 0.899 in malignant nodes, 0.941 in benign nodes, and 0.942 overall).
(b) Excellent inter-rater agreement regarding the lesion intensity to cord ratio and relative contrast ratio in DWI at b500 (ICC was 0.922 for malignant lesions, 0.911 for benign lesions with overall 0.950), and excellent inter-rater agreement was obtained regarding the benign and malignant node differentiation by assessing the average ADC value (ICC was 0.921 for malignant lesions, 0.917 for benign nodes with overall ICC 0.925).

Examples of different malignant and benign nodes were radiologically demonstrated in (Figs. 3, 4, 5, 6, 7).

Discussion

The gold-standard modality for the characterization of mediastinal lymphadenopathy remains the mediastinoscopy and pathological analysis even though not all lymph nodes are accessible, mainly those in the para-aortic level and the aorto-pulmonary window. Despite its low morbidity and mortality rates, mediastinoscopy is still an invasive intervention [9].

Other non-invasive diagnostic imaging modalities were also utilized for the same purpose including CT, PET-CT, and MRI [9].

The DWI-MRI has several advantages over the CT. The absence of irradiation is beneficial in children and pregnant women. Also, it does not require intravenous contrast injection, therefore it could be helpful for patients with renal impairment. The DWI-MRI is also more accessible and less expensive than PET-CT [9]. Additionally, changes in the ADC value could early monitor the response of chemo and radio-therapy in malignant lesions. Elevation of the ADC value corresponds to favorable tumor response [10].

The retrospective CT analysis of the mediastinal nodes in this study confirmed a significant relation between the shape of the lymph node and its nature. Luz et al. study [11] was one of the rare studies that denied this relation opposite to several studies in the literature, for example, the study of Chalian et al. [12]. Additionally, a significant relation was encountered in this study between the short axis diameter of the lymph node and its nature. This is kept with the previous studies of Sigovan et al. [9], Luz et al. [11], and Chalian et al. [12].

The estimated cutoff value of the mean ADC value that predicts malignancy in this study was similar to Sigovan M, et al. study [9] and Samir et al. study [13] ($\leq 1.2 \times 10^{-3}$ mm^2/s) and slightly higher than Nasr et al. study [14] and Abou Youssef et al. study [15] (< 1.15 the $\times 10^{-3}$ mm^2/s).

Similar to Qi et al. study [16], the signal-to-noise ratio (SNR) in this study was significantly decreased in b1000-DWI.

The estimated cutoff value of the relative contrast ratio (rCR) in this study exceeded that in the study of Sigovan et al. [9] (> 4.1 compared to > 3.6), however the higher value in the current study provided a better sensitivity and specificity (96.67% and 100% compared to 90.9% and 83% respectively). It also exceeded the estimated cutoff value in Qi et al. study [16] (3.17 ± 1.17).

By discordance from Samir et al. [13] study, the current results also emphasized the discrepancy between the estimated cutoff values of the lesion T2-signal to cord ratio that predicts malignancy regarding suspicious pulmonary parenchymal lesions and mediastinal lymphadenopathy (> 0.7 and > 1.2 respectively).

Specifically, regarding the sarcoidosis and lymphomatous-related lymph nodes, this study agreed with the study of Abou Youssef et al. [15] where the ADC value of the sarcoid-related nodes was higher than in lymphomatous nodes. On the other hand, the lesion T2-signal to cord and to muscle ratios were also significantly decreasing in sarcoid-related nodes. This is also matches the results of Santos et al. [17] study.

A moderate accuracy was depicted in the current study regarding the commonly used SUV in the literature that depicts malignancy (> 2.5) and this nearly agrees with the study of Schmidt-Hansen et al. [18] which reported 81.3% sensitivity and 79.4% specificity. However, the authors in this study also reported that increasing the SUV cutoff value to 4.5 can augment the

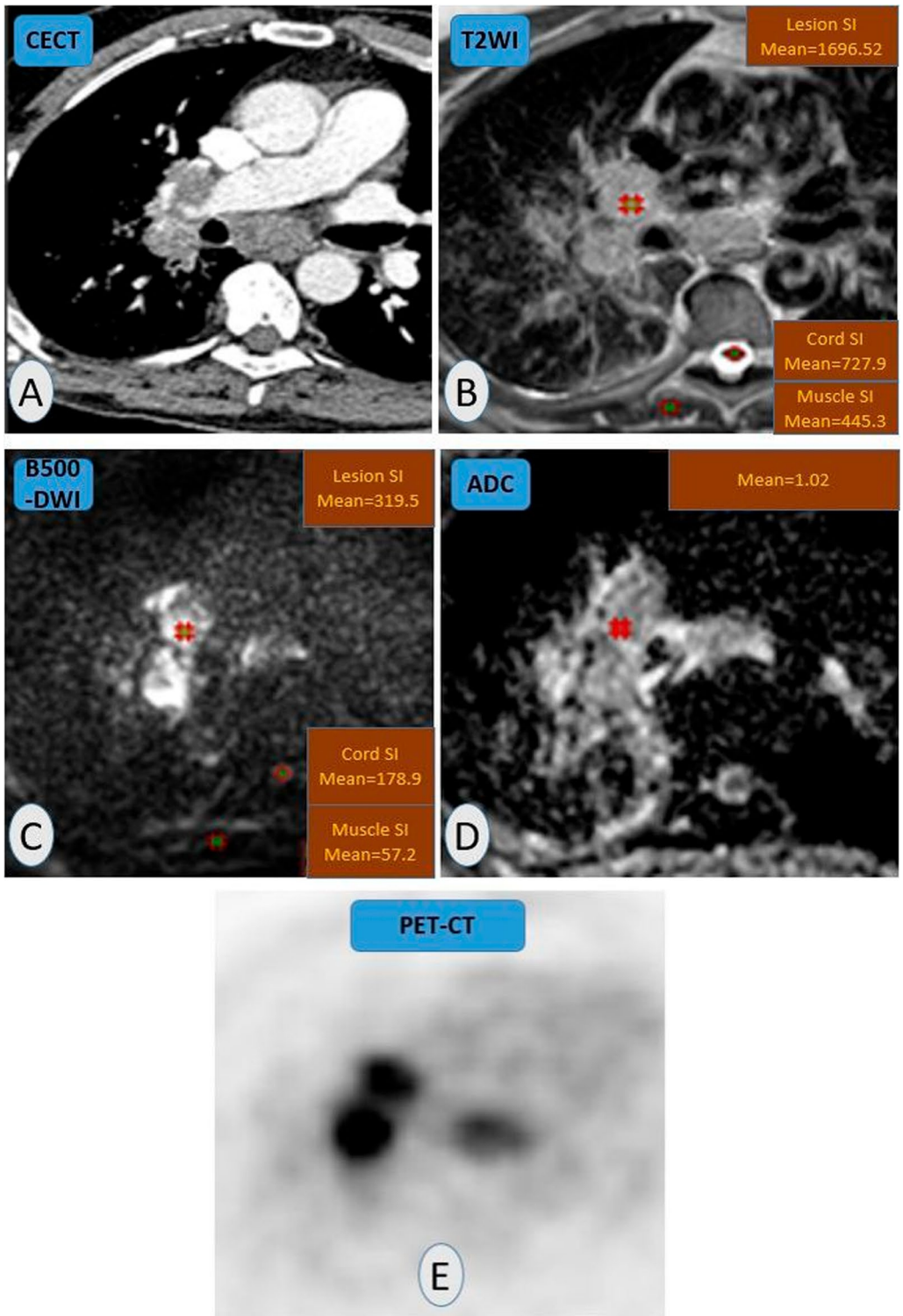

Fig. 3 A 65 years-old-male patient with pulmonary adenocarcinoma. **A** Contrast-enhanced chest CT showed two right hilar and single sub-carinal globular hypo-enhancing lymph nodes. **B** T2WI-MRI showed a homogeneous hyper-intense signal (compared to muscle signal) with lesion-to-cord signal ratio = 2.3 and lesion-to-muscle signal = 3.8. **C** b500-DWI showed a bright signal with lesion-to-cord signal ratio = 1.8 and relative contrast ratio = 4.5. **D** Mean ADC value = 1.02×10^{-3} mm^2/s (positive restriction). **E** PET-CT examination with high FDG uptake (hot spot) … Pathologic proven metastatic lymph node

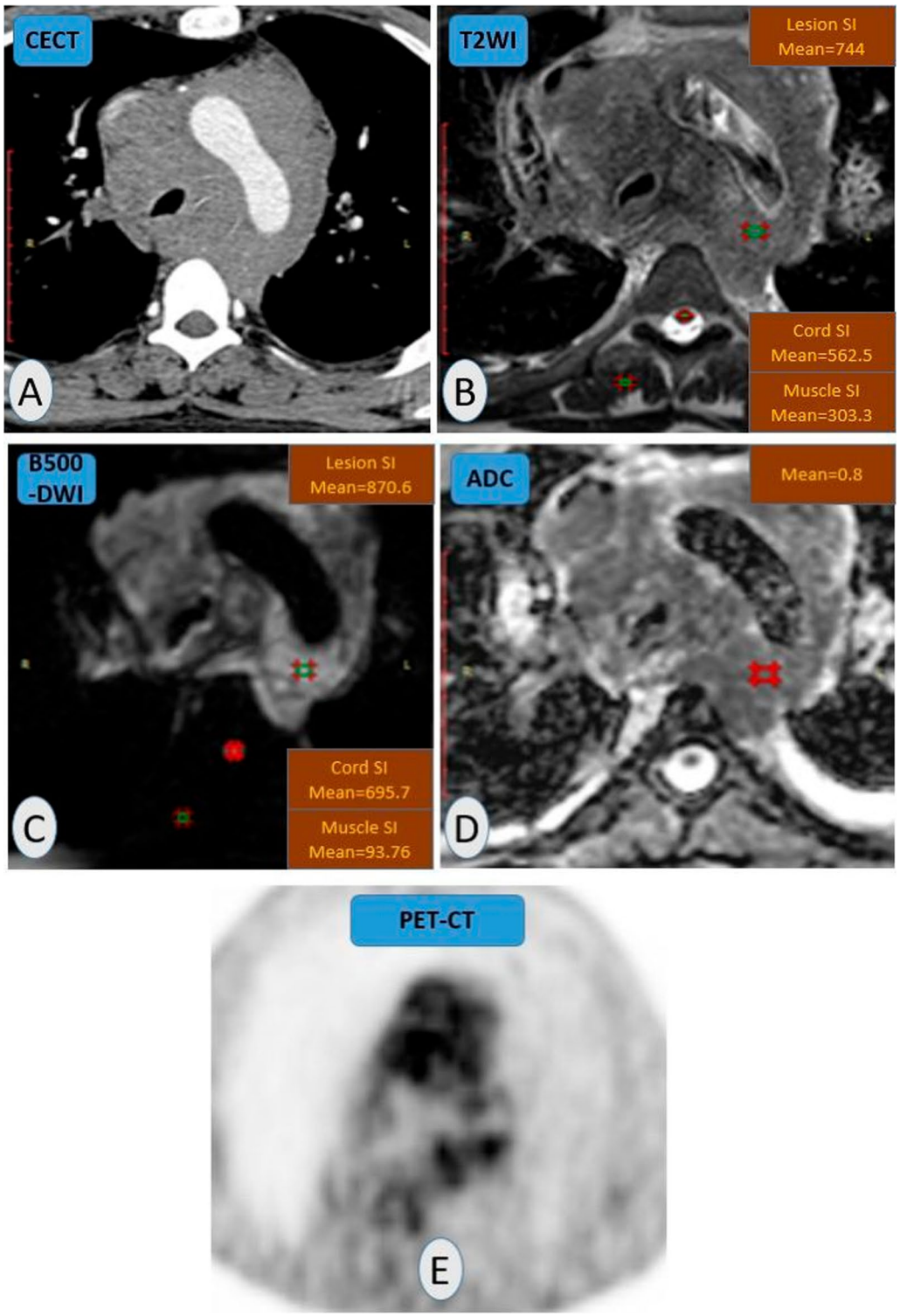

Fig. 4 A 23 years-old-male patient with dyspnea, palpitation, cough, and weight loss. **A** Contrast-enhanced chest CT showed a large anterior and posterior mediastinal hypo-enhancing nodal mass totally encasing the aortic arch and trachea. **B** T2WI-MRI showed iso to mild hyper-intense signal (compared to muscle signal) with lesion-to-cord ratio = signal 1.3 and lesion-to-muscle signal ratio = 2.4 (N.B: Signal intensity is even measured at the brightest part of the lesion). **C** b500-DWI showed only a focal bright signal at left posterior nodal tissue with lesion-to-cord signal ratio = 1.3 and relative contrast ratio = 5.3. **D** Mean ADC value = 0.8×10^{-3} mm^2/s (positive restriction). **E** PET-CT examination with high FDG uptake (hot spot) … Pathologic proven non-Hodgkin lymphoma

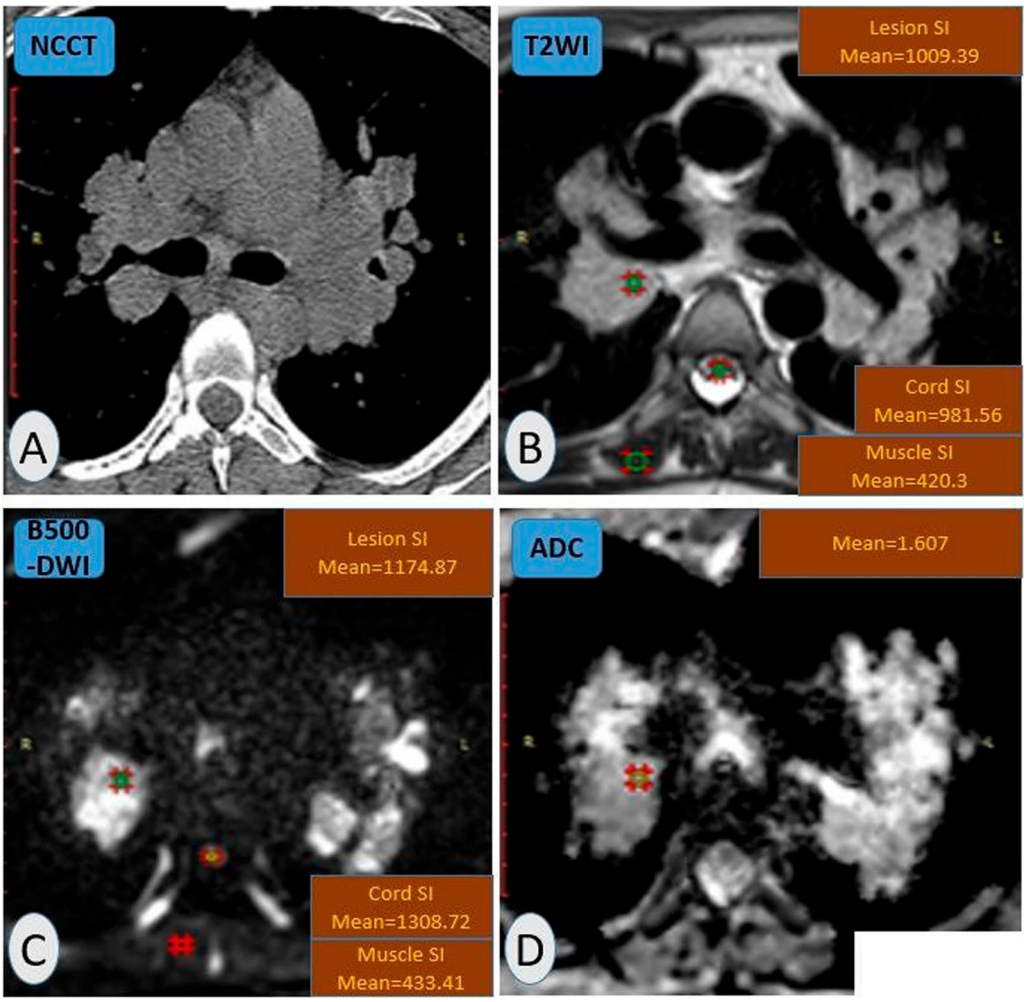

Fig. 5 A 40 years-old-female patient complaining of dyspnea and cough. **A** Non-contrast enhanced chest CT with multiple mediastinal and bilateral hilar lymph nodes. **B** T2WI-MRI showed hyper-intense globular lymph nodes (compared to muscle signal) with lesion-to-cord signal ratio = 1 and lesion-to-muscle signal ratio = 2.4 (N.B: The relatively higher T2-signal is strikingly noticed compared to Fig. 4). **C** b500-DWI showed a bright signal of few nodal tissues still with lesion-to-cord signal ratio = 0.8 and relative contrast ratio = 1.7. **D** Also, the mean ADC value = $1.\times10^{-3}$ mm^2/s (no restriction) … Pathologic proven sarcoidosis

accuracy of the PET-CT examinations. This principle matched that of Lee et al. [19] study which offered a lower cutoff value (4), and also Bryant et al. [20] study which offered a higher cutoff value (5.3), however, both approximated the same accuracy in this study. I worth mentioning that new research in the literature studied the additive role of a combination of CT and MRI findings with the SUV (for example Wumener et al. [21] study), and this even significantly augmented its accuracy.

The current study added to the literature the combination of the qualitative and quantitative MRI parameters, also the correlation with both PET-CT and pathological results.

This study faced some limitations, as follows:

(1) The small sample size of the included patients, therefore authors encourage further large-group research.
(2) A limited number of previous research in the literature for discussion.
(3) Tiny sub-centimeter nodes were not among the suspicious CT criteria, which is why they were not evaluated in this study.

Conclusions

Biopsy remains the main diagnostic modality for the characterization of mediastinal lymphadenopathy despite its hazards and limitations. This study proved that MRI could be accepted as an alternative non-invasive imaging tool that can overcome the PET-CT

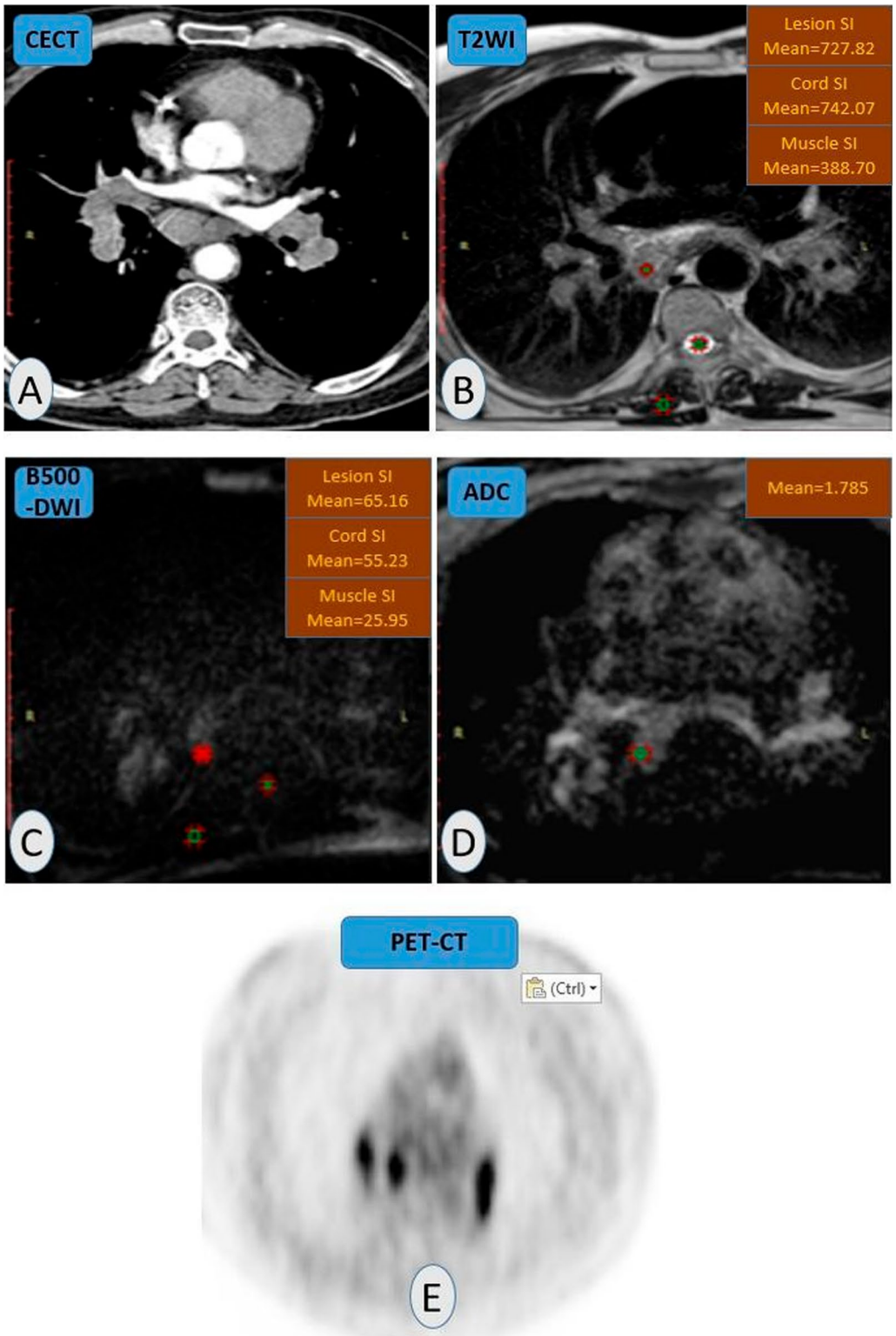

Fig. 6 A 51 years-old-male patient complaining of dyspnea and cough. **A** Contrast-enhanced chest CT with multiple mediastinal and bilateral hilar lymph nodes. **B** T2WI-MRI showed a hyper-intense signal with lesion-to-cord signal ratio = 0.96 and lesion-to-muscle signal ratio = 1.8. **C** b500-DWI showed a low signal with lesion-to-cord signal ratio = 1.18 and relative contrast ratio = 2.5. **D** Mean ADC value = 1.7×10^{-3} mm^2/s (no restriction). **E** PET-CT examination showed high FDG uptake (false positive hot spot) … Pathologic proven sarcoidosis

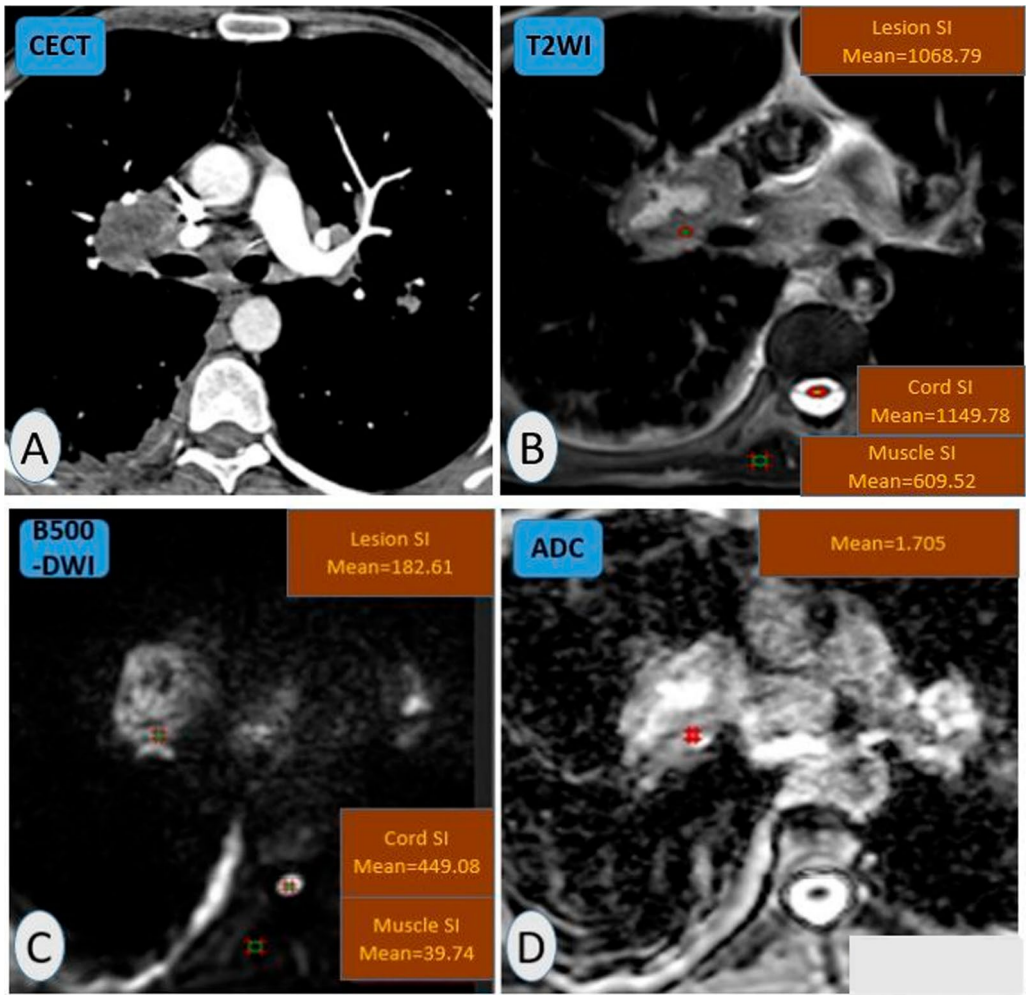

Fig. 7 A 53 years-old-male patient complaining of progressive dyspnea, cough, night fever, night sweats, and weight loss. **A** Contrast-enhanced chest CT showed a right hilar globular lymph node with heterogeneous enhancement, necrosis, and breaking. **B** T2WI-MRI showed hyper-intense globular lymph nodes with lesion-to-cord signal ratio = 0.9 and lesion-to-muscle signal ratio = 1.7. **C** b500-DWI showed a mild bright signal with lesion-to-cord signal ratio = 0.4 and relative contrast ratio = 3.5. **D** Mean ADC value = 1.7×10^{-3} mm^2/s (no restriction) … Pathologic proven necrotic TB lymph node

limitations. The lesion signal-to-cord and to-muscle SIR in both T2-WI and DWI-MRI side by side with the mean ADC value showed high statistical accuracy.

Abbreviations

DWI	Diffusion-weighted image
MRI	Magnetic resonance imaging
PET-CT	Positron emission tomography-computed tomography
SIR	Signal intensity ratio
ROC	Receiver-operating characteristic
ADC	Apparent diffusion coefficient
ICC	Intra-class correlation coefficient
PPV	Positive predictive value
NPV	Negative predictive value
AUC	Area under curve
rCR	Relative contrast ratio
SNR	Signal to noise ratio

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Author contributions
AS (the corresponding author) is responsible for ensuring that the descriptions are accurate and agreed by all authors. HE, AR, and AE had made substantial contributions to all of the following: (1) The conception and design of the radiological work, (2) The acquisition, analysis and interpretation of radiological data, (3) Drafting the work and revising it. AB and MM had made substantial contribution to; (1) acquisition, analysis and interpretation of clinico-laboratory data, and (2) Drafting the work and revising it. All authors approved the submitted revised version. All authors have agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The medical ethics were considered and respected. The study was approved by Institutional Ethics Committee in Faculty of Medicine, Alexandria University [IRB No: (00012098), FWA No: (00018699)]. The patient consent was obtained.

Consent for publication
The consent for publication was obtained.

Competing interests
None.

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