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RESEARCH

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Value of diffusion-weighted MRI and lesion-to-spinal cord signal intensity ratio in pulmonary lesion characterization

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Abstract

Background In the scenario of lung lesions, the differential diagnosis is important, since the treatment is determined by the characteristics of the lesion. The goal in the evaluation of pulmonary lesions is to distinguish malignant lesions from benign lesions in a non-invasive manner as possible. Since, CT is not sufficient to accurately distinguish malignant nodules from benign nodules and patients with benign nodules might undergo invasive diagnostic methods, such as lung biopsy or video-assisted thoracoscopic surgery, to rule out a malignancy. Now, MRI performed by using diffusion-weighted (DW) can offer both qualitative and quantitative information that can be helpful for tumour assessment. Moreover, lesion-to-spinal cord signal intensity ratio (LSR) has also been shown to be useful for the differentiation of lung lesions. Quantitative tumour assessment is possible by the calculation of ADC.

Results A total of 30 patients were eligible for inclusion in our final analysis; with male/female case number about 10/20 (33.3%/ 66.7%) and age range from 20 to 74 (46.8 ± 14.9) were subjected to MRI study and MRI diffusion. Sensitivity analysis showed that ADC mean, and ADC min value can significantly predict malignant lung lesions using cutoff point < 1.53 and < 1.34 respectively, with sensitivity 75%, 56.3%, and specificity 92.9%, 100% with *p* values 0.001, and 0.005 respectively. SI lesion can significantly predict malignant lung lesions using cutoff point > 502.8, with sensitivity 92.9% and specificity 68.7%, AUC 89.3% and *p* value 0.0001. Lesion-to-spinal cord signal intensity ratio (LSR) can significantly predict malignant lung lesions using cutoff point > 1.3, with sensitivity 85.7% and specificity 75%, AUC 79.7% and *p* value 0.006.

Conclusions This study confirmed that the DWI combined with ADC value and LSR is effective and valuable tool in differentiation of pulmonary lesions whether benign or malignant which is considered to be noninvasive alternative tool for the characterization of pulmonary lesions. We recommend before invasive intervention to perform diffusion MRI and LSR as and important aid for proper diagnosis.

Keywords Diffusion-weighted, MRI, Lesion-to-spinal cord signal intensity ratio, Pulmonary lesions

Background

Lung cancer remains the number one cause of cancer mortality worldwide. In most cases, the diagnosis is initially made through the detection of a nodule or a mass at chest radiography or CT [1].

When a patient is diagnosed with a lung lesion, the differential diagnosis is important, since the treatment is determined by the characteristics of the lesion. The

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goal in the evaluation of pulmonary lesions is to distinguish malignant lesions from benign lesions in as non-invasive a manner as possible [2].

The differential diagnosis of lung lesions is broad. The occurrence of relevant symptoms, the number of lesions, and their particular imaging characteristics (location, shape, presence and type of calcifications, and presence of spiculation or cavitation) may substantially narrow the differential diagnosis or even point toward a specific entity [3] However, it can sometimes be difficult to distinguish benign from malignant lesions, especially on CT [2].

The commonly encountered malignant pulmonary lesions include squamous cell carcinoma (SCC), adenocarcinoma, small cell lung carcinoma (SSLC) and metastasis [4].

While the most common benign pulmonary lesions include hydatid cyst, lung abscess, hamartoma, organising pneumonia, tuberculoma, sarcoidosis, round atelectasis, infection, wegner granulomatosis and neurogenic tumours [4].

With the advent of improved gradient technology, multichannel coils, and parallel imaging techniques, magnetic resonance imaging (MRI) and diffusion-weighted imaging (DWI) of the chest have become feasible [5].

Characterization of the primary tumor on CT and MR imaging is based on the imaging features of the lesion itself and its relationship to the pleura, chest wall, airways, and mediastinum, as well as its relative enhancement by contrast media [6].

MRI is superior to CT for the visualization of the pericardium, the heart and mediastinal vessels. MRI can be of use specifically for assessing invasion of the superior vena cava or myocardium, or extension of the tumor into the left atrium via pulmonary veins [7].

MRI can be used as a reliable method to determine the relationship between chest wall invasion, tumor and diaphragm, superior lung tumor and brachial plexus nerves and blood vessels [8].

MR imaging in lung cancer patients can be applied for (1) detection of pulmonary lesions (2) characterization of the pulmonary lesions, and (3) assessment of TNM classification in routine clinical practice [6].

DWI has been described to be able to differentiate malignancy from benignity for pulmonary lesions [7, 9].

The signal intensity ratios (SIRs) of the lesion divided by the rhomboid muscle on T2WI and T1WI are significantly different between benign pulmonary lesion and lung cancer [9].

The ADC and T2 contrast ratio (T2 CR) of lung cancers are significantly lower than that of benign pulmonary lesions [7].

ADC values in cases of adenocarcinoma were significantly higher than cases of SCC and large-cell carcinoma. In addition, the ADC values of well-differentiated adenocarcinoma cases were significantly higher than the cases of poorly-differentiated adenocarcinomas [4].

In addition to ADC value, lesion-to-spinal cord signal intensity ratio (LSR) has been proposed to be more accurate than mean ADC values on DWI. Moreover, LSR has also been shown to be useful for the differentiation of lung lesions and prediction of tumor invasiveness [2].

The signal intensity of the lesion-to-spinal cord ratio (LSR) can be used to differentiate lung cancer from benign lesions according to Uto et al. which described that the LSR of cancer lesions was significantly higher than that of benign lesions [10].

Aim of work

The aim of the study is to detect the usefulness of diffusion weighted MR imaging and lesion-to-spinal cord signal intensity ratio in the evaluation of pulmonary lesions and differentiating benign from malignant lesions.

Patients

- A total of 30 patients were eligible for inclusion in our final analysis; with male/female case number about 10/20 (33.3%/ 66.7%) and age range from 20 to 74 (46.8 ± 14.9) were subjected to MRI study and MRI diffusion

Inclusion criteria

- Patients with identified pulmonary lesion on CT that showed solid density and histologically confirmed or clinically proven.
- Any age.

Exclusion criteria

- Patients with contra-indication to MRI e.g. pacemakers, metallic implants, severe claustrophobia.
- Pregnancy.

Methods

1 Ethical committee approval was taken before conducting this cross sectional study.
2 All cases were subjected to the following:

- Oral consent about the technique of examination.
- Computed tomography of the chest.
- Biopsy and histo-pathological assessment for suspected malignant lung lesions.

- Magnetic resonance imaging of the chest with a 1.5-T superconducting imager (Achieva; Philips Medical Systems, Best, The Netherlands) using a 16-channel body phased-array coil.

MRI technique

- Respiratory gating was used in all patient.
- Patient Position: The patients were supine with the head directed to the scanner bore.
- Image Acquisition: The MR scanning sequences used were as follows:
  - T1WI (axial and coronal) were obtained with the spin echo sequence with the following parameters: repetition time/echo time: 10 ms/ 5 ms; number of excitations: 2; direction of frequency encoding: R/L; section thickness: 5 mm; gap: 0.5 mm; field of view: 36–40 cm; matrix: 288 × 224. Axial,
  - T2WI (axial and coronal) were obtained with the following parameters: repetition time/echo time, 664 ms/80 ms; number of excitations, 3; direction of frequency encoding: R/L; section thickness, 5 mm; gap,1.5 mm; field of view, 36–40 cm; matrix, 288 × 224
  - T2 STIR (axial) was obtained with the following parameters: repetition time/echo time, 1.6 ms/20 ms; number of excitations, 3; direction of frequency encoding: R/L; section thickness, 5 mm; gap, 0.5 mm; field of view, 36 × 40 cm; matrix, 288 × 224
  - DWI was acquired in a transverse plane, using three b values; low (0–50 s/mm^2) and intermediate-to-high b values (500-800-1000 s/mm^2). The slice thickness is 4–9 mm with an inter slice gap of 0–1.5 mm, and the number of excitations ranges from 1 to 10.
  - Quantitative DWI analysis (ADC measurement): was calculated by the MR system via linear regression analysis of the natural log of signal intensity using all three b-values (0, 500 and 1000 s/mm2).

Image assessment

Qualitative analysis

MR images were qualitatively analyzed by visual assessment of the different pulse sequences and considering the suspicious areas of interest. Areas of restricted diffusion are bright on DWI using high b value and dark on ADC map indicating low ADC value. The visual assessment included the size, location and signal intensity of the pulmonary lesion. Associated MR imaging findings e.g. chest wall, hilar or mediastinal infiltration were also recorded.

Quantitative analysis

ADCs were calculated from the ADC maps, which were constructed from b = 0, b = 500, b = 800 and b = 1000 s/mm values. A ROI (region of interest) was drown within the lesion on the ADC map. ROI was positioned within areas of the most diffusion restriction on visual judgment, trying to avoid as much as possible obviously cystic or necrotic areas. Three ROIs were placed and the average of three measurement was recorded.

The signal intensity of the nodule/mass and spinal cord was measured in the same slice on DWI. An ROI of the same size as that placed on the spinal cord was positioned on the lesion, and the LSR was calculated by dividing the lesion signal intensity by the spinal cord signal intensity.

Other ratios were calculated from T1, T2 and T2 STIR sequences by measuring the signal intensity of the lung lesion and chest wall muscles. An ROI of the same size as that placed on the chest wall muscles was positioned on the lesion, and these ratios were calculated by dividing the lesion signal intensity by the chest wall muscles signal intensity.

Statistics data analysis

Statistical analysis was conducted using SPSS 22nd edition, categorical variables were presented in mean, standard deviation, and range, it was compared using Mann Whitney U test. Categorical variables were presented in frequency and percentages. Sensitivity analysis was conducted to predict incidence of morbidity and mortality, and to set the optimal cutoff point for this prediction. Receiver curve of characteristic curve was constructed to visualize the area under the curve for predicted outcomes. Any p value < 0.05 was considered significant.

Results

A total of 30 patients were eligible for inclusion in our final analysis.

The final diagnosis showed that 16 (53.3%) patients had benign lung lesions, while 14 (46.7%) patients had malignant pulmonary lesions. And the definite diagnosis was achieved by one of the following tools (Table 1).

Our investigations showed the diagnosis of pulmonary lesions as recorded in (Table 1) with squamous cell carcinoma being the most commonly encountered lesion followed by adenocarcinoma; while the most common benign lesions were sarcoidosis and septic emboli.

Comparison of DWI-MRI parameters revealed that ADC mean, ADC min value, SI lesion and LSR showed statistically significant difference between malignant (Figs. 1, 2) and benign pulmonary lesions (Figs. 3, 4 and 5) (Table 2).

Table 1 Diagnosis of pulmonary lesions among the included patients and tool of diagnosis

	Count	%	Tools of diagnosis
Diagnosis			
Metastatic Pulmonary Nodule	3	10.0%	PET/ CT
Adenocarcinoma	4	13.3%	Pathology
Bronchogenic Cyst	1	3.3%	Radiology
Fungal Infection	1	3.3%	Bronchoalveolar lavage
Hydatid Cyst	2	6.7%	Pathology
Inflammatory Pseudotumor	1	3.3%	Pathology
Lung Abscess	2	6.7%	Radiology / clinical
Organizing Pneumonia	1	3.3%	Clinical
Sarcoidosis	3	10.0%	Pathology
Schwannoma	1	3.3%	Pathology
Septic Emboli 2ry To Infective Endocarditis	3	10.0%	Clinical
Small Cell Lung Cancer	1	3.3%	Pathology
Squamous Cell Carcinoma	6	20.0%	Pathology
Tuberculosis	1	3.3%	Serology

- The ADC mean was significantly higher among benign lesions compared to malignant ones (1.88 ± 0.51 vs. 1.31 ± 0.28 respectively) with p value 0.001.
- The ADC min value was significantly higher among benign lesions compared to malignant ones (1.45 ± 0.5 vs. 0.99 ± 0.26) with p value 0.004.
- While SI lesion was significantly higher among malignant pulmonary lesions (1431.1 ± 1518.1 vs. 433.4 ± 231.1) respectively with p value 0.0001.
- As well, LSR was significantly higher among malignant pulmonary lesions (1.6 versus 1.18) respectively with p value 0.006.
- While comparison of the T2 SI ratio, STIR SI ratio and T1 SI ratio showed statistically insignificant difference between the examined pulmonary lesions.

Sensitivity analysis showed that ADC mean, and ADC min value can significantly predict malignant lung lesions using cutoff point < 1.53 and < 1.34 respectively, with sensitivity 75%, 56.3%, and specificity 92.9%, 100% with p values 0.001, and 0.005 respectively.

SI lesion can significantly predict malignant lung lesions using cutoff point > 502.8, with sensitivity 92.9% and specificity 68.7%, AUC 89.3% and p value 0.0001.

LSR can significantly predict malignant lung lesions using cutoff point > 1.3, with sensitivity 85.7% and specificity 75%, AUC 79.7% and p value 0.006.

Discussion

The goal in the evaluation of pulmonary lesions is to distinguish malignant lesions from benign lesions in as non-invasive a manner as possible [2].

DW MRI has emerged as a radiation-free alternative for the characterization of pulmonary lesions as it allows quantification of restriction to water diffusion in biologic tissue [11].

The apparent diffusion coefficient (ADC), which is highly inversely correlated with tumor cellularity, is a useful parameter for quantifying diffusion restriction in vivo and also helps differentiate malignant from benign lesions [12].

In addition to ADC value, lesion-to-spinal cord signal intensity ratio (LSR) has been proposed to be more accurate than mean ADC values on DWI. Moreover, LSR has also been shown to be useful for the differentiation of lung lesions and prediction of tumor invasiveness [2].

The aim of the study was to detect the usefulness of diffusion weighted MR imaging and lesion-to-spinal cord signal intensity ratio in the evaluation of pulmonary lesions and differentiation of benign from malignant lesions.

We conducted a cross-section analytical study that included 30 patients who were diagnosed with benign and malignant lung lesions on CT; 20 males and 10 females, age range 20–74 years (average of 46.8 years).

In our study, we found that the mean ADC was significantly higher among benign lesions compared to malignant ones (1.88 ± 0.51 vs. 1.31 ± 0.28 respectively) with p value 0.001. Setting the cut-off value at $1.53 \times 10–3$, ADC had a sensitivity of 75% and a specificity of 92.9% for the differentiation of benign lesions from malignant lesions.

Similar results are seen in ÇAKIR et al. 2015 and Alnaghy et al. 2018 studies. The ADCs of the benign lesions were significantly higher than those of malignant lesions (mean ADC was $2.02 \times 10–3$ mm2/s for

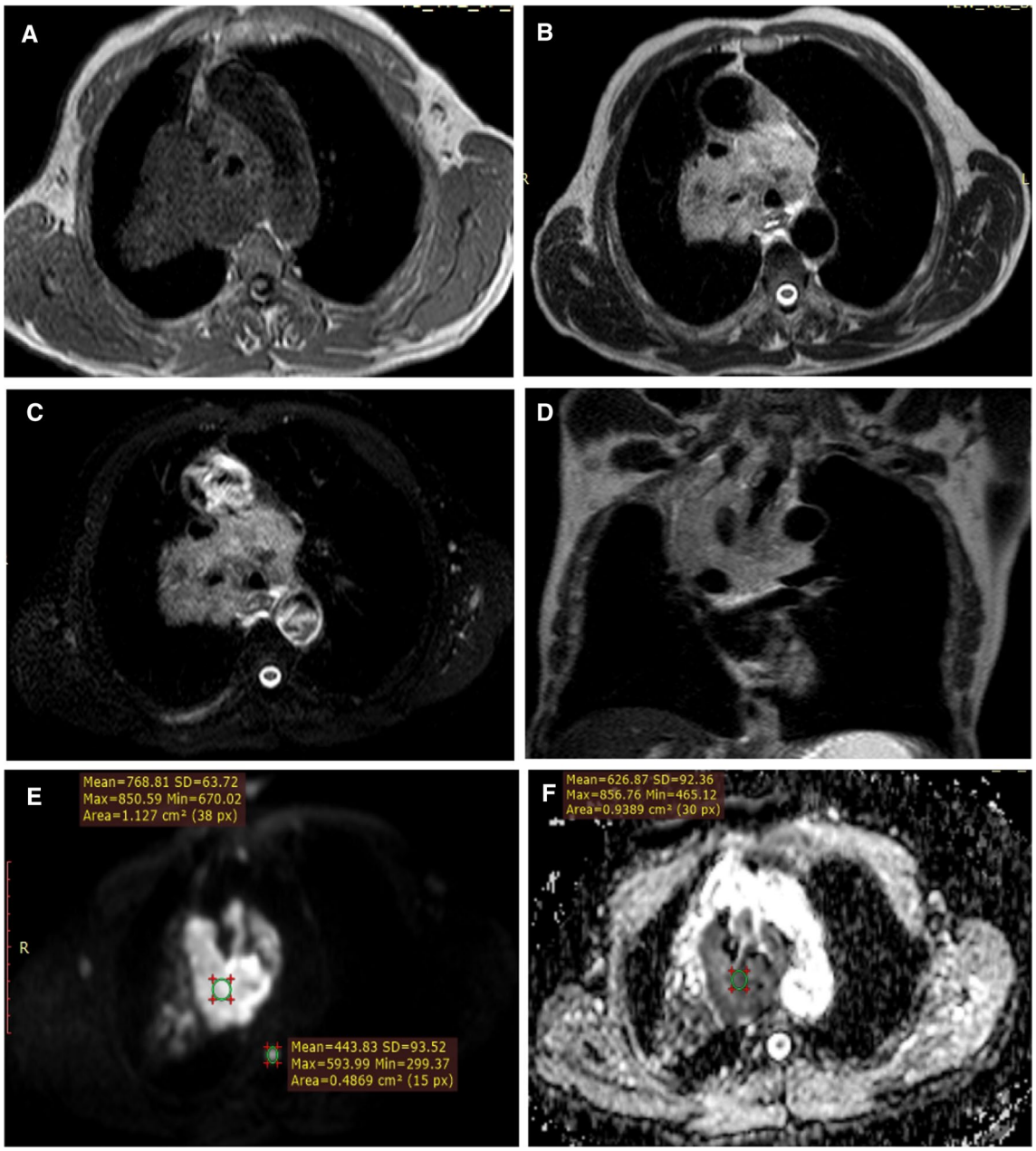

Fig. 1 63-year-old male patient presenting with massive weight loss, cachexia and hoarseness of voice. Axial T1 (**A**), axial T2 (**B**), axial STIR (**C**) and coronal T2 STIR (**D**) weighted MR images show large right upper lobar soft tissue mass lesion measuring 6 × 9.9x10.8 cm along its maximum axial and craniocaudal dimensions respectively. It elicits isointense signal and hyperintense signal relative to the surrounding muscles on T1 and T2. It shows right hilar and mediastinal extensions encroaching on the lumen of the trachea and right main bronchus with obstruction of the upper lobar bronchus causing subsequent partial collapse of the right upper lobe. It is seen abutting the SVC. DWI (**E**) and ADC map (**F**) images show restricted diffusion with LSR = 1.73, ADC mean 0.63 and ADC min 0.46. Histopathology revealed small cell lung cancer

malignant lesions, and $1.195 \times 10{-}3 \pm 0.3$ mm2/s for benign lesions) [2, 13].

According to Rasheed et al. [14] There was a significant difference between ADC means of a malignant and benign lesion ($p = 0.003$) with cutoff value $1.027 \times 10 - 3$ s/mm2.

As compared to other group of researchers who performed their study according to the ADC min.

In our study, The ADC min value was significantly higher among benign lesions compared to malignant ones (1.45 ± 0.5 vs. 0.99 ± 0.26) with cutoff point < 1.34 yielding sensitivity 56.3%, specificity 100%.

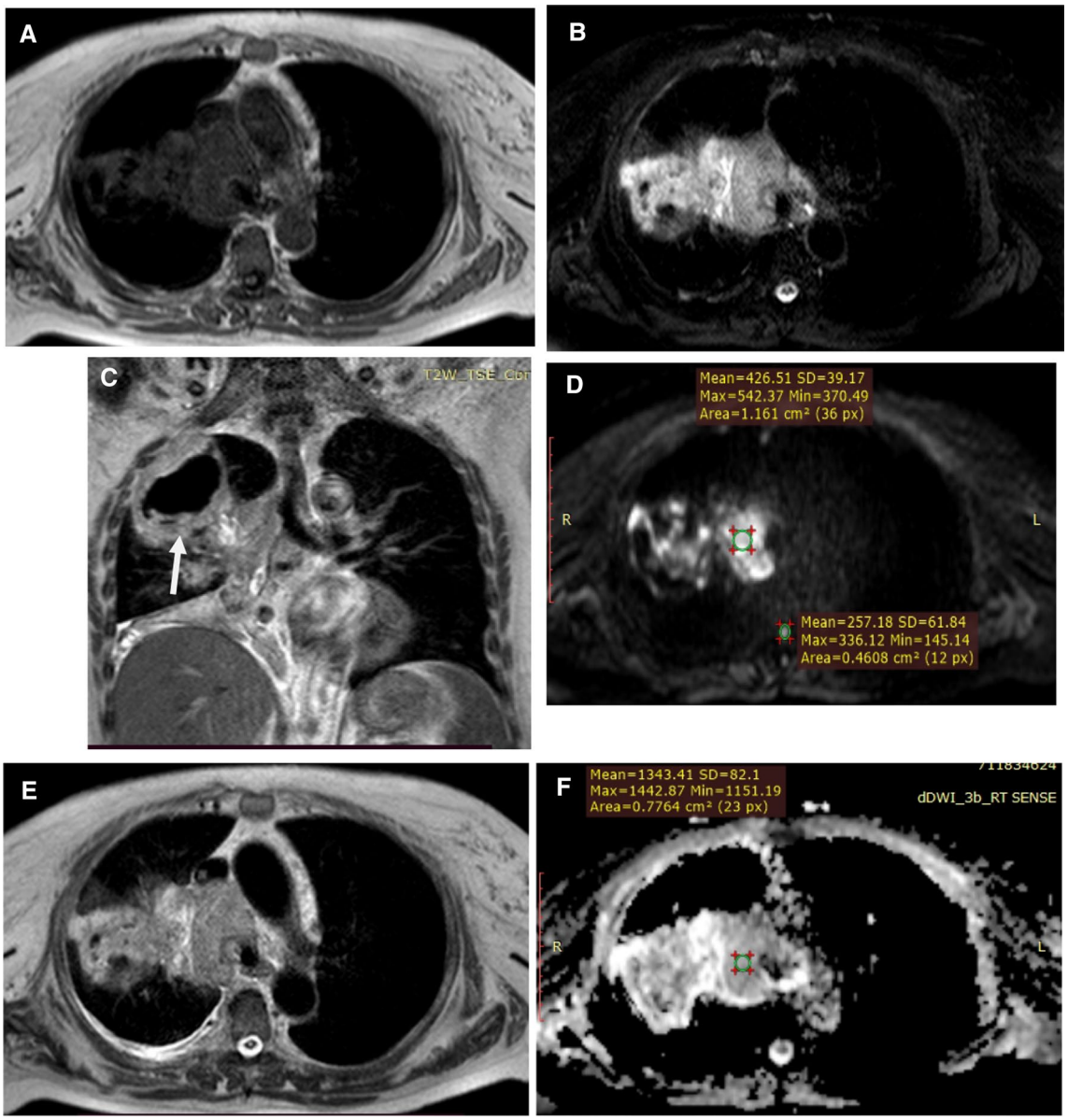

Fig. 2 Female patient 74-years-old presenting with cough, dyspnea and hemoptysis with massive weight loss. A-D: Axial T1 (**A**), axial T2 (**B**), axial STIR (**C**), coronalT2 (**D**) weighted MR images show large right upper lobar soft tissue mass lesion measuring 7.2 × 6.4x6.1 cm along its maximum axial and craniocaudal dimensions respectively. It elicits isointense signal and hyperintense signal relative to the surrounding muscles on T1 and T2 respectively. It shows right hilar and mediastinal extensions encroaching on the lumen of the trachea and right main bronchus causing partial collapse of the right upper and middle lobes. It is seen encasing and attenuating the SVC. DWI (**E**) and ADC map (**F**) images show restricted diffusion with LSR 1.65, ADC mean 1.34 and ADC min 1.15. Histopathology revealed squamous cell lung cancer

Jiang et al. [15], Kumar et al. [16] and study results also reported that the ADC min in malignant pulmonary lesions were significantly lower than benign lesions.

As regarding the signal intensity of the lesions, in our study, we found that SI of the lesions on diffusion sequences were significantly higher among malignant pulmonary lesions than benign pulmonary lesion (1431.1 ± 1518.1 vs. 433.4 ± 231.1) respectively with p value 0.0001.

Our result is comparable to Çakmak et al. [4] and Alnaghy et al. [13] which also found that the SI lesion was significantly higher among malignant pulmonary lesions than benign pulmonary lesion (231.80 ± 139.492) versus (107.10 ± 74.497) respectively with p value < 0.001.

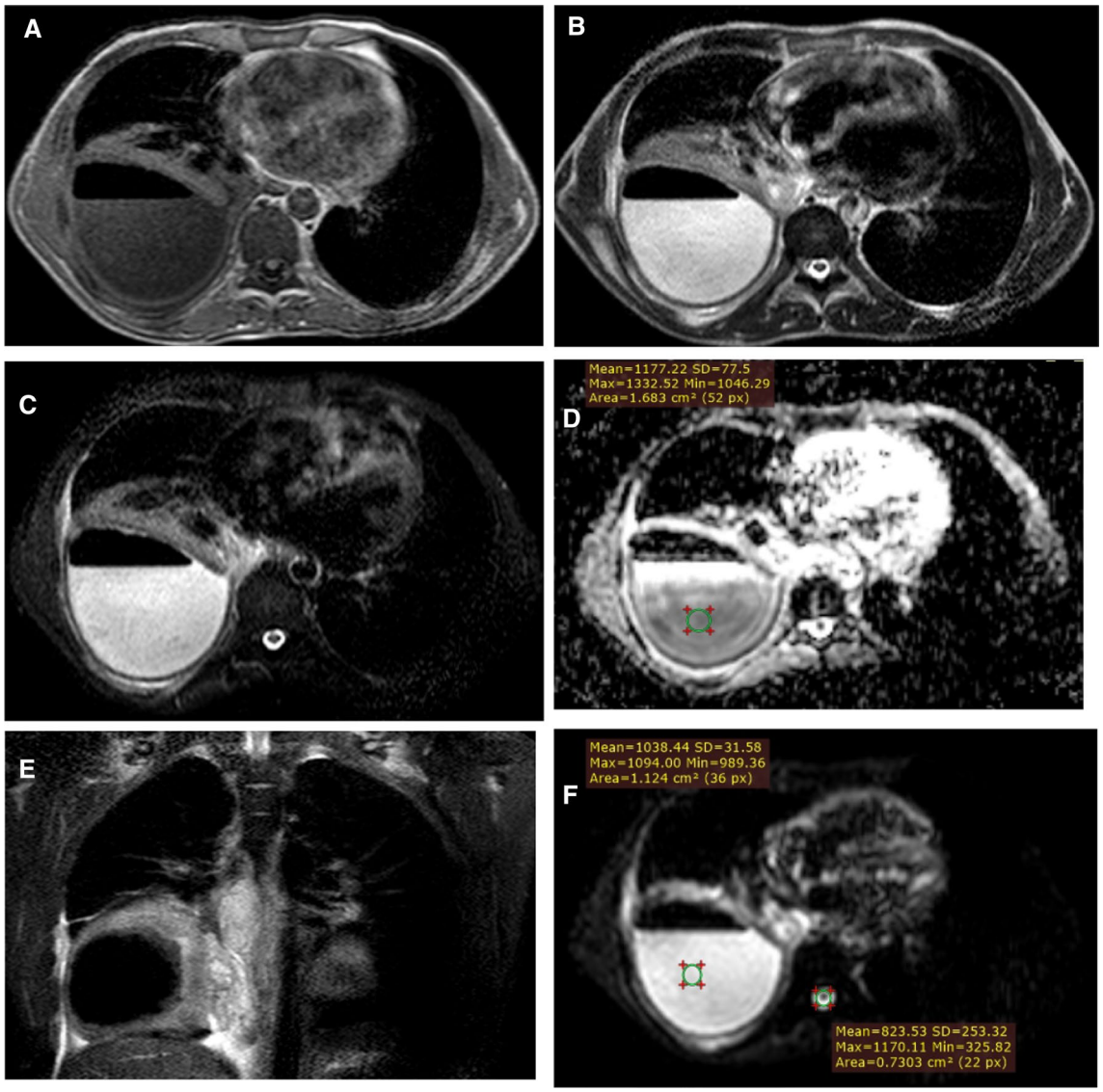

Fig. 3 Male patient 42-years-old presenting with high fever and productive cough. The laboratory tests show elevated WBCs and high ESR. A-D: Axial T1 (**A**), axial T2 (**B**), axial STIR (**C**), coronalT2 (**D**) weighted MR images show right lower lobar well defined thick walled cystic lesion with air fluid level measuring 9.6 × 9.5x14 cm along its maximum axial and craniocaudal dimensions, respectively. It elicits hypointense signal and hyperintense signal relative to the surrounding muscles on T1 and T2 respectively with surrounding lung consolidation. DWI (**E**) and ADC map (**F**) images show facilitated diffusion with LSR = 1.26, ADC mean 1.2 and ADC min 1.04. Clinical and radiological diagnosis revealed lung abscess

As comparing the signal intensity of the lesions to that of the spinal cord, in our study, the calculated LSR was higher among malignant pulmonary lesions than benign pulmonary lesions (1.6 ± 0.36 for malignant lesions and 1.18 ± 0.59 for benign lesions) with *p* value 0.006.

In our study, LSR can significantly predict malignant lung lesions using cutoff point > 1.3, with sensitivity 85.7% and specificity 75%, AUC 79.7% and *p* value 0.006.

These findings more or less agreed with Rasheed et al. [14] study which also found that the mean LCR for malignant lung lesions was significantly higher than that of the benign ones. The sensitivity of 84%, the specificity of 90%, and the accuracy of 86.2% were calculated in a cut-off of 0.983.

Another study showed that the mean LSR was 1.4 ± 0.3 for lung cancer and 1 ± 0.1 for benign lesions with a cut-off value of 1.20 × 10–3 mm2/s. (Henz Concatto at, 2016). [17].

Considering the T2 sequence signal intensity, While comparing the T2 SI ratio in our study, the results reported statistically insignificant difference between the

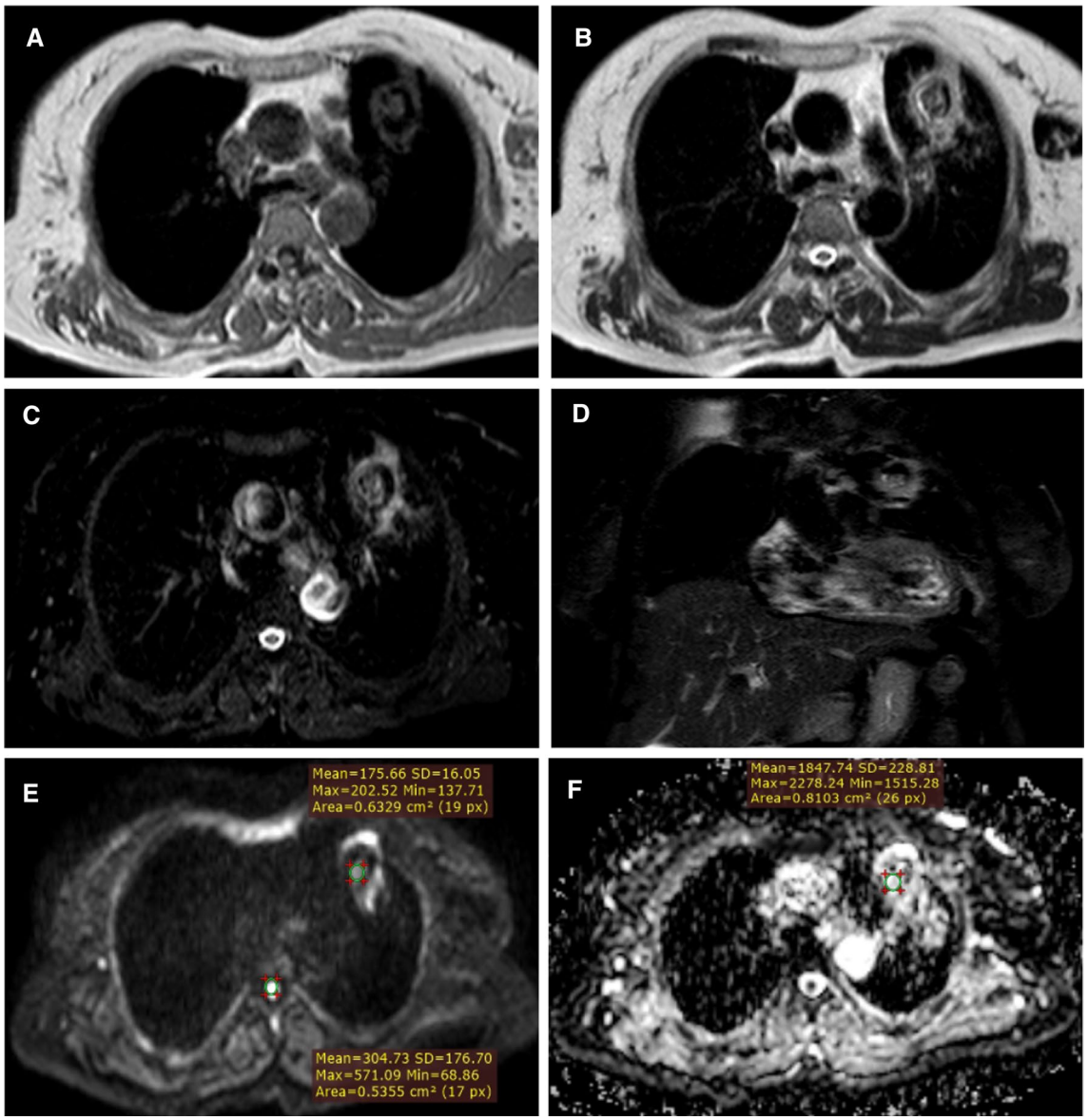

Fig. 4 Female patient 72-years-old presenting with dyspnea and cough. A-D: Axial T1 (**A**), axial T2 (**B**), axial STIR (**C**), coronal STIR (**D**), weighted MR images show left upper lobar cavitary lesion with soft tissue within and surrounding consolidation. They elicit isointense T1 signal and hyperintense T2 signal relative to the surrounding muscles with air crescent sign. DWI (**E**) and ADC map (**F**) images show facilitated diffusion and LSR = 0.58, ADC mean value 1.85 with ADC min value 1.51. Bronchoscopic examination with brocho-alveolar lavage and cytology revealed fungal infection (aspergilloma)

examined pulmonary lesions. The mean T2 SI ratio for benign was 3.28 ± 1.13 and 2.9 ± 0.88 for malignant.

This results agreed with Usuda et al. [7] study which was conducted on 52 lung cancers and 47 benign pulmonary lesions found that T2 SI ratio of lung cancers was significantly lower than that of benign pulmonary lesions ($p = 0.0021$). When the optical cutoff value of T2 SI ratio was set as 2.44, the sensitivity was 0.827, the specificity 0.596, the accuracy 0.717.

In contrast to Henz Concatto at, 2016 [17] which showed that Mean T2 SI ratio differed significantly between benign and malignant lesions (0.8 ± 0.2 vs. 1.6 ± 0.2; $P < 0.05$).

And also in contrast to, Meier-Schroers et al. [18] where the study results demonstrated that T2W imaging was most reliable for the detection of pulmonary lesions and showed that the signal intensity ratio were higher for carcinomas on T2W imaging.

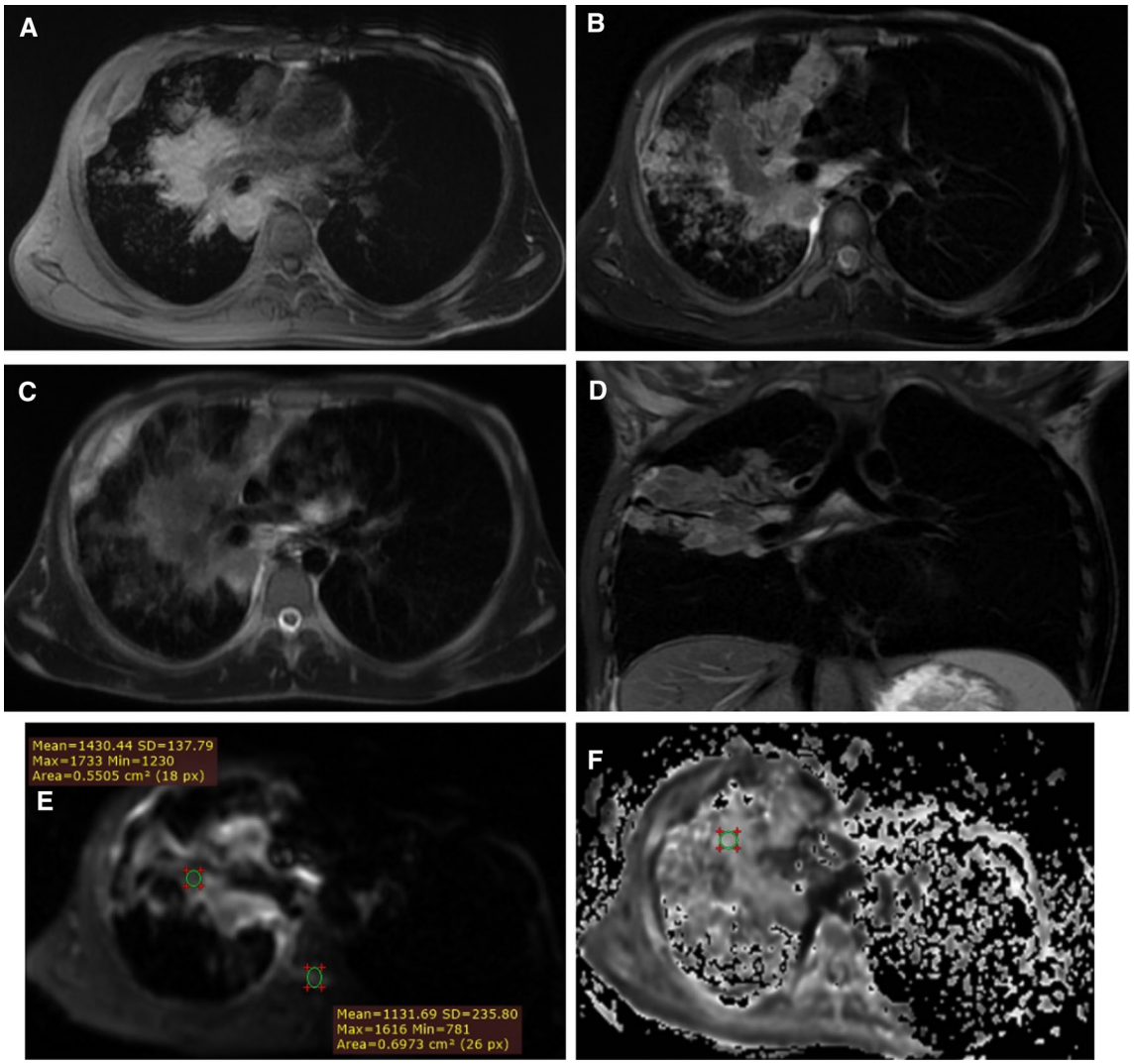

Fig. 5 Male patient 40-years=old presenting with fever, malaise and expectorations A-D: Axial T1 (**A**), axial T2 (**B**), axial STIR (**C**), coronal STIR (**D**), weighted MR images show right upper lobar consolidation with internal air bronchogram as well as surrounding tree in bud nodules. They elicit hyperintense T1 signal and mixed high/low signal intensity relative to the surrounding muscles. DWI (**E**) and ADC map (**F**) images show facilitated diffusion and LSR = 1.26, ADC mean value 1.6 with ADC min value 1.42. Clinical and laboratory results of active pulmonary tuberculosis infection

Table 2 Comparison of DWI-MRI parameters according to type of lesion

	Type of lesion				
	Benign		**Malignant**		***P* value**
Size in DWI	4.16 ± 1.57	2 -8	5.39 ± 2.45	1.2 -9	0.142
ADC mean	1.88 ± 0.51	0.7 -2.6	1.31 ± 0.28	0.69 -1.7	0.001
ADC min value	1.45 ± 0.5	0.52 -2.43	0.99 ± 0.26	0.45 -1.34	0.004
SI lesion	433.402 ± 231.063	0.61 -842.55	1431.12 ± 1518.151	378.83 -6405.08	0.0001
LSR	1.18 ± 0.59	0.51 -2.9	1.6 ± 0.36	0.32 -2.5	0.004
T2 SI Ratio	3.28 ± 1.13	1.93 -5	2.9 ± 0.88	1.89 -4.73	0.377
STIR SI Ratio	3.42 ± 0.98	1.7 -5.6	3.37 ± 0.78	2.3 -5.2	0.589
T1 SI ratio	0.99 ± 0.41	0.34 -1.8	0.89 ± 0.33	0.49 -1.79	0.394

Referring to the STIR SI, in our study, we found that STIR SI Ratio couldn't significantly predict the type of pulmonary lesions with p values > 0.05 with mean STIR SI ratio for benign lesions was 3.42 ± 0.98 and 3.37 ± 0.78 for malignant lesions.

Similar to Donmez et al. [19] results which showed that, the signal intensity ratio of the pulmonary lesions depicted on STIR weighted MR images were not sufficient for definite differentiation of malignant and benign lesions.

In contrast Henz Concatto at 2016 [17] which found that the STIR SI ratio differed significantly between benign and malignant lesions.

By the same concept as regarding T1 SI, in this study, the T1 SI ratio showed statistically insignificant difference between the examined pulmonary lesions.

And these results were consistent with Donmez et al. [19] and Henz Concatto at 2016 [17] study which demonstrated that the SI ratio of the malignant and benign lesions were not different in the T1-weighted images.

To sum up, combination of mean ADC, ADC min value, SI lesion and LSR are highly effective in differentiating benign and malignant lesions.

Our study has some limitations

A major limitation is the comparatively low number of patients involved; therefore, we could not investigate the difference in ADC among the histologic subtypes of lung cancer. Secondly, we could not obtain gross pathologic-MRI correlation in all cases. Thirdly, the pulmonary lesions of our study were controlled (> 1.0 cm), that is to say, the application of these MRI findings was limited to large lesions.

Finally in measuring LSR, we selected the signal intensity of the spinal cord as a control. The spinal cord is cylindrically located in the thoracic spine; therefore, round cross sections of the spinal cord are consistently acquired with reasonably limited diffusion unless affected by neurologic pathology. The signal integrity is guaranteed by a lack of neurologic deficit; however, the area of spinal cord cross sections is small. Therefore, the region of interest for measuring signal intensity is small and the standard deviation of the signal intensity tends to be relatively large.

Conclusions

This study confirmed that the DWI combined with ADC value and LSR is effective and valuable tool in differentiation of pulmonary lesions whether benign or malignant which is noninvasive alternative tool for the characterization of pulmonary lesions.

We recommend that before proceeding to invasive intervention to perform diffusion MRI and LSR as and important aid for proper diagnosis.

Abbreviations

SS-SE-EPI DWI	Single-shot spin echo planar imaging diffusion weighted imaging
LSR	Lesion-to-spinal cord signal intensity ratio
RF	Radiofrequency
UTE	Ultra short echo time
SIRs	Signal intensity ratios
T2 CR	T2 contrast ratio
WHO	World health organization
FISP	Fast imaging with steady-state free precession
AIDS	Acquired immunodeficiency syndrome
GRE	Gradient echo
SSFP	Steady-state free precision
BAC	Bronchoalveolar carcinoma
FISP	Fast imaging with steady-state free precession
C-ANCA	Cytoplasmic antineutrophil cytoplasmic antibody
VIBE	Volumetric interpolated breath-hold examination
SNR	Signal to noise ratio
SPIR	Spectral presaturation inversion recovery
MIP	Maximum intensity projection
MPR	Multiplaner reformatting
AUC	Area under the curve
ROC	Receiver operating characteristic
CI	Confidence interval

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Author contributions

All authors in the study were available in collecting data, processing and case diagnosis, reaching the radiological data, statistics and sharing the paper processing. All authors have read and approved the manuscript.

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Availability of data and materials

All data generated or analysed during this study are included in this published article [in the section of references].

Declarations

Ethics approval and consent to participate

No individual data was included in the study. This study was approved by the Research Ethics Committee of the Faculty of Medicine at Cairo University Kasr El-Aini in Egypt. All patients included in this study gave verbal informed consent to participate in this re- search. If the patient was unconscious at the time of the study, written informed consent for their participation was given by their legal guardian.

Consent for publication

All patients included in this study gave verbal informed consent to publish. the data contained within this study. If the patient was unconscious when. consent for publication was requested, informed consent for the. publication was given by their legal guardian.

Competing interests

The authors declare that they have no competing interests".

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