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Centri-lobular pulmonary nodules on HRCT: incidence and approach for etiological diagnosis

Mona Ahmed Fouad Hafez*, Thakur Koirala, Yasmine Hamdy El Hinnawy and Sally Fouad Tadros

Abstract

Background: Centri-lobular nodules are the most common pattern of diffuse pulmonary nodules encountered on high-resolution computed tomography (HRCT). HRCT with post-processing techniques such as obtaining maximum intensity projection (MIP) is helpful in making centri-lobular nodules more conspicuous. The study aimed to highlight the role of HRCT with its reconstruction capabilities in the detection and characterization of centri-lobular pulmonary nodules, interpret the most frequent associated findings, and correlate with the clinical findings to reach the most appropriate diagnosis.

Results: The study included 58 patients; 41.4% males and 58.6% females. Their age ranged from 2 to 67 years with mean age of 25.69. The centri-lobular nodules numbers, distribution, shape, and associated HRCT chest findings were identified. The top three etiological diagnoses were infection/inflammation in 50.0% of cases followed by acute viral bronchiolitis in 27.6% and inhalation bronchiolitis in 19.0% of cases. Correlation of HRCT findings with the clinical diagnosis was carried out with consequent formulation of an algorithm for the diagnostic approach of various etiologies of centri-lobular pulmonary nodules.

Conclusions: HRCT is a useful tool in the detection and characterization of centri-lobular pulmonary nodules. It can be used to differentiate the different etiologies that share centri-lobular nodularity. Other associated features and multidisciplinary approach are essential for further characterization of the most relevant etiological diagnosis.

Keywords: HRCT, Centri-lobular, Pulmonary nodules

Background

Diffuse small nodules are one of the most common abnormalities detected on high-resolution computed tomography (HRCT), and an accurate classification of nodules is essential to provide an appropriate differential diagnosis. Centri-lobular nodules are the most common pattern [1].

HRCT with post-processing techniques such as obtaining maximum intensity projection (MIP) using the original thin-section dataset is helpful in making tree-in-bud and centri-lobular nodules more conspicuous [2].

Centri-lobular nodule is defined as a nodular opacity within the center of the secondary pulmonary lobule. The core of the secondary pulmonary lobule contains bronchioles, pulmonary arterioles, and lymphatics. Accordingly, centrilobular nodules are conditions which affect bronchiole, peri-bronchiole, arteriole, or peri-arterial regions. It should be differentiated from peri-lymphatic nodules which follow along the pulmonary lymphatics which can be detected at the periphery and center of the secondary pulmonary lobule [3].

Centri-lobular nodules may present with a ground glass appearance when there is involvement of

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peri-bronchiolar air spaces. "Tree in bud" pattern is a subcategory of centri-lobular nodules that have a linear branching pattern. The tree represents dilated bronchioles filled with mucus, pus, or fluid; the buds are due to clusters of filled alveoli that have poorly defined margins and are seen in centri-lobular location [4].

Centri-lobular nodules can be classified to focal, segmental or diffuse according to their extension, well-defined or ill-defined nodules according to their appearance, and according to their etiology into inhalation, infection, inflammation, tumor or vascular cause [3].

This study aimed to highlight the role of HRCT with its reconstruction capabilities in the detection and characterization of centri-lobular pulmonary nodules, interpret the most frequent associated findings, and correlate with the clinical findings to reach the most appropriate diagnosis. Consequently, an algorithm to reach a proper diagnosis would be drawn.

Methods

Local institutional review board approved this prospective study, and written informed consent was obtained from all patients.

Study population

A total of 58 patients, including 24 males and 34 females; with age ranging from 2 to 67 years, were enrolled in this study during the period from January 2020 to June 2021. They were referred from the Pulmonology department to the Thoracic Imaging Unit of our Department Of Diagnostic and interventional Radiology, to perform HRCT of the lungs. The patients fulfilled the following inclusion and exclusion criteria:

Inclusion criteria

All patients, male and female, with HRCT chest showing centri-lobular pulmonary nodules were included in the current study.

Exclusion criteria

HRCT scan with no evidence of centri-lobular pulmonary nodules or HRCT scans with marked respiratory motion artifacts impeding visualization of the centri-lobular nodules.

All included cases were subjected to

Full medical history, general and chest clinical examination.

HRCT chest was performed for all cases.

Further laboratory investigation with or without biopsy according to suspected clinical condition.

Image acquisition

HRCT was performed to all patients using Siemens SOMATOM Scope, Germany (CTAWP92544) 16 channel MDCT. No preparation needed. Non contrast helical-volumetric axial cuts performed in full inspiration in supine position with 1.5 mm slice thickness, 1.5 mm pitch, 0 gantry tilt, FOV depending on patient size around 320 mm from root of neck to the level of renal arteries, KV 120, mAs 25, Rotation time 0.5 s, total exposure time 8–10 s, HRCT window width (WW) was 1000 HU and window level (WL) was −700 and mediastinal WW was 300 HU, WL was 30 HU.

Reconstructed two-dimensional axial, coronal and sagittal images, minimum intensity projection (MinIP) were done; mediastinal images were also taken.

Image analysis

- The following parameters of the centri-lobular nodules were assessed:

  1. Nodule distribution: diffuse, multiple, single or segmental distribution.
  2. Nodule location: unilateral, bilateral, upper lobe, middle lobe/ lingula, or lower lobe.
  3. Nodule margin: well or ill defined.
  4. Nodule number: few countable or multiple

- Associated findings were recorded as ground glass densities, peri-lymphatic nodules, cavitation, septal thickening, bronchiectasis, bronchial wall thickening, atelectasis, air trapping, reticulation, pleural effusion, and lymphadenopathy.
- Etiological diagnosis was suggested and guided by the clinical condition and laboratory findings.

Statistical analysis

Data were collected, revised, coded and entered to the Statistical Package for Social Science (SPSS version 20). The qualitative data were presented as number and percentages, while quantitative data were presented as mean, standard deviations and ranges when their distribution was found parametric.

The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p value was considered significant as the following: $P < 0.05$ = significant, and $P < 0.001$ = highly significant.

Results

Demographic features

This study involved 58 cases; out of which 24 (41.4%) were males and 34 (58.6%) were females. Their age ranged from 2 to 67 years with mean age of 25.69 ± 18.89 years.

Centri-lobular nodules number:

The centri-lobular pulmonary nodules were few (countable) in 19 (32.8%) case and multiple (non-countable) in 39 (67.2%) cases.

Centri-lobular nodules distribution:

The nodules were unilateral in nine (15.5%) cases and bilateral in 45 (77.6%) cases. They were diffuse throughout the lung in 10 (17.2%) cases, localized to a single segment in 11 (19%) cases and distributed in multiple segments in 37 (63.8%) cases. The lobar distribution of centri-lobular nodules is reported in Fig. 1.

Shape of centri-lobular nodules:

Well-defined nodules were detected in 36 (62.1%) cases, while ill-defined nodules were seen in 22 (37.9%) cases.

Tree-in-bud pattern was demonstrated in 13 (22.4%) of cases.

Associated HRCT chest findings

There were many associated HRCT findings detected which helped in the radiological diagnosis of each case.

Table 1 Number and percentages of the associated HRCT chest findings

	No	%
Bronchial wall thickening	27	46.6
Bronchiectasis	23	39.7
Ground glass	22	37.9
Reticulations	22	37.9
Air trapping	19	32.8
Lymphadenopathy	16	27.6
Atelectasis	13	22.4
Peri-lymphatic nodule	10	17.2
Septal thickening	6	10.3
Cavitation	4	6.9
Pleural effusion	3	5.2

The number and percentages of these findings are displayed in Table 1.

Etiological diagnosis of centri-lobular nodules

The incidence of each etiological diagnosis guided by combined radiological, clinical, laboratory data and biopsy in selected cases is recorded in Fig. 2.

Inhalation etiology

From the 12 cases with inhalation lung disease, six cases (54.5%) were diagnosed as hypersensitivity pneumonitis (HP) (Fig. 3); as they showed bilateral diffuse ill-defined ground glass centri-lobular nodules

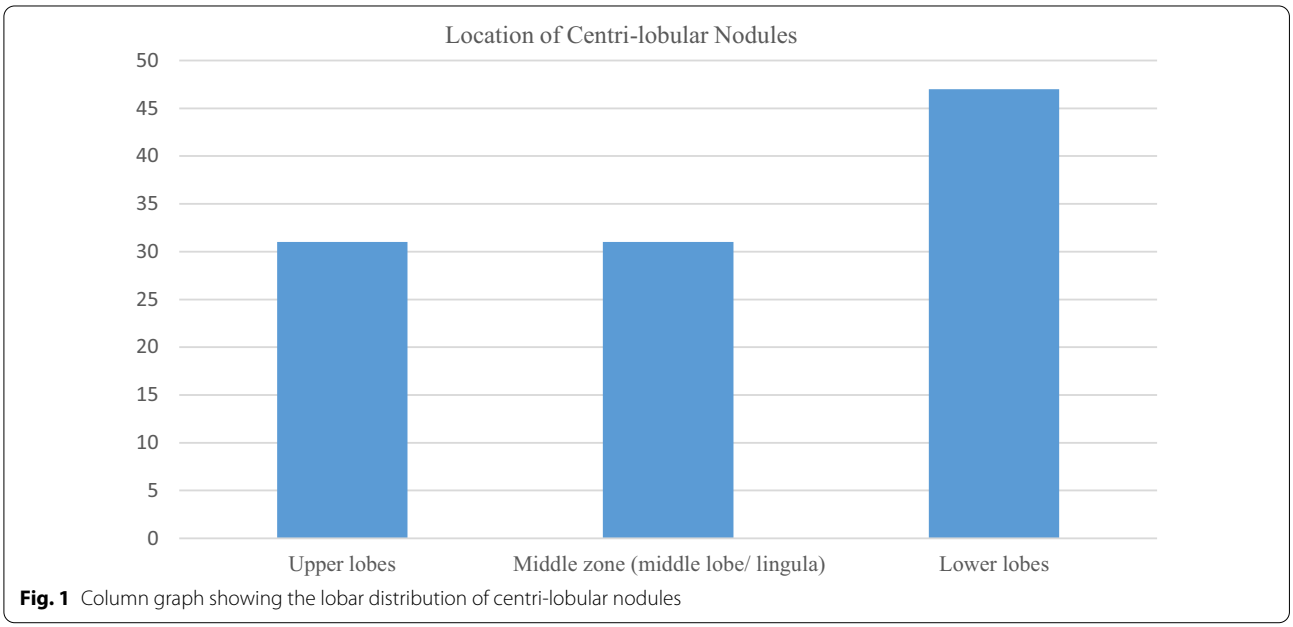

Fig. 1 Column graph showing the lobar distribution of centri-lobular nodules

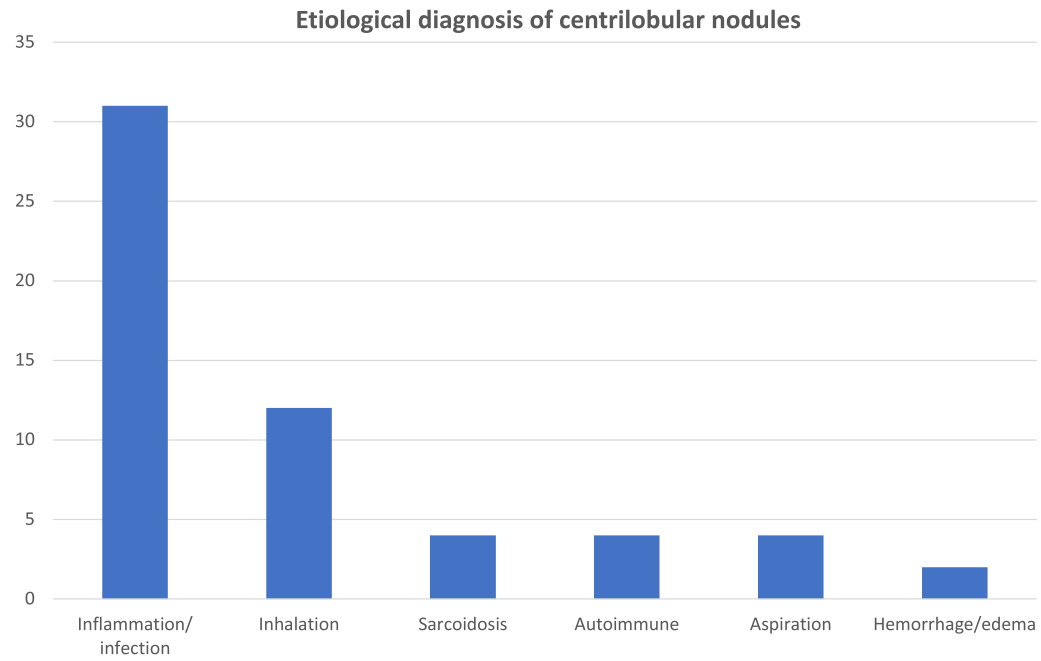

Fig. 2 Column graph showing the etiological diagnosis of the studied cases

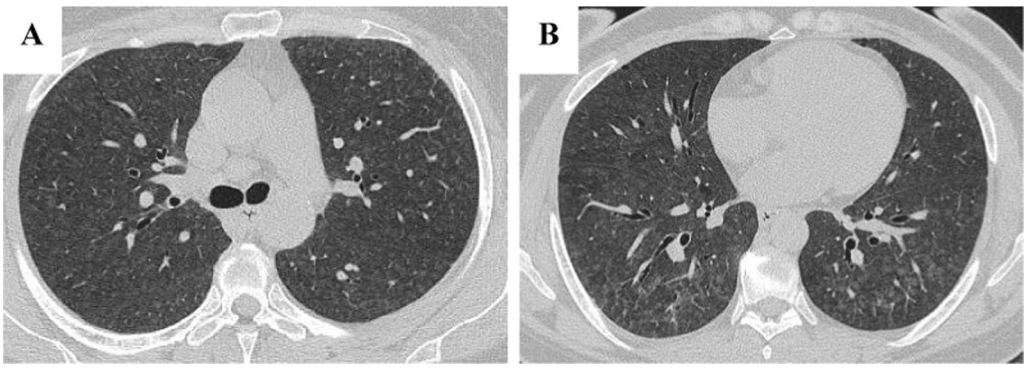

Fig. 3 A 44-year-old female complaining of progressive dyspnea and dry cough with history of raising birds. HRCT of the chest in **a, b** axial lung window images showing bilateral diffuse ill-defined ground glass centri-lobular nodules. The diagnosis of subacute hypersensitivity pneumonitis was made

mainly involving the upper and middle lobes associated with ground glass opacities and air trapping. One case (9.09%) was diagnosed as respiratory bronchiolitis (RB) (Fig. 4), which showed bilateral multiple ill-defined centri-lobular nodules involving mainly the upper lobes. Three cases (27.3%) were diagnosed as respiratory bronchiolitis interstitial lung disease (RB-ILD) which showed diffuse bilateral ill-defined centri-lobular nodules associated with ground glass opacities and reticulations. And one case (9.09%) was diagnosed as bronchiolitis obliterans secondary to toxin inhalation which showed bilateral diffuse well-defined centri-lobular nodules with tree-in-bud pattern involving all lung lobes associated with bronchiectasis, oligemic lung and air trapping.

Correlating inhalation lung disease with other etiological diagnoses of centri-lobular nodules revealed statistically significant difference regarding diffuse distribution, upper lobes predominance, and both well- and ill-defined nodules, as illustrated in Table 2.

Regarding associated HRCT lung findings, there was high statistical significant difference regarding ground glass opacities, and air trapping, as displayed in Table 3.

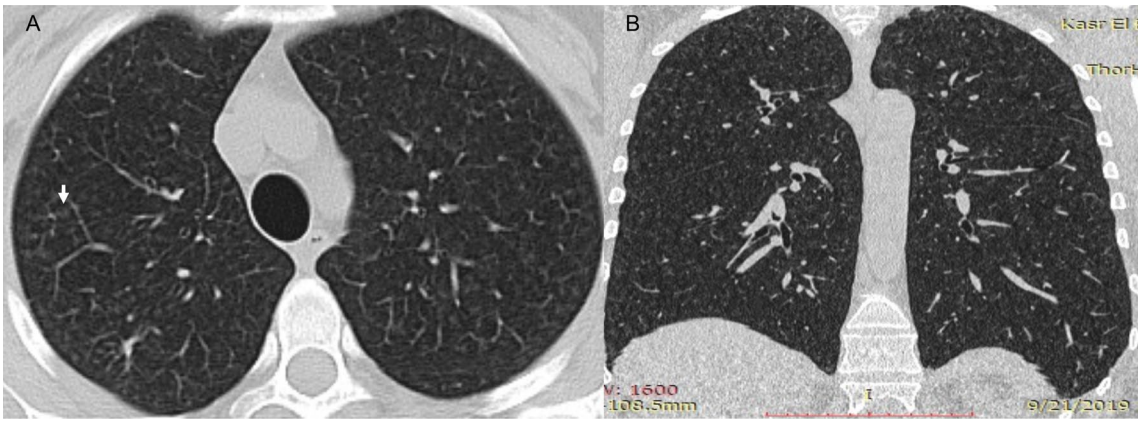

Fig. 4 A 43-year-old male, smoker over the last 20 years, HRCT lungs (**a**) axial, (**b**) coronal sections showed diffuse ill-defined faint ground glass centri-lobular nodules scattered all over the lung lobes bilaterally more prominent at upper lobes. Radiological and clinical diagnosis was made of inhalation lung disease as smoking related-respiratory bronchiolitis (RB)

Table 2 The significance of inhalation, inflammatory, autoimmune and edema/hemorrhagic lung diseases regarding lesion distribution and shape

Lesion characteristic/ *P* value		Inhalation	Inflammation	Autoimmune	Hemorrhage/EDEMA
Number	Few	0.102	0.773	0.067	0.516
	Multiple	0.207	0.279	0.113	0.430
Location	Unilateral	0.096	0.329	0.425	0.651
	Bilateral				
	Upper lobe	0.006**	0.430	0.886	0.346
	Middle lobe and lingual	0.452	0.430	0.886	0.346
	Lower lobe	0.435	0.738	0.316	0.626
Shape	Well defined	0.004**	0.791	0.773	0.246
	Ill defined	0.001**	0.279	0.606	0.197

Chi-square test, P value > 0.05: Non significant (NS); P value < 0.05*: Significant (S); P value < 0.01**: highly significant (HS)

Table 3 The significance of inhalation, inflammatory, autoimmune and edema/hemorrhagic lung diseases regarding the associated CT chest findings

HRCT findings/P value	Inhalation	Inflammatory	Autoimmune	Hemorrhage/EDEMA
Tree-in-bud	0.239	0.115	0.898	0.588
Ground glass	0.008**	1.000	0.581	0.430
Peri-lymphatic nodule	0.093	0.180	0.000**	0.067
Cavitation	0.316	0.300	0.573	0.784
Septal thickening	0.211	0.085	0.481	0.732
Bronchiectasis	0.804	0.005**	0.661	0.414
Bronchial wall thickening	0.036*	0.004**	0.886	0.346
Atelectasis	0.708	0.753	0.265	0.588
Air trapping	0.002**	0.780	0.732	0.481
Reticulations	0.207	0.279	0.105	0.430
Pleural effusion	0.390	0.553	0.628	0.814
Lymphadenopathy	0.979	0.557	0.905	0.534

Chi-square test, P value > 0.05: Non significant (NS); P value < 0.05*: Significant (S); P value < 0.01**: highly significant (HS)

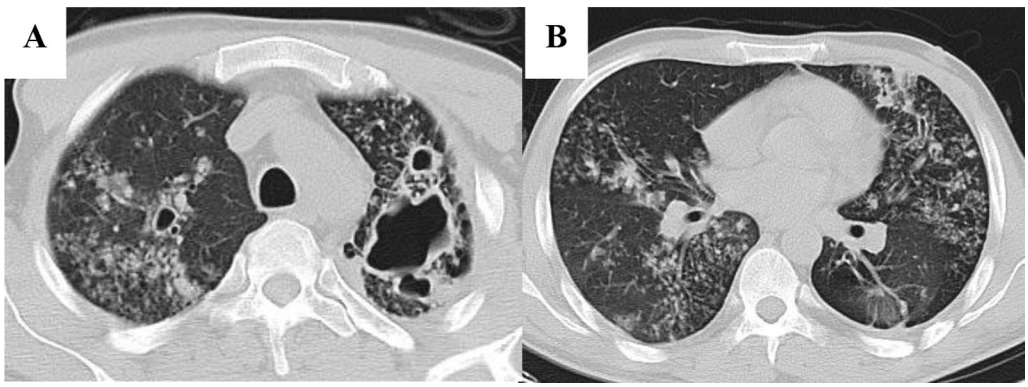

Fig. 5 A 39-year-old male complaining of fever, night sweats, productive cough with occasional blood streaking in the sputum and weight loss for about 6 months. HRCT of the chest in **a, b** axial lung window images showing bilateral multiple well-defined centri-lobular and tree-in-bud nodules with bronchiectatic changes and upper lobar cavitation. The diagnosis of active granulomatous infection (pulmonary tuberculosis) was made

inflammatory/infectious etiology

From the 31 cases with inflammation/infectious etiology, 16 (55.17%) cases were diagnosed as viral bronchiolitis, nine cases (31.03%) were diagnosed as active granulomatous infection (Fig. 5), and four cases (13.9%) were diagnosed as fungal bronchiolitis (Fig. 6). The number, distribution and shape of infection/inflammatory centrilobular nodules are listed in Table 2.

Correlating inflammatory and infectious lung diseases with other etiological diagnoses revealed high statistical significance regarding multi-segment distribution. Concerning the associated HRCT lung findings, there was high statistical significance regarding

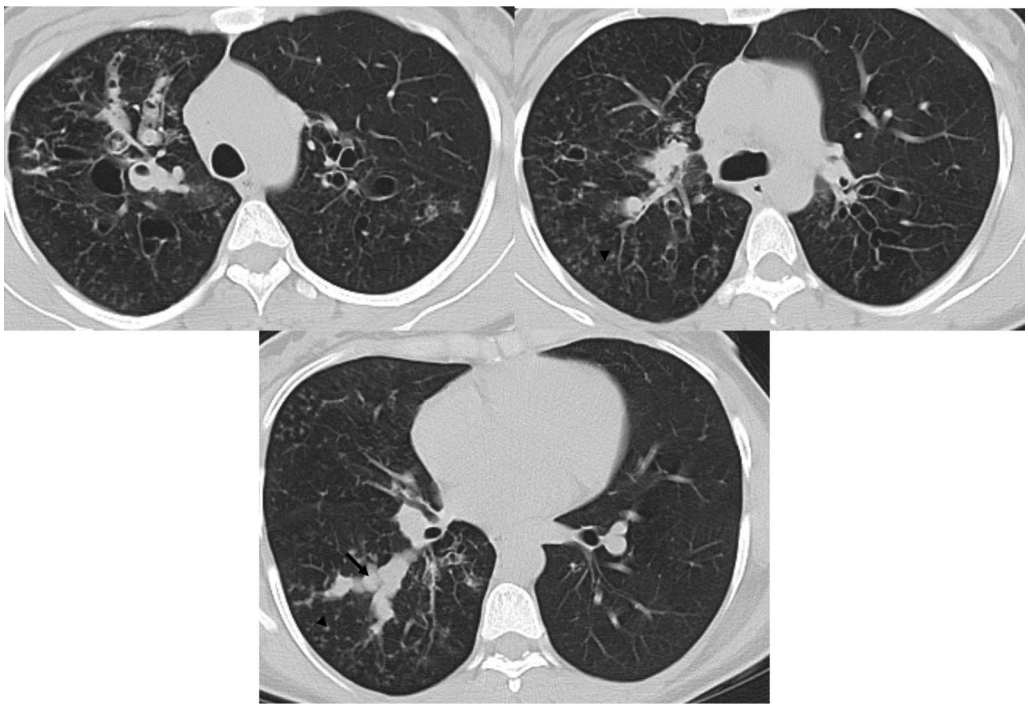

Fig. 6 A 31-year-old female presented with the chief complaints of cough with occasional blood in the sputum, shortness of breath and lethargy for 6 months and exacerbated since last 2 weeks. HRCT lungs sequential axial cuts showed bilateral mainly central bronchiectasis, with mucus blugging, multilobar well-defined centri-lobular nodules and tree-in-bud appearance. The laboratory, clinical and radiological diagnosis of fungal lung infection as ABPA was made

bronchial wall thickening and bronchiectasis as shown in Table 3.

Autoimmune etiology

From the four cases diagnosed with autoimmune disease; two cases (50%) had rheumatoid arthritis showing few single segment lower lobar ill-defined centri-lobular and peri-lymphatic nodules, while the other two cases (50%) had non-specific autoimmune disease; one of them showed bronchiolitis obliterans with imaging features of bilateral few multi-segment well-defined centri-lobular and peri-lymphatic nodules, bronchial wall thickening, bronchiectasis and air trapping, while the other case showed follicular bronchiolitis with imaging features of bilateral diffuse well-defined centri-lobular and tree-in-bud appearance with associated ground glass opacities, bronchial wall thickening, bronchiectasis and pleural effusion.

Correlation of centri-lobular nodules distribution, number, location and shape between autoimmune etiology and other etiological diagnosis revealed no statistical significance, Table 2. However, concerning the associated HRCT findings, there was statistically significant difference regarding peri-lymphatic nodule as presented in Table 3.

Other etiological diagnosis

The four cases diagnosed as sarcoidosis (Fig. 7) showed bilateral well-defined centri-lobular and peri-lymphatic nodules involving multiple lobes with nodular septal thickening and mediastinal lymphadenopathy.

The four cases diagnosed as aspiration pneumonitis (Fig. 8) showed well-defined multi-segments centri-lobular nodules with tree-in-bud pattern, and associated with ground glass opacity, bronchial wall thickening and bronchiectasis.

The one case diagnosed as pulmonary edema showed bilateral multiple ill-defined centri-lobular nodules associated with ground glass opacities, smooth septal thickening, bronchial wall thickening and pleural effusion.

The one case diagnosed as alveolar hemochromatosis (as proved by biopsy) (Fig. 9) showed bilateral diffuse ill-defined centri-lobular and peri-lymphatic nodules.

The one case diagnosed as Langerhans cell histocytosis showed bilateral multiple well-defined centri-lobular nodules involving all lung lobes with irregular cysts and cavitary lesions.

The approach used to reach the etiological diagnosis in the studied cases is illustrated in Table 4, and based on our results, the algorithm for the diagnostic approach of various etiologies of centri-lobular pulmonary nodules is shown in Fig. 10.

Discussion

Centri-lobular nodules are the most common abnormality encountered on HRCT, yet, they have a wide differential diagnosis [1].

This study recorded the predominant HRCT findings along with the centri-lobular pulmonary nodules of various conditions and compared their different etiologies.

In this study, we had four main etiological diagnosis for centri-lobular nodules that include infection/ inflammatory lung disease (as in viral, granulomatous, fungal diseases and aspiration pneumonitis), inhalation lung disease (as in hypersensitivity pneumonitis, RB, RB-ILD, and post-toxin-bronchiolitis obliterans), autoimmune diseases (as sarcoidosis, rheumatoid arthritis, and non-specific autoimmune diseases), and hemorrhage and lung edema.

Although clinical criteria and exposure to an allergic antigen are used for diagnosis of inhalation lung disease, imaging finding is crucial in supporting the diagnosis [5]. Shobeirian et al. [6] and Churg et al. [7] results were similar to this study, and ground glass opacity and reticulations were found to be the most common findings in HRCT followed by fibrosis and air trapping.

RB-ILD is a rare inflammatory lung disorder induced by heavy tobacco smoking [8]. Park et al. [9] and Sieminska and Kuziemski [10] results were consistent to this study, and bronchial wall thickening was found to be the major HRCT finding in patients with RB-ILD followed by ground glass opacities.

Bronchiolitis obliterans is associated with the inhalation of toxic gases including nitrogen dioxide, war gas, and sulfur mustard [11]. Bakhtavar et al. [12] and Travis et al. [13] studies stated that the most dominant HRCT finding in patients with bronchiolitis obliterans was concluded to be patchy air trapping mostly in the lower lobes and centri-lobular nodules, with multiple segments distribution associated with bronchial wall thickening, bronchiectasis. However, Raghu et al. [14] study showed that centri-lobular nodules if associated with ground glass opacities even with air trapping were considered inconsistent features in bronchiolitis obliterans. These results were consistent with this study.

The results of this study were in agreement with the previous studies of Shobeirian et al. [6], Iwasawa et al. [15], Razavi et al. [16] and Rossi et al. [17] concerning the distribution, location, shape, and pathological findings of inhalation lung disease centri-lobular nodules. Correlating with other etiologies, HRCT showed high statistical significance regarding diffuse distribution and upper lobes involvement, as well as associated ground glass opacities and air trapping.

Ryu et al. [18] illustrated that regarding infection and inflammatory lung diseases, centri-lobular nodules were

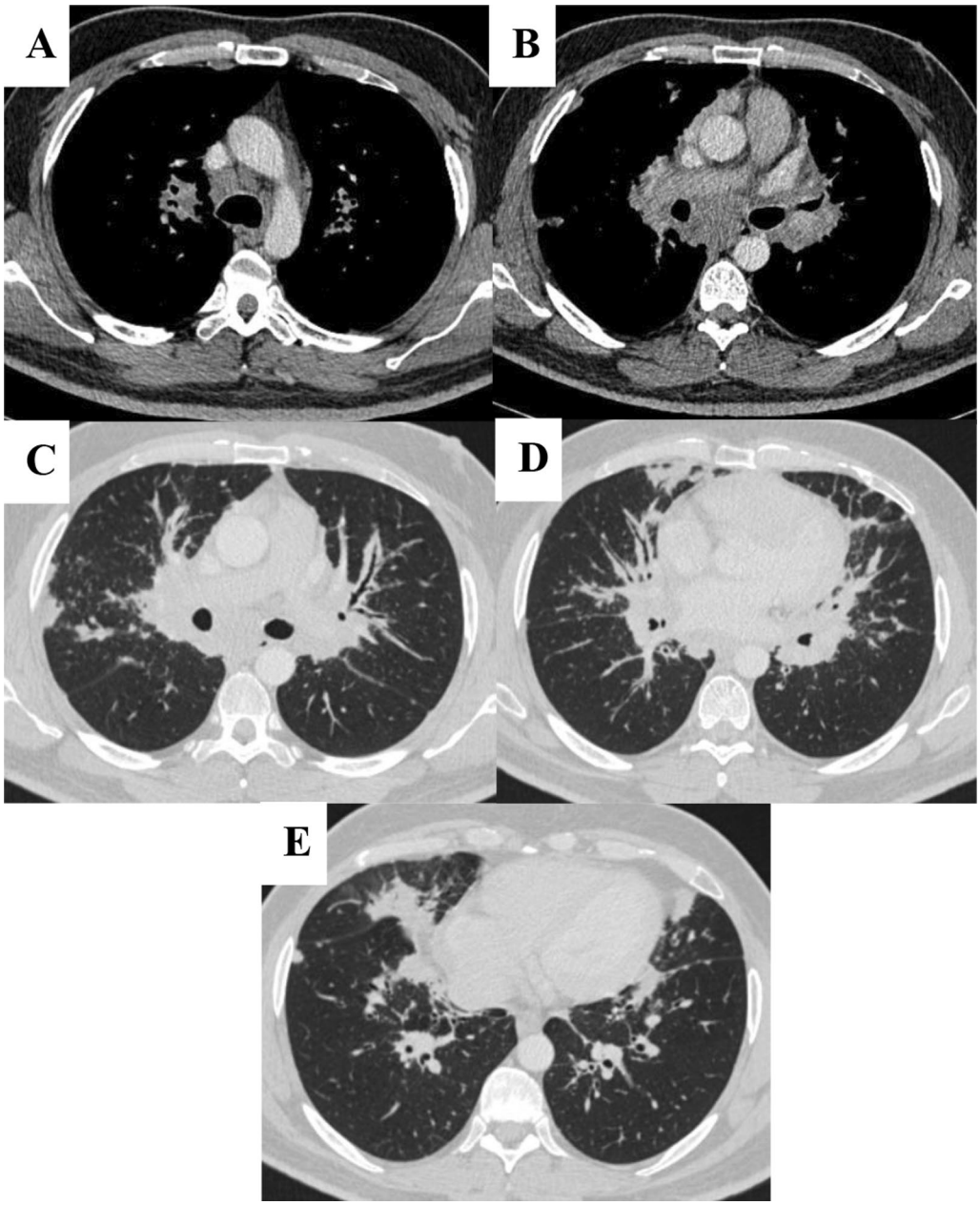

Fig. 7 A 33-year-old male complaining of persisted dry cough, wheezing and dyspnea. HRCT of the chest in **a, b** axial mediastinal window showing mediastinal and bilateral hilar lymphadenopathy, and **c**–**e** axial lung window images showing bilateral well-defined centri-lobular and peri-lymphatic nodules involving multiple lobes with nodular septal thickening and beaded fissures. The diagnosis of sarcoidosis was made

the main CT features in most cases of bronchiolitis. In a case series report by Nabeya et al. [19], HRCT findings revealed bronchial wall thickening in 80% of cases and ground glass opacities in 40% of cases. Also, Weinman et al. [2] study found that bronchial wall thickening followed by ground glass opacities was the most common HRCT finding in viral bronchiolitis.

Multi-segment distribution was most commonly demonstrated in our study. Kim et al. [20] stated that the anatomical distribution of HRCT findings in bronchiolitis is most commonly in the lower lobes (69%), followed by diffuse distribution (57%), according to the type of the infecting virus.

Following the previous results, Zhu et al. [21] stated that fungal infection granuloma showed a nodular presentation in 75.0% of cases, followed by consolidation (62.5%), and ground glass appearance (62.5%).

Fig. 8 A 56-year-old male with neuromuscular disorder complaining of dyspnea, cough and fever. HRCT of the chest in axial lung window image showing bilateral lower lobar apical segments centri-lobular and tree-in-bud nodules. The diagnosis of aspiration pneumonitis was made

Centri-lobular nodules were concluded to characterize fungal lung infection in immunocompromised patients [22, 23].

Giacomelli et al. [24] concluded that the most common HRCT findings in patients with pulmonary tuberculosis were ground glass opacities with consolidation, followed by centrilobular nodules with tree-in-bud pattern and cavitation. Likewise, to our study, Im et al. [25] study showed that, in active tuberculosis, the most common CT finding (82–100% of cases) was centri-lobular nodules with segmental distribution, which represents bronchogenic dissemination of the disease.

Similar to this study, Duan et al. [26] stated that Sarcoidosis imaging findings on HRCT included ground glass opacities, centri-lobular nodules, consolidation, and intrathoracic lymphadenopathy. Zhu et al. [21] as well reported that HRCT of pulmonary sarcoidosis typically shows nodules in 96.1% of cases in multiple or miliary distribution with variable morphological presentation and with bilaterality in 92.6% of cases mainly in the left lower lobe (85.2%) and right lower lobe (81.5%).

Corresponding to this study, Yilmazer et al. [27] results showed that while HRCT can be normal in 54% of rheumatoid arthritis patients, the most common HRCT findings were ground glass opacities

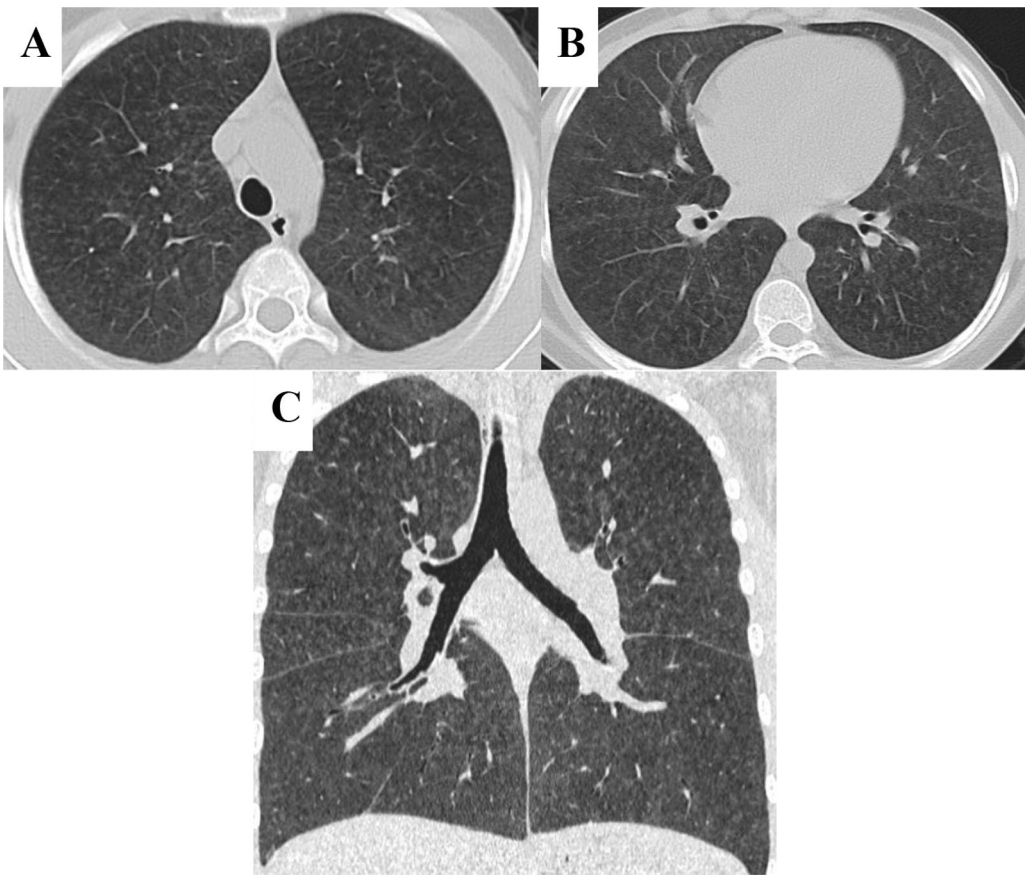

Fig. 9 A 25-year-old male complaining of hemoptysis. HRCT of the chest in **a, b** axial and **c** coronal lung window images showing bilateral diffuse ill-defined centri-lobular and peri-lymphatic nodules. Lung biopsy was taken and revealed alveolar hemochromatosis

Table 4 Summary for the diagnostic approach for the various etiologies of centri-lobular pulmonary nodules

Diagnosis	Age	Clinical data	Lesion distribution	Centri-lobular nodule shape	Associated CT chest findings	Need for other investigation
HP	Young and middle age	History of allergen exposure Chronic cough Difficulty in breathing Chest tightness	Bilateral, diffuse, mainly upper and middle lobes	Ill defined	Ground glass opacities and air trapping (mosaic attenuation) in subacute type Mainly upper fibrosis in chronic type	Broncho-alveolar lavage
RB/RB-ILD	Middle age	Smoker Chronic cough Exertional dyspnea	Bilateral, mainly upper lobar	Ill defined	Ground glass opacities, and bronchial wall thickening Reticulations and fibrosis in advanced RB-ILD	
Bronchiolitis obliterans	Mostly young age	History of toxin inhalation, lung transplantation, or history of atypical infection Dry cough Progressive difficulty in breathing	Segmental or diffuse according to etiology	Well defined	Bronchiectasis, bronchial wall thickening, oligemic lung and air trapping	
Viral bronchiolitis	Any age	Fever Dry or productive cough Mild chest pain	Differ from bilateral, unilateral, and single lobe to multiple lobes	Mostly well-defined and some ill-defined, tree-in-bud pattern	Bronchial wall thickening, ground glass opacities, atelectasis	Laboratory tests
Active granulomatous infection	Mostly middle age	Fever and night sweats Chest pain Occasional blood in the sputum Weight loss Loss of appetite Generalized weakness	Bilateral, mostly multisegmental	Mostly well-defined, tree-in-bud pattern	Bi-apical reticulations, bronchial wall thickening, bronchiectasis, sometimes cavitation, ground glass, and mediastinal lymphadenopathy	Tuberculin test
Fungal bronchiolitis	Mostly young	Cough with sputum Difficulty in breathing Fever Blood in sputum Weakness	Mostly bilateral, multi-segment, could be single lobe	Mostly well-defined, tree-in-bud pattern	Bronchial wall thickening, bronchiectasis, cavitation	CBC and sputum analysis
Autoimmune	Middle age	Dry cough Difficulty in breathing	Differ from few to diffuse, single segment to multiple segment, and unilateral to bilateral	Mostly well defined	Peri-lymphatic nodules, ground glass opacities, bronchial wall thickening, bronchiectasis and air trapping	Laboratory studies
Sarcoidosis	Middle age	Persistent dry cough Chest pain Difficulty in breathing Wheezing	Bilateral, few to multiple, multiple segments, and multiple lobes	well defined	Peri-lymphatic nodules and mediastinal lymphadenopathy Upper lobe fibrosis in advanced case	Kveim test and LN biopsy

Table 4 (continued)

Diagnosis	Age	Clinical data	Lesion distribution	Centri-lobular nodule shape	Associated CT chest findings	Need for other investigation
Aspiration pneumonitis	Any age	History of esophageal or neurological disorder Cough with sputum Difficulty in breathing Fever Foul odor breath	Bilateral, multiple segments, mostly posterior segments of upper and lower lobes	Mostly well-defined, tree-in-bud pattern	Ground glass, bronchial wall thickening, bronchiectasis and atelectasis	
Pulmonary edema	Any age	Cough with sputum Difficulty in breathing especially at night	Bilateral, multiple, multiple segments, middle and lower lobes	Ill defined	Ground glass opacities, smooth interlobular septal thickening, bronchial wall thickening and pleural effusion	Echo-cardiography and laboratory tests
Alveolar hemochromatosis	Young aged	Fatigue Difficulty in breathing on exertion Joint pain Abdominalpain Failure to gain weight	Bilateral, diffuse, all lung lobes	Ill define and fluffy	Mild interstitial fibrosis and interlobular septal thickening with repeated hemorrhage	Laboratory tests
Langerhans cell histiocytosis	Young age	Male Dry cough Difficulty in breathing Chest pain Weight loss	Bilateral, multiple, upper and middle lobar predominance	Well defined	Irregular cysts and cavitary lesions	Biopsy

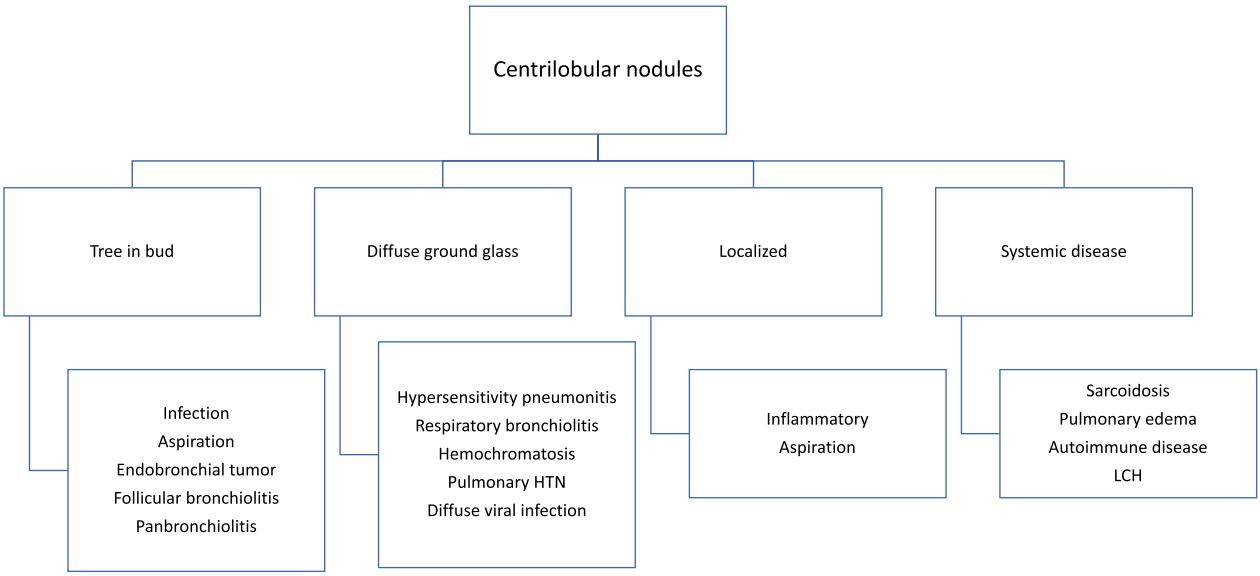

Fig. 10 HRCT simplified algorithmic approach for diagnosis of centri-lobular pulmonary nodules

(42%). While Izumiyama et al. [28] reported that centri-lobular nodules were reported in 23.6% of rheumatoid arthritis patients examined by HRCT distributed mainly in the middle and lower lobes, bronchiectasis was observed in 17.1% of patients.

Similar to this study, Scheeren et al. [29] results regarding aspiration pneumonitis showed tree-in-bud nodularity with unilateral or bilateral distribution of centri-lobular nodules on HRCT. Centri-lobular nodules, bronchiectasis, and ground glass opacities along with atelectasis and consolidation were concluded as common features of aspiration pneumonitis.

Similarly, Zakynthinos et al. [30] HRCT findings in cases of hemochromatosis showed patchy ground glass nodules mainly in the upper lobe [36], yet it was diffusely distributed in this study.

As Schmidt et al. [31] and Naidich et al. [32] studied, the main HRCT features of Langerhans cell histiocytosis were lung cysts and cavitation, followed by centri-lobular nodules. The distribution of the cystic lesion was characteristic involving predilection for mid and upper zones.

In CT chest with centri-lobular pulmonary nodules, multidisciplinary approach should be done to reach the proper diagnosis, it could be summarized as follows: first; relevant history taking, second; determine the radiographic features of nodules including shape, number, location, distribution, and surrounding pulmonary parenchymal associated findings. Then, diagnostic possibilities could be suggested. Lastly, auxiliary approach, mainly laboratory or histopathological assessment, could be done [17].

The main limitation of the study was the small number of cases over each disease category.

Conclusions

HRCT is a useful tool in the detection and characterization of centri-lobular pulmonary nodules. It can be used to differentiate the different etiologies that share centri-lobular nodularity. Other associated features and multidisciplinary approach are essential for further characterization of the most relevant etiological diagnosis.

Abbreviations

HP: Hypersensitivity pneumonitis; HRCT: High-resolution computed tomography; LCH: Langerhans cell histocytosis; MinIP: Minimum intensity projection; MIP: Maximum intensity projection; RB: Respiratory bronchiolitis; RB-ILD: Respiratory bronchiolitis interstitial lung disease.

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Author contributions

SFT and MAH reviewed the images. SFT, YHE, and MAH analyzed and interpreted the patient data. SFT wrote the manuscript and MAH reviewed it. All authors have read and approved the manuscript.

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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

Ethical approval and consent for participation
Approval of the ethical committee of the 'Radiology Department, Faculty of Medicine, Cairo University' was granted before conducting this prospective study; Reference number: not applicable. Local institutional review board approval was granted before conducting this cross-sectional study, and written informed consent was obtained from all patients.

Consent for publication
All patients included in this research gave written informed consent to publish the data contained within this study. If the patients were less than 16-year-old, deceased, or unconscious when consent for publication was requested, written informed consent for the publication of these data was given by their parents or legal guardians.

Competing interests
The authors declare that they have no competing interests.

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