Original Article

Computed tomography in secondary spontaneous pneumothorax: Reading the fine print

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ABSTRACT

Objectives: To identify specific characteristics, distribution and associated findings of lesions causing secondary spontaneous pneumothorax (SSP). **Methods:** Computed tomography (CT) chest of 37 patients (between October 2011 and January 2020) was evaluated by two radiologists. They were classified into 'Infectious' and 'Non-infectious' groups, based on cause of pneumothorax. A scoring system (score 0–10) was proposed based on parameters which were statistically significant. **Results:** Out of 37 patients with pneumothorax, 18 could be attributed to infectious aetiology and remaining 19 were due to noninfectious causes. The most common infectious cause of spontaneous pneumothorax was tuberculosis and noninfectious cause was chronic obstructive airway disease (COAD). Statistically significant difference was found for lesion wall thickness and presence of solid component between these two groups. No significant difference was found between both groups when comparing age, gender, lesion size and lesion distribution. The presence of pleural thickening, consolidation and mediastinal lymphadenopathy were statistically significant. Pleural effusion was never present in the noninfectious group. The area under receiver operating characteristic for differentiating patients in the two groups was 0.931 (standard error, 0.038; 95% CI, 0.856–1.000), and optimal threshold score for identifying patients with infectious causes was 4.5, with 77.8% sensitivity and 89.5% specificity. **Conclusion:** Pneumothorax is almost equally common due to infectious and noninfectious causes. The most common infectious cause of spontaneous pneumothorax was tuberculosis and noninfectious cause was COAD. Based on certain CT findings, we have proposed a scoring system to differentiate between these two groups.

KEY WORDS: CT, imaging, spontaneous pneumothorax

INTRODUCTION

Pneumothorax can be defined as presence of air in the pleural space, and it can be classified as traumatic or spontaneous.[1] While traumatic pneumothorax as the name suggests occurs after blunt, penetrating or barometric trauma, spontaneous pneumothorax occurs without any external event.[2] Spontaneous pneumothorax is subdivided into primary spontaneous pneumothorax (PSP) where no cause is usually identified on imaging and secondary spontaneous pneumothorax (SSP) wherein there is an underlying lung disease. The aetiology of pneumothorax determines immediate as well as definitive management significantly. The distinction between PSP and SSP is somewhat

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DOI:
10.4103/lungindia.lungindia_282_21

artificial, and some experts suggest that PSP and SSP may exist on either end of a continuum.[3]

Computed tomography (CT) has often been termed as 'gold standard' in the detection of small pneumothoraces and in their size estimation.[4,5] Goals of CT in pneumothorax are to look for underlying parenchymal disease, distinguish a bulla from a pneumothorax which can be difficult on radiographs, and for CT-guided drainage procedure for difficult cases.[6] It is desirable to divide spontaneous pneumothorax cases into infectious and noninfectious groups due to potential treatment implications. Cases with infectious causes need to be given specific antimicrobial therapy depending on the cause. In addition, it is advisable to drain all the infectious pneumothoraces. Larger bore catheters may be required in cases of pyopneumothorax.

SSP usually occurs in the background of underlying lung disease and the patient is overly sensitive to even small pneumothorax, and if the pulmonary function is already compromised, the response to interventions is also unfavourable.[7] The success rate for aspiration is lower in patients aged >50 years as well as for chronic lung disease in several series.[5] Patients with tubercular pyopneumothorax often require prolonged drainage and are at risk for persistent air leaks and bronchopleural fistulae.[8,9]

Often it is difficult to differentiate infectious and noninfectious causes of pneumothorax based on radiological findings. In this study, we aim to detect specific imaging pointers of distinction between these two groups.

MATERIALS AND METHODS

Patient selection
This retrospective study was approved by our institutional review board (Ref. No. IECPG-639/25.11.2020). We reviewed CT chest of patients ($n = 37$) with spontaneous pneumothorax whose clinical data was available, and imaging could be retrieved from our department PACS system (SYNGOPLAZA, Siemens Healthcare, Forchheim, Germany) between October 2011 and January 2020. The diagnosis of pneumothorax was based on a combination of clinical and radiological parameters, that is, presence of air in the pleural cavity on thin-section CT (mean attenuation <970 HU for ROI >30 mm^2). Clinical history was obtained to filter out cases of traumatic and iatrogenic pneumothorax. The cause of pneumothorax was obtained from the final diagnosis and response to therapy.

Each scan was examined by two radiologists with at least 5 years of experience (SS and ASB), and findings were recorded. The exclusion criteria were suboptimal CT scan, artefacts from considerable respiratory motion and the presence of traumatic/iatrogenic pneumothorax. For

patients with multiple CT scans, the CT with maximum lung expansion was considered for the study.

CT scan acquisition
All CT scans were performed on one of three scanners – SOMATOM Definition Flash Dual Source CT, 80 and 140 kV, 2 × 128 slice (Siemens Healthcare, Forchheim Germany), SOMATOM Definition Flash Single source CT (Siemens Healthcare, Forchheim, Germany) and SOMATOM Definition AS Single source CT (Siemens Healthcare, Forchheim, Germany).

All images were acquired with patients in supine position, during a single inspiratory breath-hold. The scan area was from lung apices to costophrenic angles, with collimation of 1.2 mm.

CT scan analysis
High-resolution CT and/or contrast-enhanced CT examinations were evaluated on SYNGOVIA Diagnostic workstation VersionVB10B-HF06 workstation (Siemens Healthcare, Forchheim, Germany).

Thin sections of each CT were viewed at standard lung window and mediastinal window settings, using multiplanar reformats. Lung window was also viewed in high-resolution reconstruction using appropriate image reconstruction methods like multiplanar reconstruction and thick minimum intensity projection. Imaging findings were recorded in predesigned proforma. The radiologists were blinded to the final diagnosis. Findings were recorded for laterality (right/left/bilateral), average number of lesions (0/1/2–5/>5), average number of lobes involved (out of 5), most involved lobe (with respect to number of lesions), mean lesion size (averaged over three lesions – largest/smallest/average sized on subjective examination), mean wall thickness (averaged over three lesions with maximum wall thickness), presence/absence of solid component in the lesions, presence/absence of pleural effusion, mediastinal lymphadenopathy (lymph node >10 mm in short axis diameter), presence/absence of consolidation and presence/absence of pleural thickening. Pneumothorax was classified as gross if it involved two-thirds of hemithorax.

A 10-point scoring system was devised by assigning higher points to the findings with lowest P value and including all the statistically significant parameters.

Statistics
Statistical analysis was done using IBM SPSS Statistics for Windows Version 23.0 (IBM Corp., Armonk, NY, USA). P value < 0.05 was considered statistically significant. Quantitative data were expressed as mean ± standard deviation. Frequency and percentage were used for categorical variables. Student's *t*-test was used for continuous variables and Fisher's exact test was used for categorical data. Wilcoxon rank sum test was applied for measuring lesion size due to presence of skewed data set.

The receiver operating characteristic (ROC) curve was drawn for the scoring system, and the cutoff value was proposed.

RESULTS

Patient demographics

Total 37 patients were retrospectively reviewed (23 males and 14 females). The age range was 2–78 years. Fifty-seven percent of all patients were in the age group of 20–50 years, 21.6% were >50 years old and 5.4% were <20 years old.

Unilateral pneumothorax was found in 81% (30/37) patients, out of which 17 were right sided. Bilateral pneumothorax was present in 19% (7/37) patients. The aetiology of pneumothorax in both groups is summarized in Table 1. Most common noninfectious causes were bullous diseases including COAD (50%), cystic lung disease (16.67%) and interstitial lung disease (16.67%). The most commonly observed infectious causes were tuberculosis (47%), cavitating nodules (21%) and pneumatocele (10%).

Based on the final diagnosis 37 patients were divided into two groups, those having infectious and noninfectious aetiology. Mean age and male to female ratio were comparable in both groups. Bilaterality was slightly higher in the infectious group (28%) as compared to the noninfectious group (18%); however, the difference was not statistically significant.

Consolidated results of the same are presented in Table 2. Noninfectious lesions were more diffuse in distribution involving approximately 2.9 lobes per case as compared with 2.1 for infectious causes; however, this difference was not statistically significant. The left lower lobe was the most extensively involved in both noninfectious and infectious lesions. Average lesion size was 20% larger in the infectious group (28 mm) as compared with the noninfectious group (23 mm), which was not statistically significant.

Mean lesion wall thickness was 8 mm in infectious cases mostly with cavitating nodules and cavities, whereas the wall thickness in noninfectious causes was 1.1 mm, mostly comprising of cysts and bullae. This difference in wall thickness was statistically significant as was the presence of consolidation. A solid component was associated with 44% of lesions in the infectious group compared to 5% of noninfectious lesions. This was also statistically significant. The presence of extrapulmonary findings like mediastinal lymphadenopathy, pleural effusion and pleural thickening was also compared. Pleural effusion was not noted in any case of noninfectious pneumothorax [Figures 1-6].

The parameters with *P* value < 0.05 were selected for calculation of score. These are summarized in Table 3.

Table 1: Causes of pneumothorax with frequency (*n*=37)

Cause	No. of patients	Mean age (yrs)±SD
Bullous diseases		
COAD	5	58±13
Congenital cystic adenomatoid malformation	1	13
Congenital lobar overinflation	1	38
Subpleural cysts	2	37±25
Idiopathic giant bullous emphysema	1	29
Cystic lung diseases		
Bert–Hogg–Dubè syndrome	1	23
Lymphangioleiomyomatosis	1	32
Unclassified	1	52
Interstitial lung disease		
Hypersensitivity pneumonitis	1	30
Pneumoconiosis		
Silicosis	1	45
Squamous cell carcinoma	1	73
Osteosarcoma metastasis	1	18
Foreign body	1	2
Infections		
Tuberculosis	13	35±21.2
Pneumatocele	2	9±9.8
Necrotizing pneumonia	1	70
Aspergilloma	1	27
Unclassified	2	51±27

Table 2: Study characteristics (*n*=37)

Trait	Infectious Group	Noninfectious Group	*P*
No. of patients	*n*=18	*n*=19	
Mean age (yrs)*	33±19.3	35±19.2	0.97
Male: Female	11:7	12:7	1.00
Bilateral†	4 (22.2)	3 (15.8)	0.69
Average number of lobes involved	2.1	2.9	0.47
Most dominant lobe	Left lower lobe	Left lower lobe	
Average lesion size (mm)*	28±22.3	33±28	0.50
Mean wall thickness (mm)*	8±7.5	1.1±0.55	<0.01
Solid component†	8 (44.4)	1 (5.26)	<0.01
Mediastinal lymphadenopathy†	9 (50)	3 (15.8)	0.04
Consolidation†	14 (77.8)	3 (15.8)	<0.01
Severity (gross pneumothorax)†	4 (22.2)	5 (26.3)	0.77
Pleural thickening†	17 (94.4)	3 (15.8)	<0.01

Note—Unless otherwise specified, data are frequencies, with percentages in parentheses. *Data are means±standard deviation. †Indicates percentage in parentheses

Table 3: Calculation of CT-PECS

Characteristic	Presence	Absence
Pleural thickening	2	0
Consolidation	2	0
Solid component	2	0
Pleural effusion	2	0
Wall thickness >1 mm	1	0
Mediastinal lymphadenopathy (>10 mm in short axis)	1	0
Total score	10	0

Score of 2 was given to parameters with *P* value < 0.03, and score of 1 was given to parameters with *P* value between 0.05 and 0.03. Although lesion wall thickness had *P* value < 0.05, a score of 1 was assigned due to high interobserver difference in measurement and difficulty in measuring the same. Maximum possible score was 10. A score of zero indicated PSP.

The ROC curve for our scoring system is shown in Figure 7. The area under the ROC curve for differentiating patients in infectious and noninfectious groups was 0.931 (standard error, 0.038; 95% CI, 0.856–1.000), and the optimal threshold score for identifying patients with infectious causes was 4.5, with 77.8% sensitivity and 89.5% specificity. The number of patients with score ≥ 4.5 was 14 in the infectious group and 2 in the noninfectious group, whereas the number of patients with score less than 4.5 was 4 and 17, respectively, resulting in a positive predictive value of 87.5% and a negative predictive value of 81%.

DISCUSSION

Infectious pneumothoraces often require prolonged tube drainage and are associated with persistent air leaks as compared to noninfectious causes. These patients also need targeted antimicrobial treatment and workup for possible underlying immunocompromised state depending on the CT findings.[3]

In a study of 1,70,929 hospital admissions between 1968 and 2016 from English national and regional data sets, up to 80% of SSP cases were due to emphysema/COAD, interstitial lung disease and malignancy, whereas TB, sarcoidosis and cystic fibrosis accounted for <2% of cases.[10] COAD and *Pneumocystis carinii* pneumonia associated with HIV infection are the two most common causes of secondary pneumothorax.[11] The most common cause of SSP is COAD in the developed world, whereas in endemic areas, pulmonary tuberculosis may be the most common cause.[12,13] Multiple studies from the Indian subcontinent with 80–120 patients have suggested tuberculosis as the most common cause of SSP followed by COAD, whereas few other studies also suggest COAD as the most common cause.[14,15-19] In our study, tuberculosis was the most common cause of SSP (35.1%) followed by COAD (13.5%).

Multiple Indian studies showed incidence of spontaneous pneumothorax in men approximately 5–8 times as

Figure 1: Wall thickness. (a) 13-year-old female with large multicystic lesion in lingula (arrow), which turned out to be ruptured congenital cystic adenomatoid malformation type 1 on histopathology showing thin walls as opposed to (b) 26-year-old female with active sputum positive tuberculosis showing thick walled cavity (arrow) in the left lower lobe and left pneumothorax
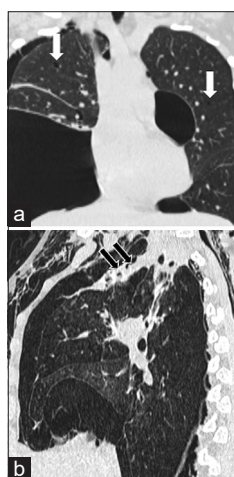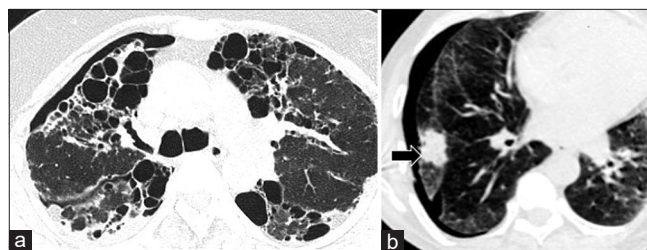

Figure 2: Solid component. (a) 52-year-old female with rheumatoid arthritis related interstitial lung disease showing multiple subpleural cysts with honeycombing and right pneumothorax. None of the lesions show a solid component. (b) 73-year-old male with subpleural mass with spiculated margins (arrow) and right-sided pneumothorax. Lesion was biopsied after placement of intercostal drainage tube, histopathology suggestive of adenocarcinoma
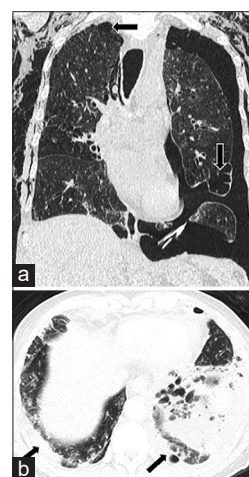

Figure 3: Pleural thickening. (a) 32-year-old female with multiple small thin-walled cysts in both lungs (arrows) with bilateral pneumothorax and no pleural thickening. (b) 16-year-old male with tuberculosis on treatment showing pleural thickening in the right upper lobe (double black arrows) with pneumothorax. The presence of pleural thickening was a strong pointer towards infectious aetiology in our study

Figure 4: Consolidation and pleural effusion. (a) 63-year-old male with COPD showing paraseptal and centriacinar emphysema (arrows) with left pneumothorax. (b) 70-year-old male with necrotizing pneumonia involving the left lower lobe with mild left hydropneumothorax and mild right pleural effusion (arrows). Both consolidation and pleural effusion are uncommon in patients with noninfectious causes of pneumothorax
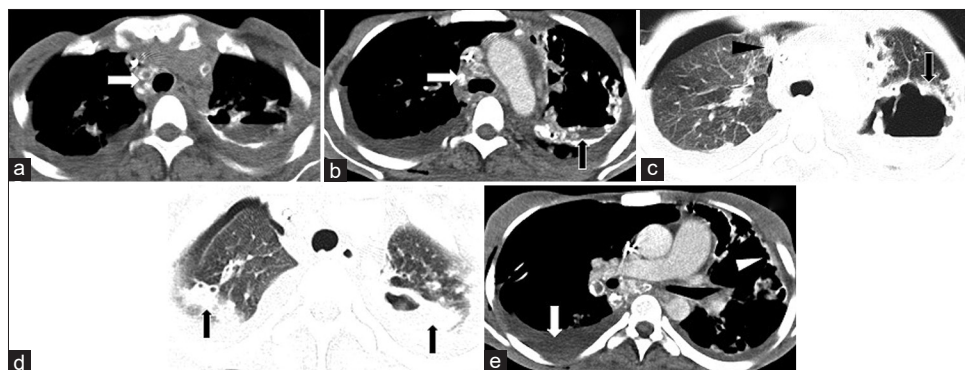
Figure 5: (a-e): 25-year-old female with active tuberculosis. (a–c) Multiple enlarged necrotic and calcified mediastinal lymph nodes (white arrows), thick walled cavity with dependent contents (black arrow) and solid nodule (arrowhead) (arrow). (d) Consolidation (arrows) and (e) showing pleural effusion (arrow) and pleural thickening (arrowhead) were also noted. Total CT-PECS score was 10 suggesting infectious aetiology
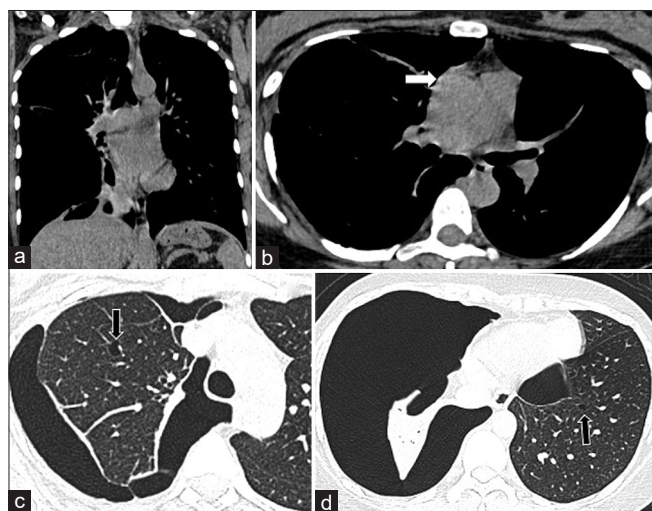

Figure 6: (a–d): 32-year-old female with mediastinal window coronal (a) and axial (b) sections showing no pleural effusion, pleural thickening or mediastinal lymphadenopathy. (c) and (d) Lung window axial sections showing multiple small lung cysts with thin walls (arrows) and gross right pneumothorax and loculated left pneumothorax. No consolidation or solid component seen. CT-PECS score for this case is zero and hence classified as noninfectious cause of pneumothorax

compared to women.[15-18] However, no such difference was observed in our study.

The mean age of patients in our study was 34.8 years (most common age group 20–50 years), which was comparable to the mean age in multiple Indian studies ranging from 30 to 45 years and significantly lower than 60–65 years age group as described in older studies.[11,14,20]

In a study from Taiwan, a higher success rate of pigtail catheter drainage was noted in SSP patients with obstructive lung conditions and malignancies than those with infectious conditions.[21] A CT-based lung dystrophy score was proposed to select patients for early surgery; however, it does not consider specific lesion characteristics and could not differentiate between infectious and noninfectious groups.[22]

A systematic evaluation of specific features can help even an inexperienced observer to distinguish between infectious and noninfectious causes of pneumothorax. We found that there are few similarities as well as differences between these two groups.

The mean age and sex distribution of the two groups was comparable, as was the incidence of bilaterality and severity of pneumothorax.

Certain features like *thick lesion wall* and *presence of solid component* can be seen in noninfectious lesions as well like granulomatous polyangiitis and malignancy; however, these lesions were not frequently associated with SSP in previous studies. In our study, we did not encounter any case of SSP due to vasculitis and only one case each of primary and secondary malignant lesions causing SSP.

Other noninfectious lesions are generally thin-walled cysts, blebs or bullae. In our study, these lesions had a mean wall thickness of 1.1 mm as compared to 8 mm in the infectious group, where thick-walled cavities, cavitating nodules and necrotizing pneumonias were more common.

A solid component was encountered in two noninfectious cases only. One of them was a peripherally located cavitating malignant lung mass, which though uncommon is well described in literature.[17,23] The other patient was a young girl with metastases from osteosarcoma of femur, which though uncommon is also a well-recognized complication of this entity.[24-26]

Parenchymal consolidation is much more common in infectious lesions; however, some noninfectious causes like interstitial lung disease can also cause similar finding on CT.

Pleural effusion and thickening are seen much more commonly with infectious causes due to inflammation of the pleural lining. *Mediastinal lymphadenopathy* is also seen more frequently in infections, particularly tuberculosis, although they can be seen in some
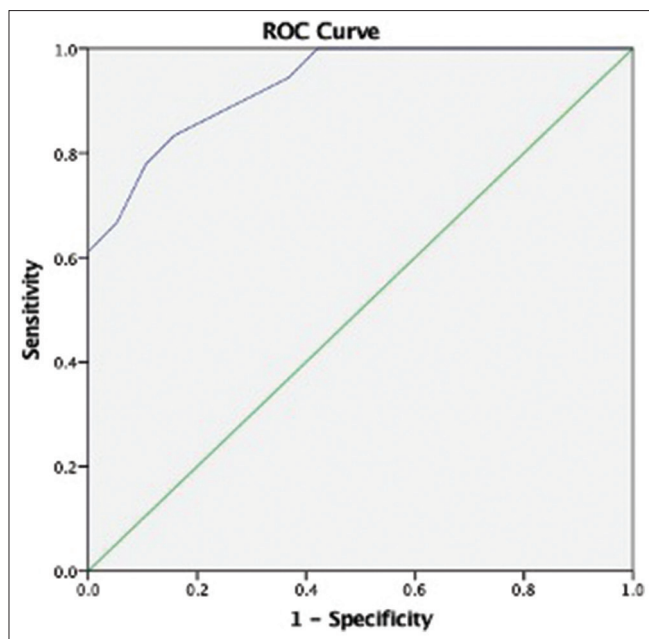
Figure 7: ROC curve for the CT-PECS scoring system

noninfectious entities like sarcoidosis and lymphoma as well.

Due to the inability of any one of the defining characteristics to reliably differentiate between these two groups in all cases and to provide some weightage to all statistically significant findings, a ***CT pneumothorax aetiology categorization score (CT-PECS)*** was proposed.

The calculation of score is demonstrated in Table 3. At cutoff value of 4.5, the sensitivity and specificity were 77.8 and 89.5%, respectively.

CONCLUSION

Determining the cause of spontaneous pneumothorax is one of the major utilities of CT. In cases where the aetiology of underlying lung disease is unclear, a structured score using imaging pointers like lesion wall thickness, solid component, pleural effusion, pleural thickening and consolidation can help us distinguish between infectious and noninfectious causes. Furthermore, it would allow for a more robust assessment and tailoring of treatment and management priorities.

Conflicts of interest
There are no conflicts of interest.

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