

# CT Characteristics and Pathologic Basis of Solitary Cystic Lung Cancer

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There are increasing reports of a type of lung cancer that manifests as solitary cystic airspaces. The purpose of this case series was to identify the CT features and possible mechanisms of solitary cystic lung cancer, on the basis of CT observations and pathologic characteristics. The clinical, imaging, and pathologic data of 106 patients with solitary cystic lung cancer were collected and analyzed between January 2011 and December 2017. CT images were reviewed independently by three radiologists who were blinded to pathologic findings. Demographic data and clinical and smoking status were extracted from the medical records. The mean age was 58.8 years  $\pm$  10.6 (standard deviation) (range, 30–82 years). CT features in the 106 patients included nonuniform cystic walls in 96 (90.6%) patients, cyst septations in 62 (58.5%) patients, nodular walls in 58 (54.7%) patients, ground-glass opacity around the cyst in 53 patients (50.0%), and irregular margins in 42 (39.6%) patients. At histologic examination, the majority of cases (81 [87.1%] of 93) were adenocarcinoma.

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There have been increasing reports of a type of lung cancer that manifests as solitary cystic airspaces (1–3). Sheard et al (4) have also emphasized the importance of early identification of this type of lung cancer. In 1941, Womack and Graham (5) first reported pulmonary cystic disease associated with lung cancer. Because such lesions are primarily characterized by cystic airspaces at CT, most authors have called this “solitary cystic lung cancer” (6–8). We define solitary cystic lung cancer as a special type of lung cancer that manifests as a thin-walled cystic airspace where the cyst walls are 4 mm or thinner at initial CT imaging.

The International Early Lung and Cardiac Action Program, or I-ELCAP, has reported that the incidence of solitary cystic lung cancer is approximately 3.7% (3). The Fleischner Society proposed a specific recommendation for the diagnosis of cystic lesions (9–12), and the recommendation includes careful assessment of the growth and stability of these types of lung findings at CT.

There are many theories about the formation mechanism of solitary cystic lung cancer (3,7,13), such as the “check-valve” effect, alveolar cavity fusion caused by alveolar wall destruction, and expectoration of necrotic tumor tissue. The purpose of this case series was to perform radiologic-pathologic correlation in this unique subtype of non-small cell lung cancer—solitary cystic lung cancer.

## Materials and Methods

### Patient Studies

With approval from our institutional review board, our study was performed with a waiver of informed consent.

We retrospectively collected and analyzed the clinical, CT, and pathologic data in 106 patients with solitary cystic lung cancer who were treated between January 2011 and December 2017 at one of three hospitals (the General Hospital of the People's Liberation Army, Affiliated Zhongshan Hospital of Dalian University, and Affiliated Beijing Shijitan Hospital of Capital Medical University). Imaging data were retrieved from a picture archiving and communication system (PACS). Tumors were characterized as solitary cystic lung cancer, and the diagnosis was confirmed at post-operative histopathologic examination or CT-guided fine-needle aspiration or bronchoscopic biopsy.

### CT Imaging

All patients included in this study underwent noncontrast CT of the chest performed with a GE LightSpeed 16-Slice CT scanner (GE Healthcare, Beijing, China) or a Siemens SOMATOM Sensation 64-Slice CT Scanner (Siemens, Forchheim, Germany). CT was performed with the following parameters: routine section thickness, 1.0, 1.25, or 1.5 mm; section thickness after reconstruction, 0.625–1.25 mm; filtered back projection reconstruction method; 80–120 kV; 200–280 mAs; and a B70f kernel. For the purposes of this work, we considered the initial CT studies of the chest as the first observation and the last CT studies in the chest just before histopathologic diagnosis as the last observation.

### CT Analysis

First, a thoracic radiologist (J.W., with 24 years of experience in cardiopulmonary imaging) and a medical student (Y.T., with 2 years of experience in pulmonary im-

## Abbreviations

GGO = ground-glass opacity, PACS = picture archiving and communication system

## Summary

Solitary cystic lung cancer has malignant features of nonuniform walls, septations, wall nodules, and irregular margins that help to distinguish this entity from benign cystic airspace on CT images.

## Key Points

- In a series of 93 patients, the majority (87.1%) of solitary cystic lung cancers were adenocarcinoma at pathologic examination; 7.5% of tumors were squamous cell carcinoma.
- Common CT features of solitary cystic lung cancer include non-uniform cyst walls (90.6%), cyst septations (58.5%), nodular walls (54.7%), ground-glass opacity around the cyst (50.0%), and irregular margins (39.6%).

aging diagnosis) in consensus reviewed the CT images from each institution by using a PACS (AGFA Healthcare, Mortsel, Belgium) (lung window width, 1500 HU; level, -500 HU) and labeled the chest CT images that showed solitary cystic lesions. Then, the studies in these patients were reviewed for confirmation of the presence of cystic airspace lesions by a radiologist in pulmonary imaging (S.Z., with 17 years of experience in pulmonary imaging diagnosis) and a dedicated pulmonary radiologist (C.W., with 15 years of experience in pulmonary imaging diagnosis). These two readings were performed for the same patient independently on the same day, and if there were differences, the radiologists resolved them through consensus. All radiologists were unaware of the pathologic diagnosis in the patient.

The following parameters were recorded for each lesion on CT images: (a) lobe of the lung, (b) location (peripheral or central), (c) cyst size (the average of the sum of the maximum diameter and its maximum vertical diameter, obtained by measuring the inner wall), (d) cyst CT presentation (nonuniform cyst walls, septation[s] within the cyst, wall nodule, ground-glass opacity [GGO] around the cyst, and an irregular margin), and (e) cyst wall thickness ( $\leq 4$  mm in thickness).

## Pathologic and Clinical Data

All existing histopathologic slides were reviewed by one senior pathologist (J.G., with 10 years of experience with pathologic diagnosis of the lung) and a Master of Pathology (G.W., with 3 years of experience with pathologic diagnosis). Clinical data recorded included the following: sex, age, smoking history, clinical symptoms, diagnostic methods, and treatment methods.

## Statistical Analysis

Data were collected by using Microsoft Excel and were analyzed using SPSS, version 20.0 (IBM Statistics, Armonk, NY). Age, number of pack-years smoked, and cyst size were expressed as means  $\pm$  standard deviations with ranges, and the Kolmogorov-Smirnov test was used for the normal distribution test. Statistically significant differences were set at *P* values of less than .05. Summary data, including smoking history, clinical symptoms, clinical diagnosis method, treatment method,

and CT features in both lungs, are expressed as frequencies and percentages. Additionally, 95% confidence intervals for the observed quantities are shown in Tables 1 and 2.

## Results

### Clinical Characteristics

Figure 1 shows the patient inclusion flowchart. A total of 106 patients (mean age, 58.8 years  $\pm$  10.6; age range, 30–82 years) (*P* > .05) with solitary cystic lung cancer were included (Table 1). Thirty-seven (34.9%) of the 106 patients were women (mean age, 54.9 years  $\pm$  11.1; age range, 30–79 years) (*P* > .05), and 69 (65.1%) were men (mean age, 60.9 years  $\pm$  9.8; age range, 38–77 years) (*P* > .05). Forty-nine (46.2%) of the 106 patients had a history of smoking. The mean number of pack-years among smokers was 35.3 pack-years  $\pm$  20.7 (range, 6–100 pack-years) (*P* > .05). Fifty-eight (54.7%) of the 106 patients had cystic lung lesions detected at CT lung cancer screening. Slightly less than half of the cohort (48 patients [45.3%]) had clinical symptoms at presentation: coughing and expectoration of sputum in 31 patients, blood in sputum in 11 patients, chest distress in 12 patients, and fever in four patients.

Ninety-three patients had the diagnosis of solitary cystic lung cancer confirmed by postoperative pathologic examination. Seventy-seven (82.8%) of these 93 patients received a definitive diagnosis after postoperative pathologic examination, 12 patients (12.9%) received the diagnosis after CT-guided fine-needle aspiration biopsy, and four patients (4.3%) received the diagnosis after bronchoscopic biopsy. There were 13 patients with no pathologic confirmation of the primary lung cancer. Of these 13 patients, three had extrapulmonary metastasis at presentation; the remaining 10 patients were given a diagnosis of solitary cystic lung cancer after they were found to have experienced disease progression at follow-up chest CT.

Regarding treatment, 75 (70.8%) of the 106 patients underwent video-assisted thoracoscopic surgery lobectomy, 13 patients (12.3%) underwent chemotherapy alone because of intrapulmonary or extrapulmonary metastasis, five patients (4.7%) underwent surgery followed by adjuvant chemotherapy, one patient (0.9%) underwent radiofrequency ablation, and 12 patients (11.3%) did not undergo any treatment (Fig 1).

### CT Characteristics of Solitary Cystic Lung Cancer

Table 2 shows the CT imaging features of solitary cystic lung cancer determined in consensus. No lobar predilection was present (Table 2). Solitary cystic lung cancer was present in the periphery of either lung in 70 (66.0%) of the 106 patients, in the middle of either lung in 21 patients (19.8%), in the middle and the periphery of the lung in four patients (3.8%), and in the center of either lung in 11 patients (10.4%). The average diameter of the cystic airspace (mean of the maximum diameter on the same section and the maximum vertical diameter) was 2.0 cm  $\pm$  1.4 (range, 0.25–8.52 cm).

CT features of solitary cystic lung cancer included non-uniform cystic walls, septation(s) in the cyst, wall nodules, GGO around the cyst, and irregular margins (Fig 2).

**Table 1: Clinical Characteristics of Patients with Solitary Cystic Lung Cancer**

Characteristic	No. of Patients	Datum
Age of all 106 patients (y)	...	58.8 ± 10.6 (33.0, 51.9)
Age of 69 male patients (y)	...	60.9 ± 9.8 (35.8, 54.8)
Age of 37 female patients (y)	...	54.9 ± 11.1 (97.2, 100.0)
No. of current smokers	49	46.2 (36.5, 56.2)
No. of nonsmokers	57	53.8 (44.3, 63.0)
No. of pack-years in the 49 patients who smoked	...	35.3 ± 20.7 (19.5, 45.8)
No. of patients with emphysema	5	4.7 (1.5, 10.7)
Symptoms		
Blood in sputum	11	10.4 (5.3, 17.8)
Cough, sputum	31	29.2 (20.8, 38.9)
Chest pain	12	11.3 (6.0, 18.9)
Fever	4	3.8 (1.0, 9.4)
No symptoms	48	45.3 (35.6, 55.2)
Method of diagnosis in 93 patients		
Postoperative pathologic examination	77	82.8 (73.6, 89.8)
Percutaneous biopsy	12	12.9 (6.8, 21.5)
Bronchoscopic biopsy	4	4.3 (1.2, 10.6)
Stage of cancer in 106 patients		
Stage I	67	63.2 (53.7, 71.8)
Stage II	12	11.3 (6.5, 18.9)
Stage III	11	10.4 (5.3, 17.8)
Stage IV	16	15.1 (8.9, 23.4)
Treatment in 106 patients		
Lobectomy	51	48.1 (38.3, 58.0)
Wedge resection	24	22.7 (15.7, 31.5)
Chemotherapy	13	12.3 (6.7, 20.1)
Surgery and chemotherapy	5	4.7 (1.5, 10.7)
Radiofrequency ablation	1	0.9 (0, 5.1)
Follow-up	12	11.3 (6.0, 18.9)

Note.—Data are means ± standard deviations or percentages. Data in parentheses are 95% confidence intervals.

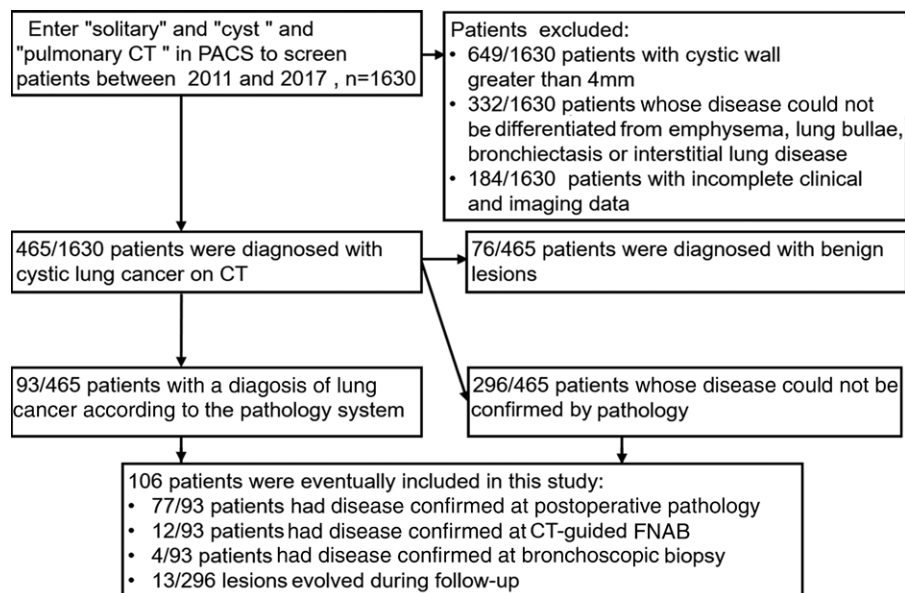
**Table 2: CT Characteristics in Patients with Solitary Cystic Lung Cancer**

CT Characteristic and Location	No. of Patients (n = 106)	Datum
Disease location*		
Right upper lobe	25	23.6 (16.5, 32.6)
Right middle lobe	10	9.4 (4.6, 16.7)
Right lower lobe	27	25.5 (17.5, 34.9)
Left upper lobe	23	21.7 (14.9, 30.5)
Left lower lobe	21	19.8 (12.7, 28.7)
Lung periphery	70	66.0 (56.2, 75.0)
Central lung	11	10.4 (5.3, 17.8)
Cyst size (mm) <sup>†</sup>	...	2.0 ± 1.4 (0.7, 8.8)
Nonuniform cyst wall	96	90.6 (83.3, 95.4)
Septation in cyst	62	58.5 (48.5, 68.0)
Wall nodule	58	54.7 (44.8, 64.4)
Ground-glass opacity	53	50.0 (40.1, 59.9)
Irregular, nonspherical margin	42	39.6 (30.3, 49.6)

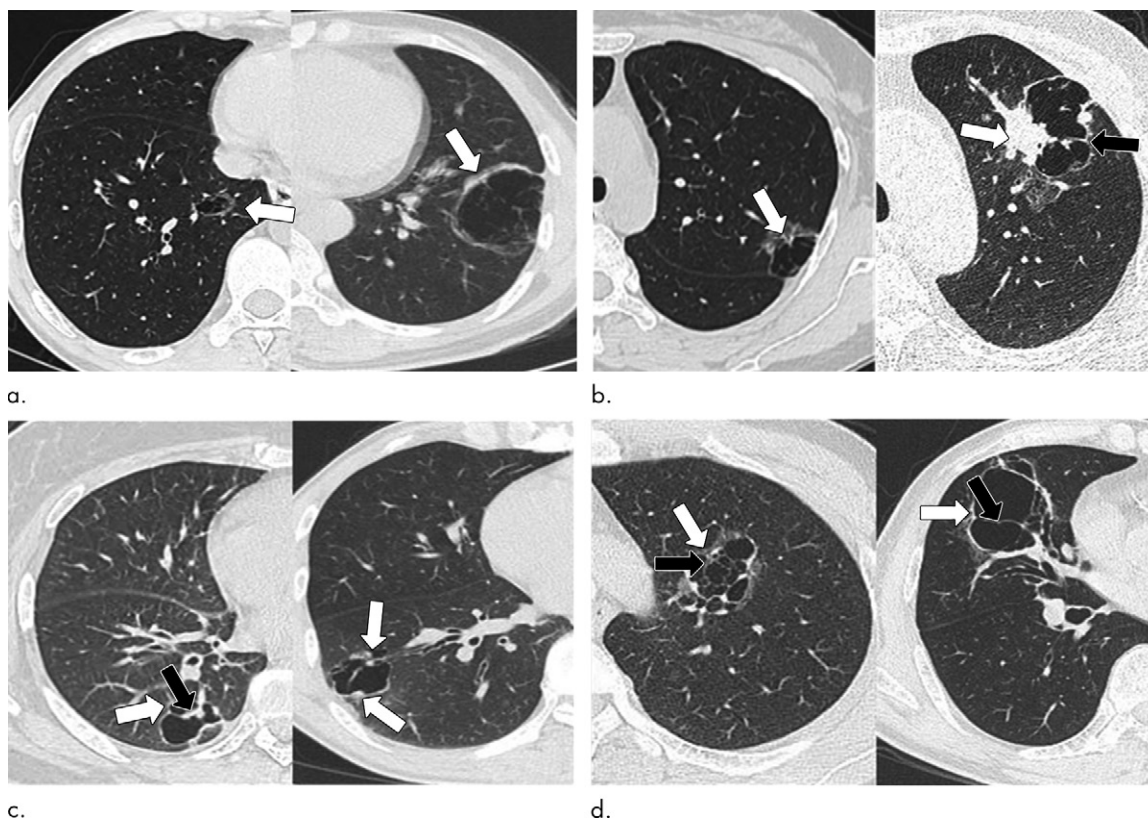
Note.—Data are percentages or means ± standard deviations. Data in parentheses are 95% confidence intervals.

\* Based on evaluation of the last chest CT study performed before histopathologic diagnosis.

<sup>†</sup> Cyst size was calculated after measuring the inner wall as the average of the sum of the maximum diameter and the maximum vertical diameter.



**Figure 1:** Patient inclusion flowchart shows the number of patients, evaluation of the imaging studies, and pathologic analysis. *FNAB* = fine-needle aspiration biopsy, *PACS* = picture archiving and communication system.

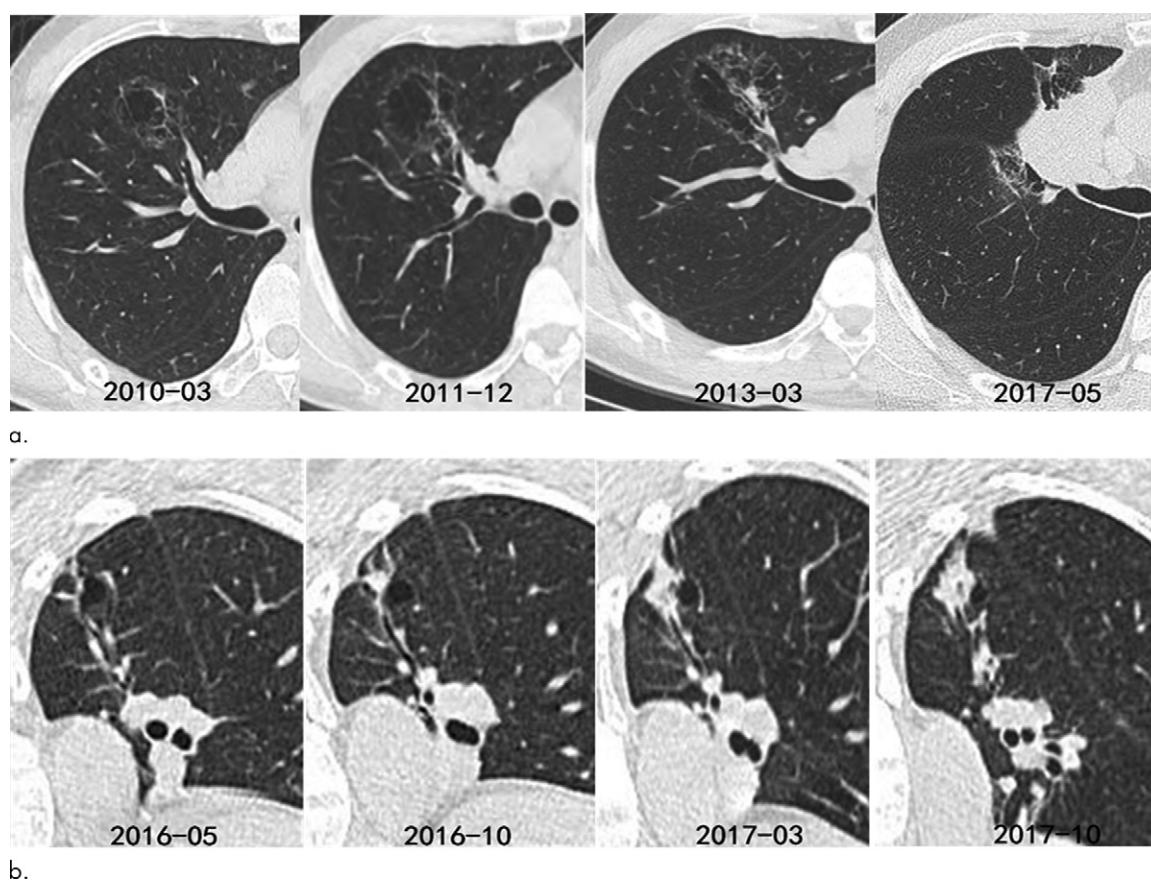


**Figure 2:** Axial CT images show examples of CT features of solitary cystic lung cancer, including (a) an asymmetric cystic wall (arrows); (b) ground-glass opacity (GGO) around the cyst and a wall nodule (white arrows); (c) septation in the cyst (black arrow) and an irregular margin (white arrows); and (d) GGO around the cyst (white arrows), septation in cyst (black arrows), and an irregular margin.

Ninety-six (90.6%) of 106 patients had cysts with nonuniform cystic walls, 62 patients (58.5%) had septation(s) in the cyst, 58 patients (54.7%) had a wall nodule, 53 patients

(50.0%) had GGO around the cyst, and 42 patients (39.6%) had an irregular margin. Several CT features could often be seen in one patient.





**Figure 3:** Axial CT images show the evolution of cystic airspaces during follow-up. Sequential images in **(a)** a 41-year-old man and **(b)** a 49-year-old woman, each of whom had adenocarcinoma, show that the cystic airspace enlarged, cystic walls thickened, wall nodules appeared, and, ultimately, the cystic airspace was lessened or disappeared during follow-up.

To explore the potential mechanism of the formation of cystic airspaces in these lung cancers, we focused on reconstructions along the bronchus and the evolution of cysts during follow-up in 106 patients. In 65 (61.3%) of 106 patients, the bronchus that communicated with the cystic airspaces was thick, narrow, and blocked by a solid component outside the cyst. There were seven patients whose cystic airspace increased in size at follow-up. Over time, the cystic airspace diameter enlarged, cystic walls thickened, wall nodules appeared, and, eventually, the cystic airspace was lessened (Fig 3, Fig E1 [online]). Two patients had cystic airspaces that gradually disappeared, and those lesions eventually became solid masses.

### Pathologic Basis

There were 93 patients with a definitive histopathologic diagnosis. Pathologic findings confirmed that these lesions were lung adenocarcinoma in 81 (87.1%) of the 93 patients, squamous cell carcinoma in seven patients (7.5%), adenosquamous carcinoma in four patients (4.3%), and pulmonary lymphoma in one patient (1.1%). No necrotic tumor tissue was found in any of the cystic airspaces.

After surgery, we correlated imaging findings with the pathologic findings. The CT imaging feature that was responsible for the presence of nonuniform cystic walls was the differential extent and location of tumor cells infiltrating the surrounding

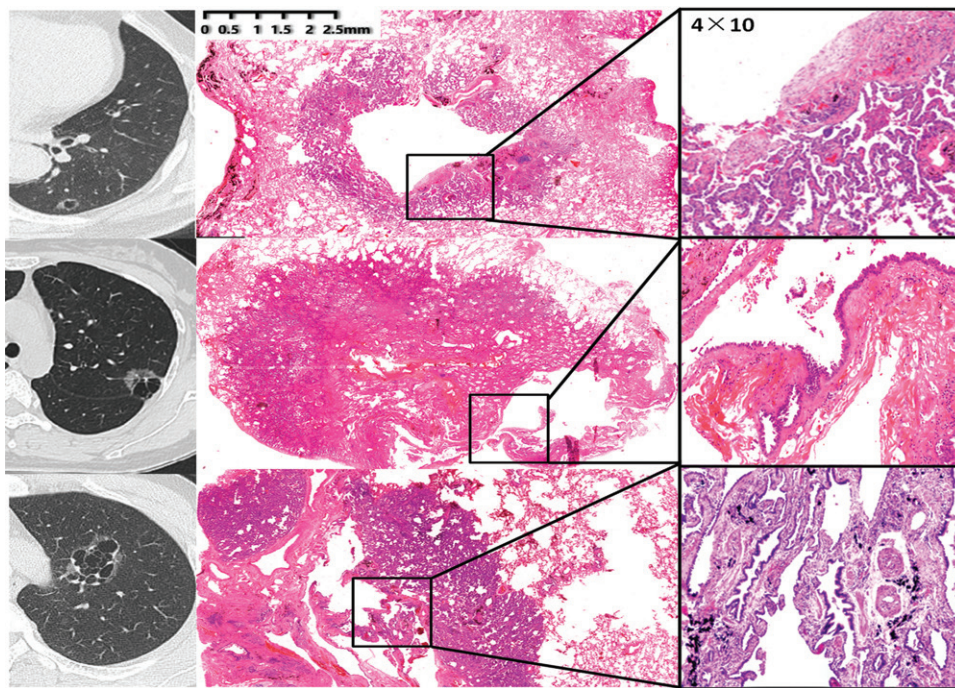
normal lung tissue (Fig 4, top row). Wall nodules at CT were found at pathologic examination to be related to proliferating tumor cells filling in the alveolar spaces, but GGO around the cyst at CT was found to be related to tumor cells along the alveolar wall (not completely filling the alveolar space). An irregular margin at CT corresponded to fibrous tissue produced by tumor cells with infolding cyst walls (Fig 4, middle row). Septations within the cyst at CT were composed of many types of tissue: fibrous tissue produced by tumor cells, bronchus, or blood vessels (Fig 4, bottom row).

At hematoxylin-eosin staining, photomicrographs at  $\times 40$  magnification showed that tumor cells in 57 (61.3%) of the 93 patients produced abundant fibrous tissue that seemed to have mass effect, resulting in local extrinsic compression of the adjacent bronchus that communicated with the cystic airspace (Fig 5). In 34 (36.6%) of the 93 patients, the tumor cells directly invaded the bronchial/bronchiolar wall, causing occlusion.

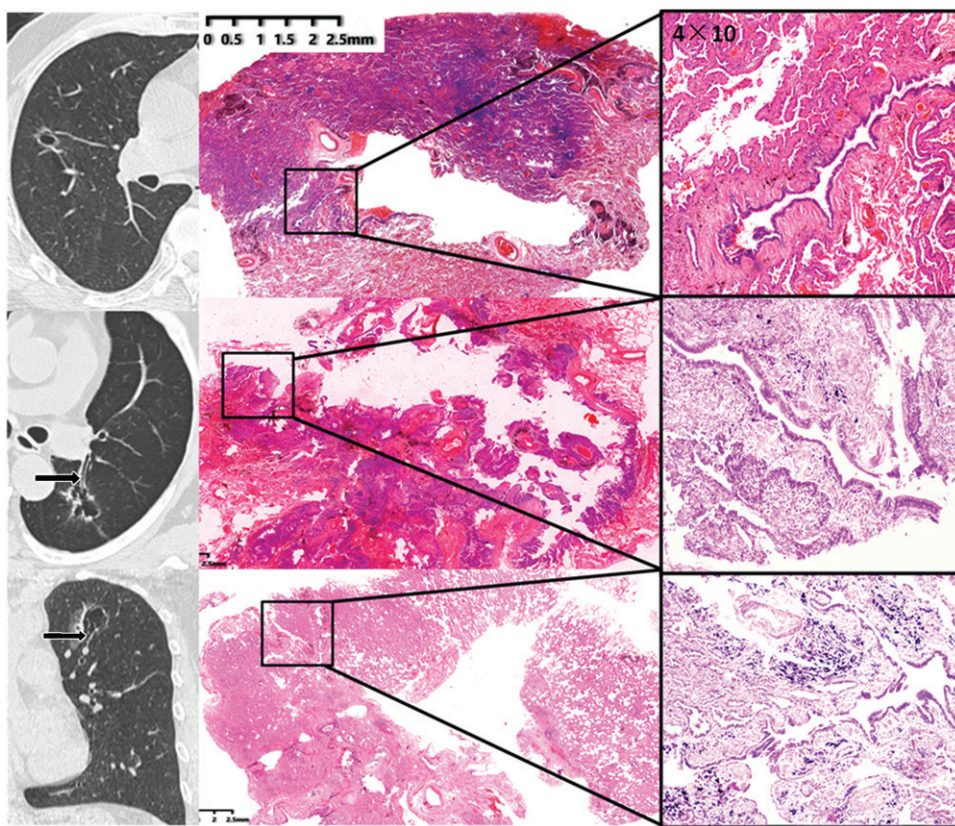
### Discussion

Solitary cystic lung cancer has a unique imaging appearance and may be a potential cause of diagnostic error (2). In this study, we investigated the CT characteristics of 106 patients with solitary cystic lung cancer to correlate their respective imaging findings with histopathologic findings. CT features of these tumors including nonuniform cyst walls (90.6%),





**Figure 4:** Axial CT images and corresponding hematoxylin-eosin-stained histologic findings in solitary cystic lung cancer. Top row: Images in 69-year-old man with adenocarcinoma. The nonuniform cyst wall seen at CT corresponded to cells along the wall of the cyst infiltrating the surrounding normal lung tissue. Middle row: Images in 43-year-old woman with adenocarcinoma. The irregular margin seen at CT corresponded to fibrous tissue produced by the tumor cell with infolding cyst walls. Bottom row: Images in 45-year-old man with adenocarcinoma. Septations within the cyst at CT were composed of many types of tissue: fibrous tissue produced by tumor cells, bronchus, and blood vessels.

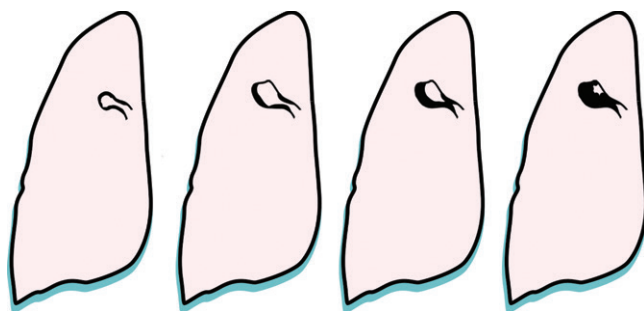


**Figure 5:** CT images and corresponding hematoxylin-eosin-stained histologic findings in solitary cystic lung cancer show a narrow bronchus of the cystic wall. Top row: Axial CT and histologic images in 58-year-old man with adenocarcinoma. The bronchus of the cystic wall is clearly narrowed because of the compression of surrounding cancer cells and large numbers of fibrous tissues. Middle row: Axial CT and histologic images in 67-year-old man with squamous cell carcinoma. Bronchus communication with the cyst at CT corresponded to tumor cells producing abundant fibrous tissue that pressured the surrounding bronchus. Bottom row: Coronal CT and histologic images in 45-year-old man with adenocarcinoma. The CT finding "narrow bronchus" corresponded to the compression of surrounding fibrous tissue and tumor cells.

septation(s) within the cyst (58.5%), wall nodule(s) (54.7%), GGO around the cyst (50.0%), irregular margins, and, in some cases, gradual expansion of the cystic airspaces. This appearance is distinct from that of benign cystic airspaces, which typically have thin, symmetrical walls without nodularity (Fig E2 [online]).

To date, the number of solitary cystic lung cancers reported in the English-language literature is not large, and the most recent references are case reports and small case reviews (7,14–18). In this series, the most common pathologic types of solitary cystic lung cancer were adenocarcinoma (81 [87.1%] of 93), but in situ adenocarcinoma is rare (14). Less common pathologic





**Figure 6:** Potential evolution of solitary cystic lung cancer. The tumor cells originate from the alveolar wall and bronchus wall, directly invade the bronchus, and cause local stenosis, forming a unidirectional check-valve. With the accumulation of gases entering the cystic airspace, the airspace gets larger and larger with the increased inner pressure. But when the tumor tissue completely blocks the bronchus, the cystic airspace becomes smaller and smaller because of tumor tissue growing into the cystic airspace.

subtypes were squamous carcinoma (seven [7.5%] of 93), adenocarcinoma (four [4.3%] of 93), and pulmonary lymphoma (one [1.1%] of 93). Additionally, microscopic observation showed that most tumor cells produced abundant fibrous tissue that in turn could extrinsically cause airway occlusion. This may allow air in but not out (the so-called ball-valve phenomenon), which may help to generate the cyst.

The formation mechanism of solitary cystic lung cancer is uncertain. Aronberg et al (19) first proposed a “check-valve” mechanism, but some scholars have speculated that the cyst interferes with ventilation, leading to alveolar epithelial carcinogenesis (20–22). It has also been proposed (15) that these lesions show coagulative necrotic foci in the cancer-cavity junction, indicating ischemic change of the surrounding pulmonary tissue. A study by Nakamura (23) found that mucus retention plays a key role in the formation of lung adenocarcinoma cavities, but some studies (24,25) have shown that nonmucinous adenocarcinomas also form cysts. Subsequently, Xue et al (6) proposed that the tumor cell directly invades the bronchus and forms a unidirectional check-valve. Our results also suggest a check-valve mechanism (Fig 6), wherein the tumor originates from the alveolar wall and produces abundant fibrous tissue, resulting in narrowing and focal stenosis of the airway feeding that portion of the lung.

In summary, solitary cystic lung cancer should be suspected at CT when the cyst has nonuniform cyst walls, septation(s) within it, wall nodule(s), ground-glass opacities around it, and irregular margins. Recognition of these features can help to make an early diagnosis of this disease.

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## References

- Chen W, Zheng R, Baade PD, et al. Cancer statistics in China, 2015. *CA Cancer J Clin* 2016;66(2):115–132.
- Horeweg N, Scholten ET, de Jong PA, et al. Detection of lung cancer through low-dose CT screening (NELSON): a prespecified analysis of screening test performance and interval cancers. *Lancet Oncol* 2014;15(12):1342–1350.
- Farooqi AO, Cham M, Zhang L, et al. Lung cancer associated with cystic airspaces. *AJR Am J Roentgenol* 2012;199(4):781–786.
- Sheard S, Moser J, Sayer C, Stefanidis K, Devaraj A, Vlahos I. Lung cancers associated with cystic airspaces: underrecognized features of early disease. *RadioGraphics* 2018;38(3):704–717.
- Womack NA, Graham EA. Epithelial metaplasia in congenital cystic disease of the lung: Its possible relation to carcinoma of the bronchus. *Am J Pathol* 1941;17(5):645–654.
- Xue X, Wang P, Xue Q, et al. Comparative study of solitary thin-walled cavity lung cancer with computed tomography and pathological findings. *Lung Cancer* 2012;78(1):45–50.
- Masuzawa K, Minematsu N, Sasaki M, et al. Invasive mucinous adenocarcinoma of the lung presenting as a large, thin-walled cyst: A case report and literature review. *Mol Clin Oncol* 2017;6(3):433–437.
- Guo J, Liang C, Sun Y, Zhou N, Liu Y, Chu X. Lung cancer presenting as thin-walled cysts: An analysis of 15 cases and review of literature. *Asia Pac J Clin Oncol* 2016;12(1):e105–e112.
- MacMahon H, Naidich DP, Goo JM, et al. guidelines for management of incidental pulmonary nodules detected on CT images: from the Fleischner Society 2017. *Radiology* 2017;284(1):228–243.
- Yankelevitz DF, Yip R, Smith JP, et al. CT screening for lung cancer: nonsolid nodules in baseline and annual repeat rounds. *Radiology* 2015;277(2):555–564.
- Yip R, Wolf A, Tam K, et al. Outcomes of lung cancers manifesting as nonsolid nodules. *Lung Cancer* 2016;97:35–42.
- Yip R, Yankelevitz DF, Hu M, et al. Lung cancer deaths in the national lung screening trial attributed to nonsolid nodules. *Radiology* 2016;281(2):589–596.
- Fintelmann FJ, Brinkmann JK, Jeck WR, et al. Lung cancers associated with cystic airspaces: natural history, pathologic correlation, and mutational analysis. *J Thorac Imaging* 2017;32(3):176–188.
- Prichard MG, Brown PJ, Sterrett GF. Bronchioloalveolar carcinoma arising in long-standing lung cysts. *Thorax* 1984;39(7):545–549.
- Isobe K, Hata Y, Iwata M, et al. An autopsy case of mucinous bronchioloalveolar carcinoma associated with multiple thin-walled cavities [in Japanese]. *Nihon Kokyuki Gakkai Zasshi* 2009;47(6):512–517.
- Kataoka K, Nakamura I, Sumiyoshi H, et al. A case of bronchioloalveolar carcinoma with a thin-walled cavity associated with high uptake of 18F-fluorodeoxyglucose on positron emission tomography. *Jpn J Lung Cancer* 2008;48(7):861–865.
- Maki D, Takahashi M, Murata K, Sawai S, Fujino S, Inoue S. Computed tomography appearances of bronchogenic carcinoma associated with bullous lung disease. *J Comput Assist Tomogr* 2006;30(3):447–452.
- Boddu P, Parimi V, Taddonio M, Kane JR, Yeldandi A. Pathologic and radiologic correlation of adult cystic lung disease: a comprehensive review. *Pathol Res Int* 2017;2017:3502438.
- Aronberg DJ, Sagel SS, LeFrak S, Kuhn C, Susman N. Lung carcinoma associated with bullous lung disease in young men. *AJR Am J Roentgenol* 1980;134(2):249–252.
- Womack NA, Graham EA. Epithelial metaplasia in congenital cystic disease of the lung: Its possible relation to carcinoma of the bronchus. *Am J Pathol* 1941;17(5):645–654.
- Goldstein MJ, Snider GL, Liberson M, Poske RM. Bronchogenic carcinoma and giant bullous disease. *Am Rev Respir Dis* 1968;97(6):1062–1070.
- Stoloff IL, Kanofsky P, Magilner L. The risk of lung cancer in males with bullous disease of the lung. *Arch Environ Health* 1971;22(1):163–167.
- Nakamura S. CT Findings of pneumonic type adenocarcinoma: comparison between invasive mucinous adenocarcinoma and nonmucinous adenocarcinoma. *GJMR-D* 14: version 1.0, 2014. <https://pdfs.semanticscholar.org/f66b/7811d8fcc2e68ef87603b3b1aff7d450f87.pdf>. Accessed December 11, 2018.
- Matsushima H, Oda T, Hasejima N, Kou E, Kadoyama C, Takezawa S. Pulmonary adenocarcinoma with multiloculated cystic change [in Japanese]. *Nihon Kokyuki Gakkai Zasshi* 2007;45(7):556–559.
- Yoshida T, Harada T, Fuke S, et al. Lung adenocarcinoma presenting with enlarged and multiloculated cystic lesions over 2 years. *Respir Care* 2004;49(12):1522–1524.