Biomedical Sciences and Clinical Medicine. 2022;61(2):79-89.
doi: 10.12982/CMUMEDJ.2022.11
https://www.med.cmu.ac.th/bscm/

BSCM
Biomedical Sciences and Clinical Medicine

Original Article **Open Access**

The Prevalence of Pneumonia in Children under 15 Years of Age Who Have Air Bronchogram Sign on Chest Computed Tomography Studies

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Received: July 17, 2021;
Revised: September 20, 2021;
Accepted: October 14, 2021

ABSTRACT

OBJECTIVE The aim of the study was to investigate the prevalence of pneumonia in the presence of air bronchogram on chest computed tomography (CT) according to pediatrician's concerning about the presence of air bronchogram in favor of pneumonia in children under 15 years of age.

METHODS A total of 371 children under 15 years of age who had air bronchogram on chest CT studies from January 2015 to December 2019 in Siriraj Hospital were included, of which 182 cases had been diagnosed with pneumonia. CT analysis was conducted, including identification of the location of air bronchograms, consolidation, atelectasis, interstitial infiltration, ground glass opacity (GGO), pleural effusion, bronchiectasis, lymphadenopathy, cardiomegaly, lung abscess and nodules and findings were determined by consensus of an experienced pediatric radiologist and an in-training resident.

RESULTS The prevalence of pneumonia in this group was 49.1% and that of atelectasis was 68.2%. Air bronchograms in consolidation, especially at the right lower lobe, were more likely associated with pneumonia. Air bronchograms in atelectasis were more likely associated with non-pneumonia conditions. Air bronchogram sign in consolidation combined with GGO, pleural effusion or bronchiectasis in union pattern were associated with an increased incidence of pneumonia of 69.2%, 67.1% and 74.6%, respectively.

CONCLUSIONS The presence of air bronchograms is not specific for pneumonia. Air bronchograms were found more frequently in atelectasis than in pneumonia (68.2% vs. 49.1%). Although air bronchogram in consolidation should raise concerns for lesions in both pneumonia and non-pneumonia cases, the combination of air bronchogram in consolidation with additional GGO, pleural effusion and bronchiectasis is associated with an increased likelihood of pneumonia.

KEYWORDS air bronchogram, atelectasis, chest computed tomography, ground glass opacity, interstitial infiltration, pneumonia

INTRODUCTION

Pneumonia is one of the major causes of death in the Thai population, especially among pediatric patients (1). The World Health Organization (WHO) reported that pneumonia accounted for nearly 400,000 deaths annually and more than 60 deaths per 100,000 people in 2012-2013. Among children younger than 5 years, pneumonia accounted for 10-25% of the total mortality (1). In 2016, the Thai Department of Disease Control, Ministry of Public Health reported that during the period 2006-2015, there was an increase in the mortality rate, especially in children less than 4 years of age (2). This is an indication that the correct diagnosis of pneumonia and exclusion of other medical

mimics are crucial to determining appropriate treatment.

In practice, the diagnosis of pneumonia relies primarily on history taking and physical examination. Chest radiographs are generally used only to confirm a diagnosis and as baselines for pre-treatment evaluations. Chest CT scans are normally performed only in selected pediatric cases which do not improve after appropriate treatment with antibiotic drugs or which are suspected of having complications such as lung abscess. It is important to be aware of possible complications in immunocompromised patients, who are prone to develop severe diseases (3,4).

The air bronchogram sign was first described by Fleischner and was named by Felson (5) as a means to distinguish pulmonary parenchymal lesions from extrapulmonary lesions such as pleural effusion. Fleischner (5) stated that airless lung tissue surrounding normal open airways could produce a radiographic effect. The consolidation processes in alveoli with airway preservation results in the appearance of the air bronchogram sign. Traditionally, the air bronchogram sign was used to identify alveolar diseases. The sign is defined as air-containing distal bronchi and/or bronchioles within the alveolar infiltrated area (6).

A review of the literature showed that the air bronchogram can be found in many conditions, including pneumonia which was the focus of this study, causing the pathology in the alveoli. Air bronchograms are found in pneumonia that occur in alveoli which is known as alveolar pneumonia. However, they are also found in interstitia (contiguous fluid-filled spaces between alveoli), including interstitial pneumonia. They can potentially lead to compressive atelectasis and can cause crowding of tissue around open airways (7,8).

The presence of air bronchograms in pediatric patients has been considered as an indication of pneumonia, although controversial. However, a review of the literature on adult populations shows that air bronchograms are found not only in pneumonia, but also in other diseases or conditions, e.g., atelectasis, pulmonary hemorrhage, pulmonary alveolar proteinosis, bronchioloalveolar cell carcinoma, alveolar sarcoidosis and lymphoma (7,8). This study sought to determine if air bronchograms on chest CT scans documented in OPD cards can be an indication of diseases or conditions other than pneumonia in children.

A review of the relevant literature found no publications on the prevalence of pneumonia in pediatric patients under 15 years of age who had air bronchograms on chest CT studies. This study was conducted to explore the prevalence of pneumonia in pediatric patients under 15 with air bronchograms and other signs on chest CT scans. We anticipated that the results of our study could provide information on the prevalence of air bronchograms and whether the presence of air bronchograms favors a diagnosis of pneumonia. The study was also intended to enhance pediatrician's awareness of pneumonia and other mimic conditions in combination with various imaging features and clinical contexts to help achieve correct diagnoses and proper treatments.

METHODS

Ethical approval for this study was obtained from Siriraj Institutional Review Board (SiRB), Code Number 905/2562 (IRB4).

Patient selection

This retrospective cohort study enrolled 0-15 year old patients in Siriraj Hospital who had had chest CT or chest CTA studies from January 2015 to December 2019. All had undergone 64-slice chest CT scans using standard machines. In cases of repeated studies, the earliest study was selected. Chest CT studies which appeared to be without air bronchograms, e.g., asymptomatic cases and annual follow-ups of non-respiratory diseases were also excluded.

CT protocols

All studies were performed using a 64 row multi-slice helical CT scanner system (LightSpeed VCT, Discovery CT 750 HD and Optimal CT660, GE Healthcare, Cleveland, OH, USA; SOMATOM Definition Dual Source, Siemens, Munich, Germany. All images were stored in PACS digital formats. CT parameters were adjusted for age and body weight according to the Siriraj pediatric body CT zone protocol using

a tube voltage of 80-120 kV, tube current of 100-224 mA, matrix of 512×512 mm, rotation time of 0.5 seconds, pitch of 0.984 in chest CT studies and 1.375 in chest CTA studies, layer thickness of 5 mm, reconstruction thickness of 1.25 mm, and a reconstruction interval of 0.625 mm. About 1.0-1.5 mL/kg of nonionic iodinated contrast agent was injected in contrast-enhanced studies.

Imaging analysis

All patients were analyzed using retrospective reviews of CT chest studies for the air bronchogram sign by consensus of an experienced pediatric radiologist and an in-training 3rd year resident who were blinded to the report findings and diagnosis, and knew only clinical presentations, underlying diseases and/or chest trauma history.

The gold standard for diagnosis of pneumonia is clinical presentation and radiographic findings of consolidation. However, the sputum results are also used, not for diagnostic purposes but for determining appropriate treatment with adequate antibiotics. Some patients also had chest CT studies due to severe diseases. Those patients are described as 'severe cases' in this study.

There are many other radiographic signs of potential concern which need to be evaluated together in cases of pneumonia, e.g., infiltration and consolidation. In addition, frequently found complications such as bronchiectasis and/or pleural effusion can also occur (6). For that reason, the chest CT image analyses in this study included the location of the air bronchogram, consolidation, atelectasis, interstitial infiltration, ground glass opacity (GGO), pleural effusion, bronchiectasis, lymphadenopathy, cardiomegaly, lung abscess and nodules.

To differentiate air bronchogram signs in consolidation and in atelectasis evaluated by CT findings, contrast study is helpful. The air bronchogram sign in atelectasis represents a lung volume loss with enhancement, while in consolidation it does not. However, in the patients who did not receive intravenous contrast media, the air bronchogram sign in atelectasis was interpreted based on the evidence of lung volume loss which could be differentiated from consolidation. In cases where the lesions were unclear, we reached at a consensus of the most likely diagnosis. Following that, the definite diagnosis in each case was retrospectively reviewed using an electronic record summary.

Statistical analysis

Statistical analysis was performed using SPSS software (version 17, IBM Corp, Chicago, IL, USA).

The descriptive statistics of the patients under 15 years of age with air bronchogram are given in percentages and 95% confidence intervals (CI) to represent prevalence. Quantitative age group variables are shown as median (25th and 75th percentiles).

Comparison of baseline characteristics between groups of quantitative variables was done using the Independent T-test or the Mann Whitney U test, and for group variables using the Chi-squared test. Crude Odds ratio (95% CI) was analyzed by univariate analysis using simple logistic regression. *P*-values < 0.05 were considered statistically significant. Further analysis of the significant univariate parameters using adjusted odds ratio (95% CI) and *p*-value was performed using multiple logistic regression.

RESULTS

Patient characteristics

A total of 2,030 patients under 15 years of age who underwent chest CT studies in Siriraj Hospital were included in this study. After exclusion of repeated studies of the same patient, 821 studies remained. After exclusion of chest CT studies that appeared to lack an air bronchogram based on screening of clinical presentations as described above, a total of 621 patients were enrolled for evaluation of whether air bronchogram signs were present or not. After a case-by-case evaluation and with the consensus of an experienced pediatric radiologist and an in-training 3rd year resident, a total of 371 patients showing evidence of the presence of air bronchograms were included in the study (Figure 1). All study findings were similarly arrived at by consensus.

A total of 182 patients with air bronchogram signs were diagnosed with pneumonia. The

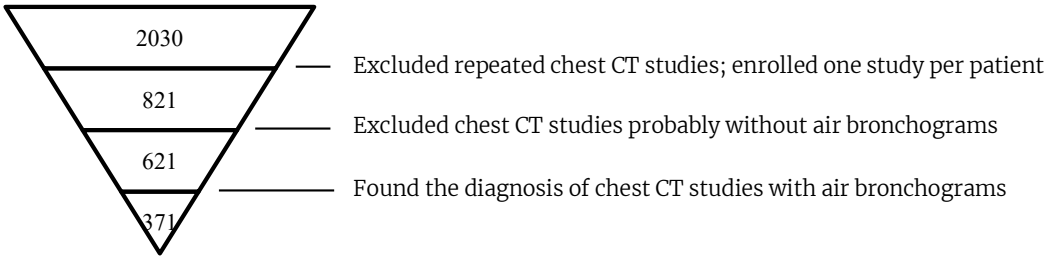

Figure 1. Patient selection algorithm

median age of patients with air bronchogram signs was 3 years (range P25-P75:1-10 year olds) (Table 1). Multivariate analysis found no significant differences in age between patients with and without pneumonia (Table 2). However, an analysis of age alone found the median age of patients with air bronchogram signs who were diagnosed pneumonia was 5.5 years (range P25-P75: 1-12 years), while for those without pneumonia the median was 2 years (range P25-P75: 0.6-9 years). The male to female ratio in the selected patients was 182/189 with no significant difference in gender among the included cases.

There was no difference between CT scans with contrast and those without contrast or between the first study and follow-up studies in the evaluation of whether air bronchograms were present in consolidation or atelectasis (Table 1).

Imaging features of the air bronchogram sign and diagnosis

The prevalence of pneumonia in our study was 49.1% and 95%CI (44.0, 54.1) which was less than that of atelectasis at 68.2% and 95%CI (63.3, 72.7). The prevalence of pulmonary hemorrhage was 2.7% and 95%CI (1.5, 4.9). The prevalence of lung abscess was 4.9% and 95%CI (3.1, 7.5). The prevalence of carcinoma was 1.3% and 95%CI (0.6, 3.1). The prevalence of other diseases was 31.3% and 95%CI (26.8, 36.2). A case-by-case inspection review found that there was a high diversity of other diseases, most being consistent with a co-diagnosis of pneumonia and/or atelectasis (Table 3).

Statistical analysis showed that only leukemia/lymphoma significantly increased the risk of developing pneumonia ($p < 0.05$) (Tables 1 and 2). Most of these had cases received induction chemotherapy at the time of diagnosis.

Cases could have more than one lesion and location. Considering the location of air bronchograms in consolidation, we found that most cases had a lesion in one location, median (P25, P75) of 1 (0, 2). In the pneumonia group, most patients also had a lesion/location, median (P25, P75) of 1 (1, 2) while those in the non-pneumonia group had a median (P25, P75) of 0 (0, 0) consolidation lesions which was statistically significant. The location of the air bronchograms in atelectasis showed that most cases had a lesion in one location, median (P25, P75) of 1 (0, 2). Most cases in the pneumonia group had a lesion/location at median (P25, P75) of 1 (0, 2) while in those in the non-pneumonia group had had two lesions/location, median (P25, P75) of 2 (1, 2) which was also statistically significant.

Knowing that consolidation was more likely related to pneumonia than to atelectasis, if CT findings showed consolidation associated with clinical dyspnea, the patient would be diagnosed with pneumonia and would receive proper antibiotic treatment. According to the CT findings, the air bronchogram sign in consolidation was significantly associated with pneumonia, while that in atelectasis was not (Table 2). The air bronchogram sign in consolidation was related to pneumonia in all lobes of the lungs. The air bronchogram sign in atelectasis was associated with non-pneumonia in both upper and both lower lobes. We also analyzed the association between the overall air bronchogram sign in consolidation and in atelectasis without reference to the lobes of the lungs. The air bronchogram sign in consolidation was found to be significantly associated with pneumonia but not with atelectasis (Table 1). Further multivariate analysis showed that only air bronchogram sign in consolidation at RLL was related to pneumonia (Table 2).

Table 1. Comparison of patients with air bronchogram sign in pneumonia and non-pneumonia groups

Baseline characteristics	All (n=371)	Pneumonia (n=182)	Non-Pneumonia (n=189)	*p*-value
Gender: male	182	96	108	0.395
Age: median (P25, P75)	3 (1,10)	5.5 (1,12)	2.0 (0.6,9.0)	< 0.001
Underlying disease* n (%)				
Congenital lung disease	28 (75.5)	16 (8.8)	12 (6.3)	0.373
Congenital heart disease	46 (12.4)	26 (14.3)	20 (10.6)	0.279
Primary lung cancer	1 (0.3)	0 (0.0)	1 (0.5)	1
Leukemia/Lymphoma	42 (11.3)	30 (16.5)	12 (6.3)	0.002
Lung metastasis	8 (21.6)	2 (1.1)	6 (3.2)	0.284
HIV	4 (10.8)	4 (2.2)	0 (0.0)	0.057
Pulmonary TB	10 (2.7)	7 (3.8)	3 (1.6)	0.213
Other underlying diseases	215 (58.0)	98 (53.8)	117 (61.9)	0.116
The first study in the selected period	340 (91.6)	166 (91.2)	174 (92.1)	0.766
CT with contrast	353 (95.1)	170 (93.4)	183 (96.8)	0.1215
Median of consolidated lesion/cases	1 (0,2)	1 (1,2)	0 (0,0)	< 0.001
Consolidation*	187 (50.4)	140 (76.9)	47 (24.9)	< 0.001
LUL	52 (14)	39 (21.4)	13 (6.9)	< 0.001
LLL	102 (27.5)	74 (40.7)	28 (14.8)	< 0.001
RUL	73 (19.7)	57 (31.3)	16 (8.5)	< 0.001
RML	40 (10.8)	34 (18.7)	6 (3.2)	< 0.001
RLL	104 (28.0)	84 (46.2)	20 (10.6)	< 0.001
Median of atelectatic lesion/cases	1 (0,2)	1 (0,2)	2 (1,2)	< 0.001
Atelectasis*	266 (71.7)	97 (53.3)	169 (89.4)	< 0.001
LUL	87 (23.5)	33 (18.1)	54 (28.6)	0.018
LLL	167 (45.0)	58 (31.9)	109 (57.7)	< 0.001
RUL	105 (28.3)	34 (18.7)	71 (37.6)	< 0.001
RML	32 (8.6)	17 (9.3)	15 (7.9)	0.63
RLL	159 (42.9)	59 (32.4)	100 (52.9)	< 0.001
Other CT findings*				
Interstitial infiltration	18 (4.9)	11 (6.0)	7 (3.7)	0.294
GGO	109 (29.4)	76 (41.8)	33 (17.5)	< 0.001
Pleural effusion	113 (30.5)	71 (39.0)	42 (22.2)	< 0.001
Bronchiectasis	38 (10.2)	31(17.0)	7 (3.7)	< 0.001
Lymphadenopathy	91 (24.5)	56 (30.8)	35 (18.5)	0.006
Cardiomegaly	31 (8.4)	17 (9.3)	14 (7.4)	0.501
Lung abscess	14 (3.8)	13 (7.1)	1 (0.5)	0.001
Nodule	48 (12.9)	34 (18.7)	14 (7.4)	0.001
Others	167 (45.0)	67 (36.8)	100 (52.9)	0.002

*One case could have more than one lesion location, CT finding and underlying disease.

Additionally, we grouped the subtypes of atelectasis into four groups: compressive, adhesive, obstructive and cicatrizing types. Of the total of 266 cases of atelectasis with air bronchogram, 246 cases (92.8%) were of the compressive type, while adhesive, obstructive and cicatrizing types were found in 7 (1.9%), 4 (1.1%), and 8 (2.2%) cases, respectively.

Among the other signs on chest CT studies, ground glass opacity, pleural effusion and bronchiectasis were significantly associated with pneumonia after odd ratio adjustment using multivariable analysis (Table 2).

In our series, patients who were diagnosed with pneumonia had a significantly higher chance of having air bronchogram in consolidation. In practice, pneumonia can have more than one finding. Hence, we combined the other significant findings and air bronchogram in consolidation to increase the sensitivity to detect pneumonia using prevalence as the parameter. The other significant CT findings consisted of GGO, pleural effusion and bronchiectasis. The results showed the prevalence of pneu-

Table 2. Comparison of patients with air bronchogram sign in pneumonia and non-pneumonia groups using multivariate analysis

Baseline characteristics	Univariate analysis		Multivariate analysis	
	Crude OR (95% CI)	*p*-value	Adjusted OR (95% CI)	*p*-value
Age	1.07 (1.03, 1.12)	0.001	1.00 (0.95, 1.07)	0.894
Leukemia/Lymphoma	2.91 (1.44 5.88)	0.003	2.99 (1.27,7.06)	0.012
Consolidation at LUL	3.69 (1.90, 7.18)	< 0.001	1.01 (0.42, 2.45)	0.982
Consolidation at LLL	3.94 (2.39, 6.49)	< 0.001	1.40 (0.70, 2.79)	0.338
Consolidation at RUL	4.93 (2.70, 8.99)	< 0.001	1.88 (0.84, 4.17)	0.123
Consolidation at RML	7.01 (2.86, 17.14)	< 0.001	1.88 (0.60, 5.86)	0.282
Consolidation at RLL	7.24 (4.19, 12.52)	< 0.001	5.43 (2.60, 11.35)	< 0.001
Atelectasis at LUL	0.55 (0.34, 0.91)	0.018	0.82 (0.41, 1.63)	0.5678
Atelectasis at LLL	0.34 (0.22, 0.53)	< 0.001	0.66 (0.37, 1.20)	0.174
Atelectasis at RUL	0.38 (0.24, 0.61)	< 0.001	0.48 (0.25, 0.93)	0.029
Atelectasis at RLL	0.43 (0.28, 0.65)	< 0.001	0.84 (0.47, 1.52)	0.562
Other CT findings				
GGO	3.39 (2.10, 5.46)	< 0.001	3.31 (1.82, 6.04)	< 0.001
Pleural effusion	2.24 (1.42, 3.53)	< 0.001	2.68 (1.45, 4.94)	0.002
Bronchiectasis	5.34 (2.29, 12.46)	< 0.001	5.39 (2.04, 14.22)	0.001
Lymphadenopathy	1.96 (1.21, 3.17)	0.007	0.94 (0.49, 1.80)	0.842
Lung abscess	14.46 (1.87, 111.72)	0.01	9.33 (0.98, 88.72)	0.052
Nodule	2.87 (1.48, 5.55)	0.002	2.19 (0.94, 5.10)	0.069
Others	0.52 (0.34, 0.79)	0.002	0.65 (0.15, 2.80)	0.563

Table 3. Prevalence of final diagnosis

Final diagnosis from the chart summaries by pediatrician*	Number (n=371)	Prevalence (%)	95%CI
Pneumonia	182	49.1	(44.0, 54.1)
Atelectasis	253	68.2	(63.3, 72.7)
Pulmonary hemorrhage	10	2.7	(1.5, 4.9)
Lung abscess	18	4.9	(3.1, 7.5)
Cancer	5	1.3	(0.6, 3.1)
Others	116	31.3	(26.8, 36.2)

monia was 69.2, 67.1 and 74.6%, respectively, which showed increase in prevalence as compared to the prevalence of pneumonia with air bronchogram was 49.1%. We interpreted this to mean that the incidence of patients under 15 years of age who had air bronchogram in consolidation or GGO on chest CT scans associated with pneumonia was 69.2%. The incidence in patients who had air bronchogram in consolidation or pleural effusion on chest CT scans associated with pneumonia was 67.1%. The incidence of patients who had air bronchogram in consolidation or bronchiectasis on chest CT scans associated with pneumonia was 74.6%.

DISCUSSION

An air bronchogram is defined as air-filled bronchi which appear as dark attenuation on CT images. It is visible due to the opacification of surrounding alveoli which appear gray or white. It is almost always caused by a pathologic alveolar process occurring in a secondary pulmonary lobule, in which lesions other than air fills the alveoli, e.g., water, blood, pus or cells (8).

There were no significant differences in gender, age, first studies and the contrast enhanced CT findings among patients with and without pneumonia (Table 2). However, analyzing only age independently found the median age of patients with air bronchogram signs diagnosed with pneumonia was 5.5 years while for those without pneumonia it was 2 years. Older patients might have had more lesions than the younger ones (Table 1).

Air bronchogram can be found in consolidation and/or atelectasis. Most consolidation lesions are found to represent pneumonia after correlation with evaluation of the clinical context. The morphology of consolidation and of atelectasis have been analyzed over the past decade. Consolidation shows high attenuation areas and poor enhancement of preserved lung

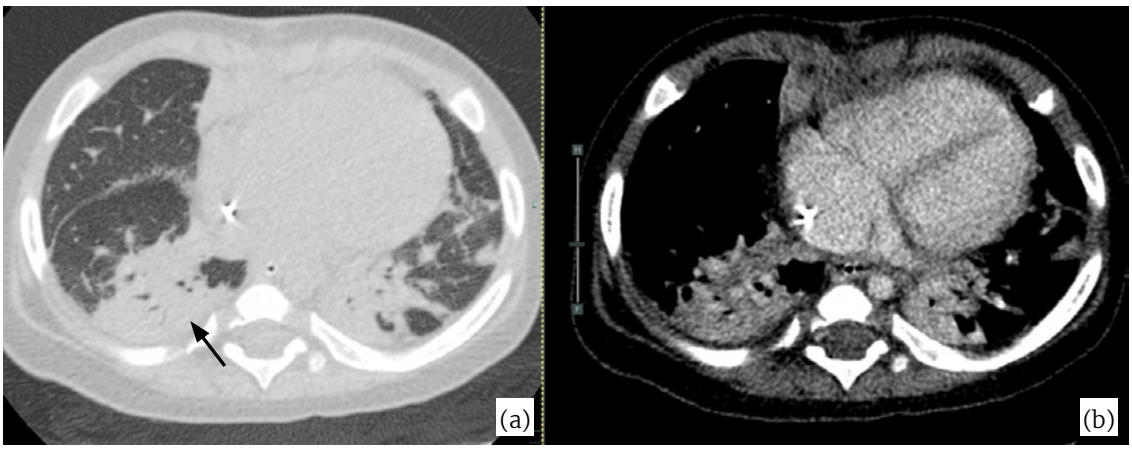

Figure 2. An 11-month-old girl with Down syndrome, ASD, VSD, PDA with subtotal correction presented with dyspnea. Her axial chest CT scan showed consolidation which was represented as a poor enhancing area (b) with preserved lung volume at both lower lobes. The air bronchogram (black arrow) (a) was also found in the consolidation at RLL. The final diagnosis was pneumonia.

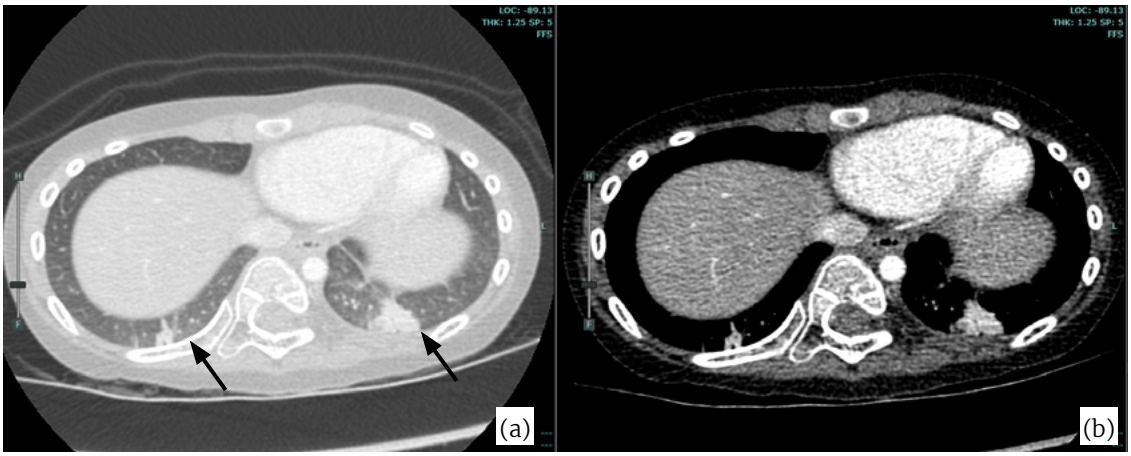

Figure 3. A 7-year-old boy with Lennox-Gastaut syndrome (LGS) presented with dyspnea. His axial chest CT scan showed wedged shaped homogeneous enhancement (b), representing atelectasis with air bronchogram signs (black arrows) (a) at both lower lobes.

volume (Figure 2) (8). Conversely, atelectasis has lesions with lung volume loss and homogeneous enhancement on chest CT studies (Figure 3). However, in our study there was no difference between CT scans with contrast and without contrast in the evaluation of whether air bronchogram was present in consolidation or in atelectasis. This could be due to the fact that in non-contrast studies we used associated findings such as lung volume loss to differentiate between consolidation and atelectasis.

In our study, we assessed the role of air bronchogram sign in the diagnosis of pneumonia and found a higher prevalence of air bronchogram with atelectasis than with pneumonia. Further serial case-by-case data analysis found patients who had chest CT scans mostly had dependent atelectasis at both lower lobes due to severe underlying diseases and long stays in bed during hospitalization. A limitation of CT chest scans in our study was that they were primarily performed only in the severe patients with dyspnea or unimproved pneumonia after appropriate antibiotic treatment. The long stays in bed during hospitalization explained the result that dependent atelectasis was found at both lower lobes. Our findings could be used to help determine the prevalence of air bronchogram sign in severe cases of pneumonia, but not in mild cases. In addition, pulmonary hemorrhage also presents with air bronchogram sign in traumatic lung injury cases with the same pathophysiology as pneumonia, called consolidation process. Lung abscess and lung cancer act as mass lesions that compress lung parenchyma, causing compressive atelectasis

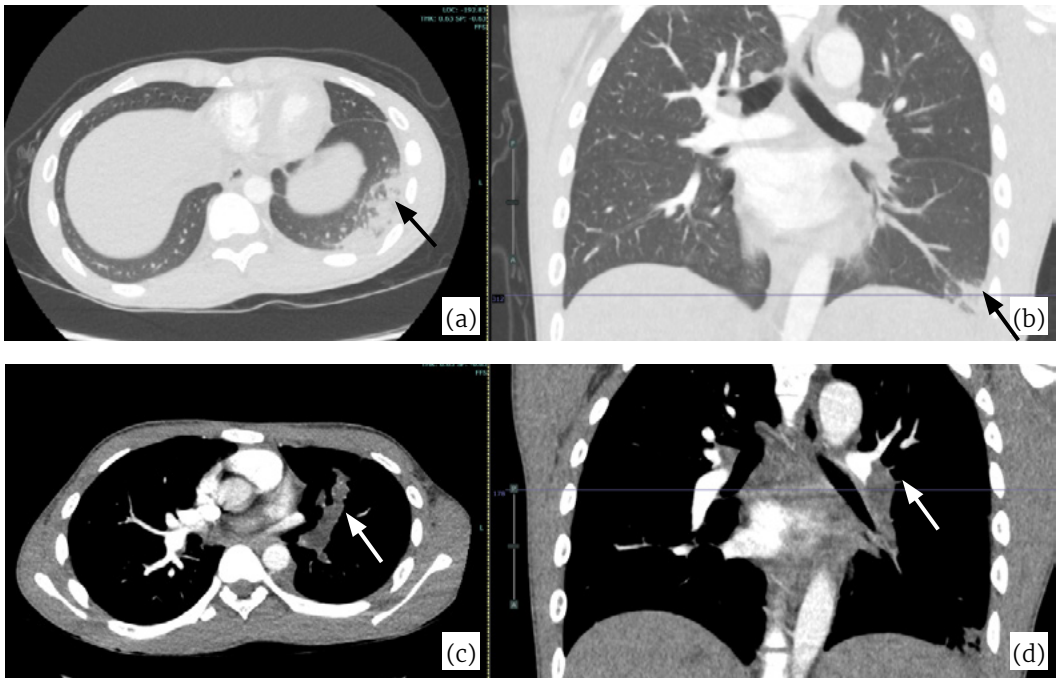

Figure 4. A 13-year-old boy, who presented with chondroblastic osteosarcoma at the left iliac bone with intravascular lung metastasis, developed progressive legs edema and dyspnea. The axial and coronal chest CT scan showed an air bronchogram in consolidation at the posterobasal segments of LLL (black arrow) (a, b), related to a resolving pulmonary infarction following a pulmonary embolism at the lingular segment and lateral basal segment of LLL. A massive tumor thrombus was seen in the left main pulmonary artery in axial and coronal views (white arrow) (c, d).

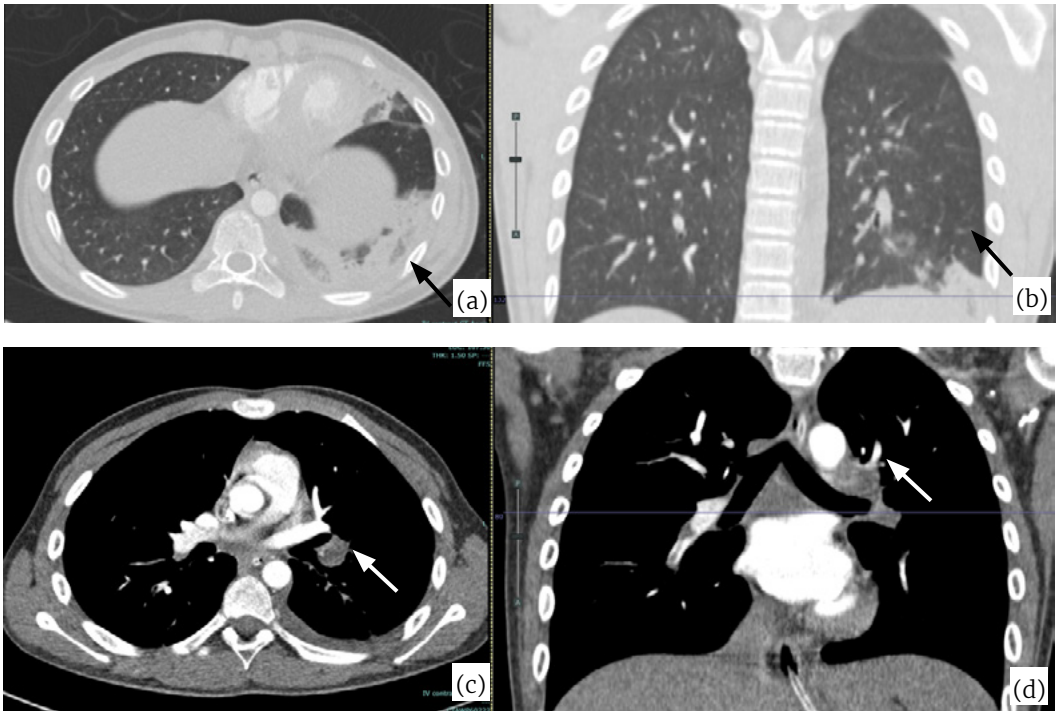

Figure 5. A 14-year-old boy with deep venous thrombosis of the left internal iliac artery developed progressive legs edema, dyspnea and hemoptysis. The axial and coronal chest CT scan showed air bronchogram in consolidation at the posterior basal segments of LLL (black arrows) (a, b), and a suspected infarction. The massive tumor thrombus was seen in the left main pulmonary artery in axial and coronal views (white arrow) (c, d).

which also appear as air bronchograms.

Other diagnoses with air bronchogram were found in 31.3% of cases (Table 1). Analysis of the crude data found a diversity of diagnoses. We chose two interesting cases (Figures 4 and 5) which had air bronchogram in consolidation

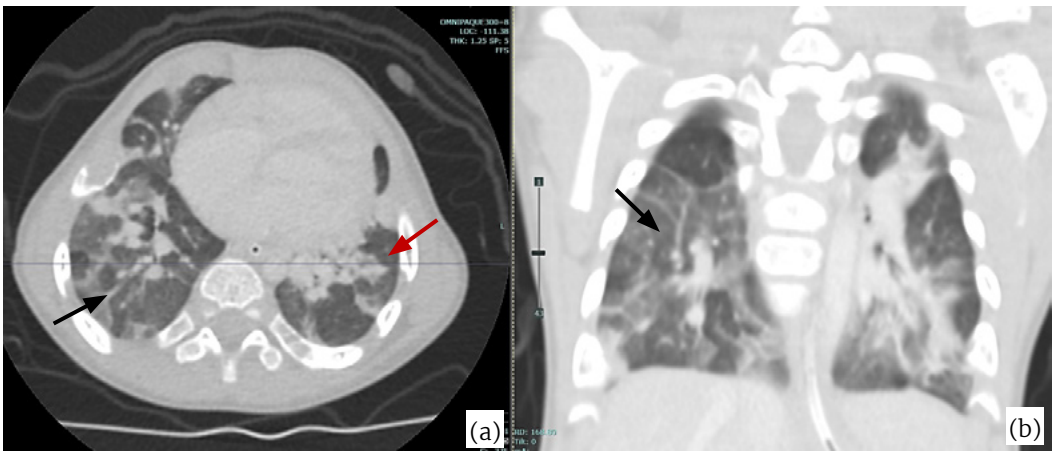

Figure 6. A 10-month-old male infant with oral-facial-digital syndrome and skeletal dysplasia, presented with recurrent pneumonia. His chest CT findings showed air bronchogram in consolidation (red arrow) at LLL with diffuse GGO (black arrows) at both lungs in axial and coronal views (a, b). The final diagnosis was pseudomonas aeruginosa and influenza pneumonia.

but were not diagnosed as pneumonia. The first patient was a 13-year-old boy who presented with chondroblastic osteosarcoma at the left iliac bone with intravascular lung metastasis who developed progressive leg edema and dyspnea. His CTPA showed progressive tumor thrombi at the left main pulmonary artery and lateral basal segmental branch of LLL and a resolving pulmonary infarction following a pulmonary embolism at the lateral basal segment of LLL. This lesion appeared as an air bronchogram in consolidation (Figure 4). The other case was a 14-year-old boy with deep venous thrombosis of the left internal iliac artery. He developed progressive leg edema, dyspnea and hemoptysis. His CTPA showed a filling defect at the left main pulmonary artery and all segmental branches of the upper, middle and lower lobes of the left pulmonary artery as well as the medial, anterior, lateral and posterior basal segmental branches of the right lower lobar artery, suggestive of acute pulmonary embolism and air bronchogram in consolidation at the posterior basal segment of LLL, and suspected infarction (Figure 5). This indicates that a lung infarction can manifest the appearance of air bronchogram.

Garcia et al (10) reported that pneumonia is common during induction chemotherapy for acute leukemia and is associated with increased morbidity, mortality, and health care resource utilization (9). Our study supported this result, i.e., the risk of pneumonia was significantly increased in the leukemia/lymphoma group with induction chemotherapy. Congenital heart and lung diseases did not increase the risk of developing severe pediatric pneumonia in our series. However, some underlying diseases, including primary lung cancer, lung metastasis, HIV and pulmonary tuberculosis, also showed no statistically significant correlation which could be due to the study's small sample size (Table 1).

Air bronchogram in consolidation was associated with an increased risk of pneumonia while there was no such association with atelectasis (Table 1). This indicates that air bronchogram in consolidation favors pneumonia more than in atelectasis. As we considered the location of the lesions, we found that air bronchogram in consolidation in the RLL significantly increased the risk of pneumonia (Table 2).

In theory, atelectasis with air bronchogram sign was primarily found in the compressive type (4). Our study also supported this association with a high prevalence of 92.8%. However, we are still concerned that adhesive, obstructive and cicatrizing atelectasis can also be associated with air bronchogram.

Other CT factors significantly associated with an enhanced risk of severe pneumonia in pediatric patients are GGO, pleural effusion and bronchiectasis (Table 2). However, some CT findings could not be well evaluated due to the small sample size, e.g., interstitial infiltration, cardiomegaly, lung abscess and nodules. Significant findings were identified in three

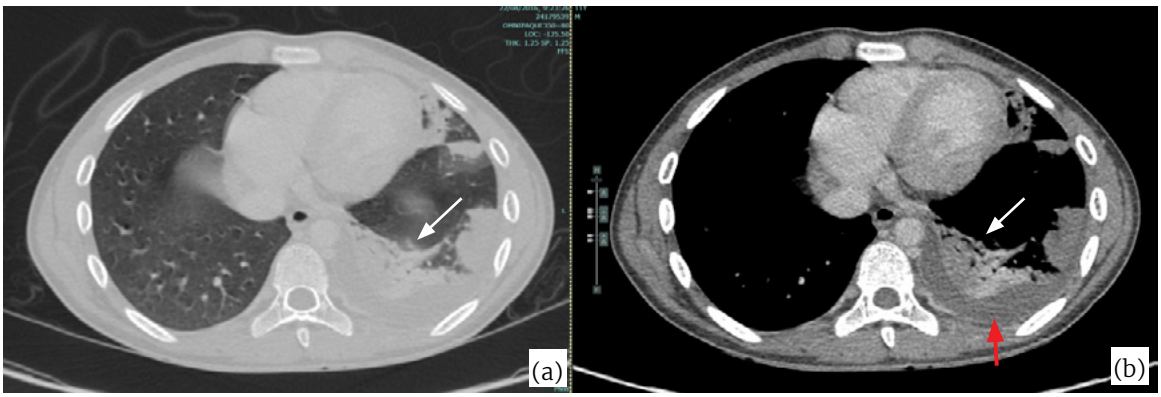

Figure 7. An 11-year-old boy with antiphospholipid syndrome, deep venous thrombosis and pulmonary embolism, presented with dyspnea. His axial chest CT study showed LLL atelectasis with patchy areas of faint enhancement (dashed white arrow) (b) which represented an air bronchogram in consolidation (solid white arrow) (a). The finding was suspected concomitant pneumonia. Left pleural effusion (red arrow) (b) was also demonstrated at LLL. The final diagnosis was pneumonia.

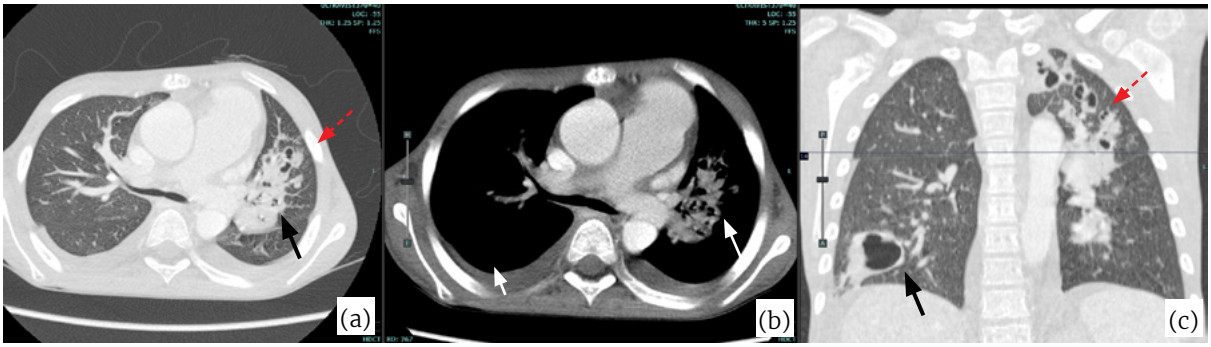

Figure 8. A 12-year-old boy with post-infectious glomerulonephritis causing RPGN presented with persistent LUL and RLL infiltration. The chest CT study revealed air bronchogram (solid black arrow) (a) in consolidation (solid white arrow) (b) which presented as a less enhanced area at LUL. The adjacent bronchiectasis with bronchial and bronchiolar wall thickening at LUL was also related to a superimposed infection in axial and coronal views (dashed red arrows) (a, c). A cavitary lesion with wall thickening at RLL (black arrow) (c) was also noted as infection. The final diagnosis was Nocardiosis and Aspergillosis pneumonia with bronchiectasis.

different cases as shown below (Figures 6, 7, 8). Following on the result that in all patients air bronchogram in consolidation favored a diagnosis of pneumonia, when we combined air bronchogram in consolidation with other significant CT findings, including GGO, pleural effusion and bronchiectasis in union pattern, the prevalence of pneumonia increased to 69.2, 67.1 and 74.6%, respectively. In comparison, the prevalence of pneumonia with air bronchogram alone was 49.1%. These results could be applied to clinical practice. Pediatricians should pay attention to these statistically significant signs to help confirm a diagnosis of pneumonia in severe cases.

There are some limitations in our study. First, CT studies are not regularly performed on out-patients or on patients with mild cases of pneumonia, so the prevalence of pneumonia in our study represents only severe cases. Second, some of the study groups were too small to evaluate statistical significance. Further studies are warranted.

In conclusion, chest CT findings can play a crucial role in the evaluation of air bronchogram signs in consolidation and atelectasis. The presence of an air bronchogram alone is not definitive for pneumonia. A higher prevalence of air bronchograms was found in atelectasis cases (68.2% in atelectasis vs. 49.1% in pneumonia). Although air bronchograms in consolidation favor a diagnosis of pneumonia, especially in RLL, air bronchogram sign should raise concern for lesions in both pneumonia and non-pneumonia. Consequently, air bronchogram in consolidation combined with GGO,

pleural effusion and/or bronchiectasis increases the likelihood of pneumonia. The results of the study should be focused on severe cases of pneumonia or immunocompromised patients who are suspected of having complications rather than on mild cases of pneumonia.

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