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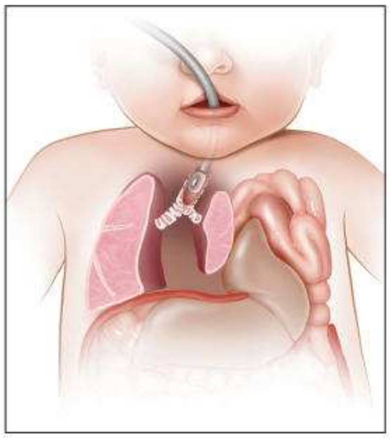

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B-Lines on Pediatric Lung Sonography

Comparison With Computed Tomography

Laura Martelius, MD, Henna Heldt, MD, Kirsi Lauerma, MD, PhD

Objectives—Sonographic artifacts known as B-lines can been used to estimate alterations of lung parenchyma. Multiple B-lines on sonography are seen in congestive heart disease, interstitial lung disease, respiratory infections, and neonates. The aim of this study was to compare the amount of B-lines on sonography to the extent of parenchymal changes on computed tomography (CT) in children.

Methods—Lung sonography was performed on 60 patients aged 18 years and younger referred for chest CT at our institution. B-lines were counted from 5 anterolateral intercostal spaces bilaterally. The CT findings were documented and graded as absent, minimal, partial, or complete.

Results—The number of B-lines on sonography increased consistently with the growing extent of parenchymal changes on CT. The differences in the B-line counts between the patients grouped according to the extent of parenchymal changes on CT were statistically significant except between patients with minimal and no changes ($P < .01$ Kruskal-Wallis and Tukey tests).

Conclusions—The number of B-lines on sonography correlates with the extent of parenchymal changes on CT. Various parenchymal changes were seen in patients with B-lines on sonography. B-lines were more frequently seen in patients with no changes on CT when imaged during general anesthesia.

Key Words—computed tomography; B-lines; lung sonography; pediatrics; pediatric ultrasound

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Abbreviations
CT, computed tomography

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Sonographic artifacts from the surface of the lungs can be used to estimate alterations of lung parenchyma.[1] A sonogram of normal air-filled lungs consists of horizontal artifacts from the pleural line, known as A-lines.[2] Vertical artifacts, known as B-lines, are nonspecific sonographic findings (Figure 1). Multiple B-lines are seen in lung edema, interstitial lung disease, infections, lung contusion, and atelectasis.[3–8] Sporadic B-lines can also be seen in healthy individuals.[4,9,10]

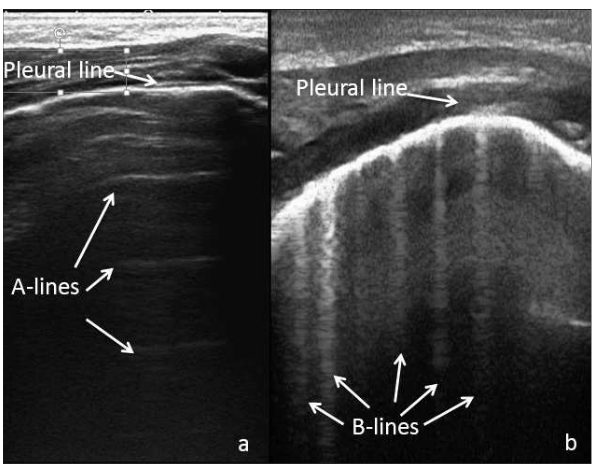
B-lines can be used to estimate lung water.[11] The number of B-lines correlates with lung edema scores from chest radiographs and with extravascular lung water measured invasively using the transpulmonary thermodilution method.[12,13] The number of B-lines decreases during hemodialysis and in neonates during postnatal pulmonary adaptation.[14–16]

B-lines are suggested to originate as ring-down artifacts from irregularities at the lung-pleura interface.[17] Computed tomography (CT) has revealed ground glass opacities and interlobular septal thickening in patients with multiple B-lines on sonography.[1,3] All previous studies comparing B-lines on lung sonography and chest CT have examined only adults with lung disease or respiratory symptoms. Data on lung sonographic findings in healthy individuals are sparse. Our aim was to compare the number of B-lines on lung sonography and the extent of parenchymal changes on chest CT in pediatric patients referred for chest CT at our institution.

Materials and Methods

We conducted a prospective observational study approved by the local Ethics Committee. Sixty consecutive pediatric patients were enrolled between April 2013 and January 2014. Inclusion criteria were a referral for chest CT and age of 0 to 18 years. Each patient who received a CT study was also studied with lung sonography. There were no exclusion criteria except lack of consent. Patients were enrolled at arrival for the CT study. Written consent was obtained from all parents and children aged 7 to 18 years. Verbal consent was obtained from children aged 0 to 6 years. The indications for the CT studies included screening for metastases, interstitial lung disease, lung transplant follow-up, congenital heart disease, and congenital malformations (Table 1).

Figure 1. Lung sonograms taken along intercostal spaces. **a**, Normal lung parenchyma. Beyond the pleural line, the image consists of horizontal reverberation artifacts from the pleural line, known as A-lines. **b**, Vertical artifacts, known as B-lines, are nonspecific signs of lung disorders that originate from irregularities at the lung-pleura interface.



A linear transducer (frequency range, 4–13 MHz) was used. Five intercostal spaces were scanned bilaterally starting along an intercostal space immediately below the clavicle. Each intercostal space was scanned from the sternum to the midaxillary line by sliding the transducer. Sonograms were stored, and B-lines were counted by 2 observers. Observers were blinded to the CT data, patient identity, and the B-line count given by the other observer. The parenchymal changes reaching the pleural surface in the corresponding regions on CT were documented, and the extent was graded as absent, minimal (1–2 intercostal spaces), partial (larger areas of parenchymal alterations and areas of normal parenchyma), and complete (throughout the parenchyma).

Comparisons were performed with the Mann-Whitney *U* test and the Kruskal-Wallis test followed by the Tukey test (SPSS version 22; IBM Corporation, Armonk, NY). Spearman correlation analysis was performed to study interobserver agreement. $P < .05$ was considered significant.

Results

Demographic data and study details for the patients are listed in Table 2. In 30 patients, parenchymal changes were seen in the anterolateral regions on CT (Table 1). The number of B-lines on sonography increased consistently with the growing extent of parenchymal changes on CT. Differences in B-line counts between the patients grouped according to the extent of parenchymal changes on CT were statistically significant except between patients with minimal changes or no changes (Figure 2). Parenchymal changes associated with a significantly increased B-line count included ground glass opacities, interlobular septal thickening, parenchymal bands, and atelectasis.

In 30 patients, no parenchymal changes were seen on CT. In these patients general anesthesia was associated with a significantly higher B-line count ($P < .05$, Mann-Whitney *U* test). The median (range) B-line count in the patients (n = 15) studied under general anesthesia was 4 (0–8), and in patients not under general anesthesia, the count was 0 (0–16).

There were no significant differences in the B-line counts depending on the sex, age, CT scanning technique used, or use of an intravenous contrast agent. The correlation between the observers in quantifying the B-lines was clinically significant ($R = 0.93$). The median time difference between sonography and CT was 22 minutes. In 2 patients, sonography took place on the day after CT.

Table 1. Indications for CT, Findings on CT, and B-Line Counts on Sonography Grouped According to the Extent of Parenchymal Changes Reaching the Pleural Surface on CT

Extent of Parenchymal Changes on CT	n	Indication for CT	Findings on CT	Median B-Line Count, (Range)
No changes	30			1 (0–16)
	22	Malignancy		
	6	Suspicion of interstitial lung disease		
	2	Congenital pulmonary adenomatoid malformation		
Minimal (1–2 intercostal spaces)	18			1 (0–21)
	10	Malignancy	Atelectasis, nodules, parenchymal bands, traction bronchiectasis	
	4	Congenital heart disease	Atelectasis	
	2	Suspicion of interstitial lung disease	Ground glass opacity	
	1	Lung transplant follow-up	Parenchymal bands	
	1	Scoliosis	Atelectasis	
Partial (>2 intercostal spaces, also normal parenchyma)	5			14 (7–19)
	3	Interstitial lung disease	Ground glass opacity, atelectasis, parenchymal bands	
	2	Lung transplant follow-up	Ground glass opacity, interlobular septal thickening	
Complete (throughout the parenchyma)	7			
	3	Interstitial lung disease	Ground glass opacity, interlobular septal thickening	35 (13–51)
	2	Congenital heart disease	Ground glass opacity	
	1	Lung transplant follow-up	Ground glass opacity, interlobular septal thickening	
	1	*Pneumocystis* pneumonia	Ground glass opacity	

Discussion

There was a consistent connection between the extent of parenchymal changes on CT and the number of B-lines on lung sonography. The B-line counts were highest in the patients with the most widespread changes on CT and lowest in the patients with no changes. Various parenchymal changes were associated with B-lines. In patients with no changes on CT, B-lines were more frequently seen when imaged during general anesthesia.

The parenchymal changes associated with an increased B-line count in this study included ground glass opacities, interlobular septal thickening, parenchymal bands, and atelectasis. Previous studies in adults described various CT findings in association with multiple B-lines on lung sonography. Cardiogenic lung edema, interlobular septal thickening, ground glass opacities, subpleural lines, honeycombing, and subpleural parenchymal changes have been seen in association with multiple B-lines in patients with heart failure, interstitial lung disease, pulmonary fibrosis, sarcoidosis, chronic obstructive pulmonary disease, acute respiratory distress syndrome, and asthma.[1,3,4]

The number of B-lines on sonography increased consistently with the growing extent of parenchymal changes on CT. To our knowledge, no similar data are available. All previous studies comparing chest CT and lung sonography examined only adult patients with lung disease or respiratory symptoms. The extent of parenchymal changes on CT has been compared to lung sonography only in systemic sclerosis. The Warrick score is a high-resolution CT scoring system for pulmonary involvement of systemic sclerosis, which combined both the extent and severity of the disease.[18] A significant correlation between the number

Table 2. Demographic Data and Study Details

Characteristic	Value
Median age (range), y	6 (0–18)
Male, n	33
Helical scan, n	46
High-resolution CT, n	14
General anesthesia, n	29
Controlled ventilation, n	20
Intravenous contrast	29
Total	60

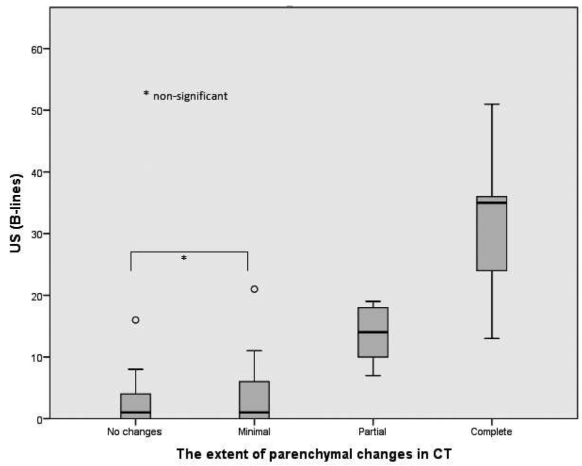


Figure 2. The parenchymal changes reaching the anterolateral pleural surface on CT were graded on a 4-step scale: 1, no changes; 2, minimal (1–2 intercostal spaces); 3, partial (changes over >2 intercostal spaces, also areas of normal parenchyma); and 4, complete (changes throughout the parenchyma). B-lines were most abundant in patients with the most widespread changes on CT. The differences between the groups were statistically significant except between patients with minimal changes and no changes on CT ($P < .01$, Kruskal-Wallis and Tukey tests). Outliers are marked with circles.

of B-lines on sonography and the Warrick score has been reported.[19,20]

General anesthesia was associated with a significantly higher B-line count in patients with no parenchymal changes on CT. Atelectasis is the likely cause of the B-lines in these patients. When general anesthesia was needed for CT, sonography was mostly performed in the recovery room after the CT study. Atelectasis due to hypoventilation occurs frequently in healthy lungs investigated for other reasons.[21] Anesthesia-induced atelectasis has been seen on lung sonography as subpleural consolidations, irregularities of the pleural line, air bronchograms, and B-lines when compared to magnetic resonance imaging.[8]

In this study, there were 15 patients with no changes on CT who were studied without general anesthesia: 10 of these showed no B-lines; 4 had 1 to 4 B-lines; and 1 patient had 16 B-lines. To our knowledge, no other data are available on the B-line count in normal lung parenchyma with a comparison to CT. A study showing that the origin of B-lines is not always visible on CT has not been reported previously. Few data on lung sonographic findings in healthy individuals are available. A study of lung sonography in bronchiolitis examined 52 children (aged 1–22 months) with suspected gastroesophageal reflex disease as a control group. Few isolated B-lines were reported in 5 controls.[22] In healthy adults scanned over all ventral and dorsal intercostal spaces, B-lines were seen in each participant in a report consisting of 35 individuals. Most participants showed only a few isolated B-lines, but 5 showed 7 to 10 B-lines.[4] Our results add to the evidence that a few isolated B-lines bear little importance.

There were 2 discordant patients (Figure 2). One patient (male, 17 years, liver sarcoidosis and suspected hepatopulmonary syndrome) grouped as having no changes on CT had a B-line count of 16. The CT report given by a radiologist who was aware of the possible hepatopulmonary syndrome suspected pulmonary vessels that extended further to the periphery of the lungs than normal. Another patient (female, 7 months, aortic arch anomaly and laryngomalasia) with minimal parenchymal changes (atelectasis) on CT had a B-line count of 21. The patient needed nasal continuous positive airway pressure treatment for laryngomalasia. Sonography was performed before CT with no general anesthesia. Computed tomography was performed during general anesthesia with controlled ventilation, which may have partially opened the hypoventilation atelectasis in this patient.

Lung sonography has proved useful in evaluation of patients with respiratory symptoms, but few published data are available on lung sonographic findings in healthy individuals.[23] Determining such findings is an important area of future research to further validate lung sonography for estimating lung disease. Also, a nonblinded comparison of CT and sonographic findings in various diseases is needed. In this study the person performing the sonographic examinations was unaware of the findings on CT. This process was essential for a nonbiased comparison of sonography and CT but did not allow specific correlation of sonographic and CT images.

Due to consecutive patient enrollment, the study population was heterogeneous, with CT findings ranging from normal to diverse diseases of lung parenchyma. No comparisons could be made between B-line counts in different diseases, which was a limitation of this study. A benefit of the study setting was the comparison of sonography and CT in patients with normal findings on CT. Healthy individuals cannot be scanned for this purpose because of the radiation dose associated with CT.

In conclusion, our data suggest that B-lines are highly nonspecific in children and cannot be used to differentiate between pathologic processes of lung parenchyma. Lung sonography has potential for estimating the extent of parenchymal changes in children and could serve in screening or follow-up.

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