

## Diagnostic value of lung ultrasound for pregnant women with community-acquired pneumonia

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### Abstract

**Objective:** Lung ultrasound (LUS) is a non-radiation, easy diagnostic tool for lung diseases. This study aims to explore the diagnostic value of LUS for pregnant women with community-acquired pneumonia (CAP).

**Methods:** Forty-five women with a pregnancy duration of over one month, admitted to the emergency department with fever, cough, and sputum between January 1 and December 31, 2014 were recruited. Chest X-ray, LUS, peripheral blood cell count, and high-sensitivity C-reactive protein examination were conducted within 24 hours after admission. The specificity, sensitivity, false positive rate, false negative rate, positive prediction ratio, negative prediction ratio, and accuracy were calculated. LUS and chest X-ray were compared by t-test.  $P < 0.05$  was considered as statistically significant.

**Results:** The white blood cell count and the content of high-sensitivity C-reactive protein in the pneumonia group were significantly higher than that in the control group ( $P < 0.01$ ). There were 21 (77.8%), 25 (92.6%), 25 (92.6%), and 5 (18.5%) patients in the pneumonia group with pulmonary consolidation, increased B-line, A-line disappearance, and pulmonary pulse by LUS, respectively. There were one (5.6%) and two (11.1%) patients with increased B-line and A-line disappearance, respectively in the control group. Difference was significant ( $P < 0.01$ ). CAP was diagnosed with sensitivity of 92.6%, specificity of 89.5%, false positive rate of 10.5%, false negative rate of 3.8%, positive prediction ratio of 82.6%, negative prediction ratio of 94.4%, accuracy of 93.3% and t- test value of 0.862, indicating good consistency between LUS and chest X-ray.

**Conclusion:** Pregnant women with CAP were diagnosed by LUS and chest X-ray with good consistency. LUS should be further investigated since its advantages of no-radiation and repeatability, making it more suitable.

**Keywords:** LUS, CAP, Diagnosis, Pregnancy. (JPMA 70: 57 [Special Issue]; 2020)

### Introduction

Community-acquired pneumonia (CAP) is the third most common non-obstetric cause of death of pregnant women in North America.<sup>1</sup> The incidence of CAP was similar in pregnant and non-pregnant women (around 6/1000),<sup>2</sup> which highlights the serious outcome of CAP in gravid women, because increased morbidity and mortality was demonstrated to be associated with CAP during pregnancy.<sup>3</sup> Moreover, premature delivery and low-birth weight infants were more often found in pregnant women with CAP. Weak constitution, malnutrition, excess fatigue and upper respiratory tract infection were reported to be common causes of pneumonia.<sup>4</sup> In this study, LUS was compared with the results of chest X-ray in pregnant women with suspected CAP to assess its diagnostic value.

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### Patients and Methods

This prospective diagnostic study included patients with suspected CAP admitted to our emergency department between January 1 and December 31, 2014. A total of 45 (53%) pregnant women, above 18 years age, fulfilling the inclusion criteria, and agreeing to undergo chest X-ray examination were studied. Inclusion criteria were 1) pregnancy duration > one month; 2) clinical symptoms as concurrent fever, cough and sputum; 3) lung consolidation and/or moist rales observed during physical examination. The exclusion criteria were 1) concurrent congenital heart disease and various types of cardiomyopathy; 2) heart failure; 3) pneumothorax; 4) pregnancy duration < one month; 5) refusal of chest X-ray examination; 6) voluntarily discharged within a short period of time, or expired.

According to the results of 10 pretests, CAP patients were diagnosed with LUS and chest X-ray respectively, and the  $\kappa$  examination value of the two methods was 0.841. According to the results of 0.708 in the literature 5, the estimation equation of the sample sizes of the two groups of measurement data was calculated as follows:

$$n_1 = n_2 = 2[(z_{\alpha} + z_{\beta})^2 \sigma^2 / \delta^2]$$

Among them,  $\alpha = 0.05$ ,  $\beta = 0.1$ ,  $z_{\alpha} = 1.6449$ ,  $z_{\beta} = 1.2816$ ,  $\sigma = 0.841$ ,  $\delta = 0.708$ . After calculation,  $n_1$  and  $n_2$  were 17. Since about 10% of the estimated cases need to be eliminated, 20 cases were sampled in each group, a total of about 40 cases.

The study was approved by the ethics committee of our hospital. Informed consent was signed by each participant. The recruited patients underwent chest X-ray, LUS, blood cell count, and high-sensitivity C-reactive protein test within 24 hours of admission. Chest X-ray was examined by qualified radiologists, and LUS was performed by a physician from the emergency department who was trained for bedside B ultrasound examination or by a qualified B ultrasound physician. The examination results from X-ray or LUS were not shared, to avoid any interference in the diagnosis. The diagnosis was based on imaging and blood cell counts. The patients diagnosed as CAP by chest X-ray were classified into the pneumonia group, and the others were classified into the control group.

The observed indicators of LUS were divided into normal characteristics and abnormal characteristics. The normal features included: 1) Lung pleural line smooth, clear and regular, with the sign of 'lung slip'; 2) A-lines clearly displayed, parallel distributed with equal distance; 3) None or only a few B-lines (usually < 3); 4) No pleural effusion; 5) Normal lung tissue presenting as low echo signal (black colour), no alveolar interstitial syndrome (Figure-1).

Abnormal features included: 1) Disappearance of A-line, serial lines with high echo signal inferior and parallel to pleural line; 2) Alveolar interstitial syndrome, three or more B-lines appearing in the lung field (Figure-2); 3) Pulmonary consolidation, pulmonary tissue presenting as hepatization under B ultrasound with air bronchogram (Figure-3).

Lung B ultrasound examination was conducted with SIEMENS ACUSON  $\times 150$  with a low-frequency probe of 5 MHz. The pregnant women were placed in supine, lateral or sitting positions. The lung was separated into front, lateral, and rear regions according to front, middle and posterior axillary lines. The probe was vertical to the rib and the lung was scanned at each intercostal space. A positive finding was defined based on the abnormal features described above. According to the severity of the disease, the patients were treated by standards set by the "Guidelines for the Management of Community-acquired Pneumonia in Adults in the United States" in

2017.<sup>5</sup> For medical treatment, on the basis of antibiotic treatment, it was necessary to ensure the mother's oxygen supply and nutritional support. For obstetrical management, the monitoring of the foetus was mandatory. For patients with threatened abortion in the first trimester, foetal preservation treatment was given. Patients in the second trimester were given intravenous infusion of magnesium sulfate till the full term and patients in the third trimester were asked to consider termination of pregnancy.

SPSS 19.0 software was used for statistical analysis. The measurement data was presented as mean $\pm$ SD and analyzed by t-test for inter-group comparison. The specificity, sensitivity, false positive rate, false negative rate, positive prediction rate, negative prediction rate, and accuracy of LUS for diagnosis of CAP were calculated. The diagnostic consistency between chest X-ray and LUS was analyzed by  $\kappa$  test.  $P < 0.05$  was considered as statistically significant.

## Results

A total of 85 pregnant women with suspected CAP were admitted to the Emergency department of the No. 1 People's Hospital of Hangzhou, China between January 1

**Table-1:** Comparison of lung ultrasound examination data between the two groups.

LUS features	Control group No. (%)	Pneumonia group No. (%)	P value
Pulmonary consolidation	0 (0)	21 (77.8)	<0.001
Increased B-line	1 (5.6)	25 (92.6)	<0.001
A-line disappearance	2 (11.1)	25 (92.6)	<0.011

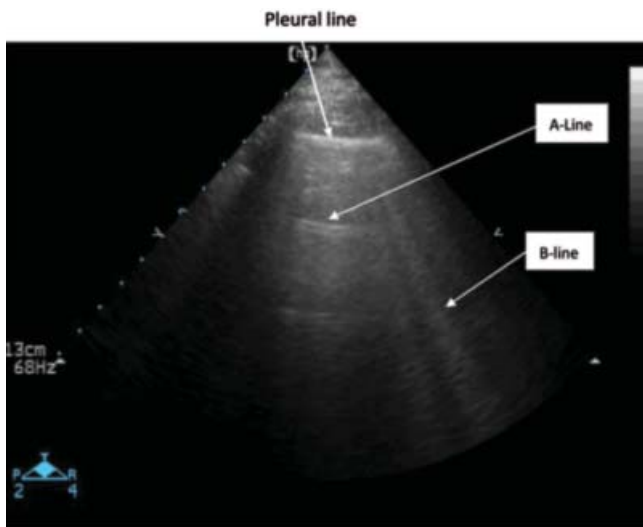
**Table-2:** Sensitivity and specificity of concurrent pulmonary consolidation, increased B-line and A-line disappearance for diagnosis of community-acquired pneumonia.

Group	Concurrence of three signs	No concurrence of three signs	Total
Pneumonia	21	0	21
Control	0	18	18
Total	21	18	39

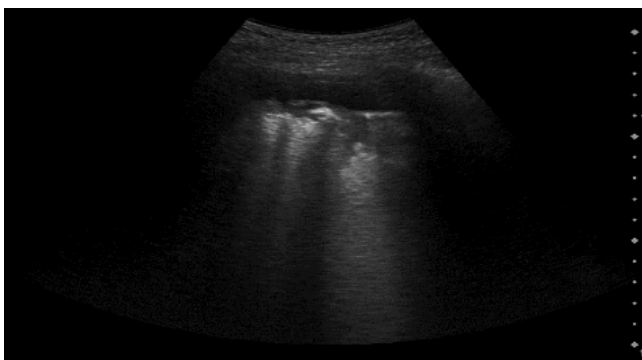
**Table-3:** Community-acquired pneumonia diagnosis by lung ultrasound.

		Diagnosis		Suspected positive or negative
		Pneumonia	Control	
LUS	Negative	2	17	0
	Positive	25	1	0
Total		27	18	45

LUS: Lung Ultrasound.

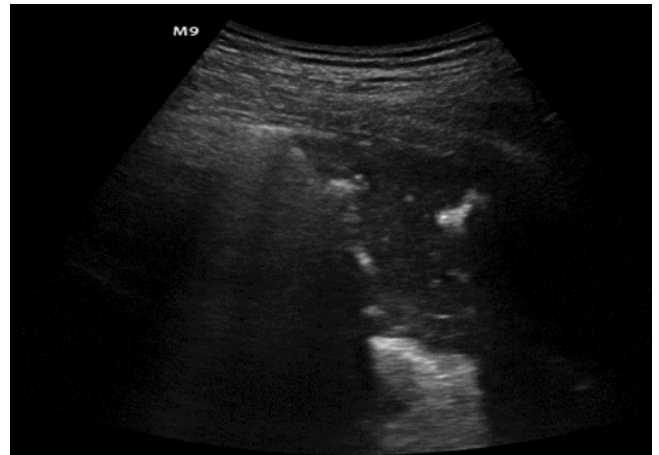


**Figure-1:** Lung ultrasonography image of a healthy control.



**Figure-2:** Alveolar interstitial syndrome revealed by lung ultrasound.

and December 31, 2014. A total of 45 patients were eligible and eventually included in the study with suspected pneumonia. The ages of the patients were between 20 and 37 years old, with an average age of  $28.6 \pm 8.9$  years. There were 9 patients who were pregnant from January to March, 21 patients who were pregnant from March to July, and 15 patients who were pregnant between 7 and 9.5 months. Finally, A total of 27 patients were diagnosed with CAP and assigned to the pneumonia group, while 18 others were assigned to the control group. The average age of the patients in the control group was  $28.5 \pm 2.3$  years old, and the average gestational age was  $20.4 \pm 9.3$  weeks. The mean age of the pneumonia group was  $28.1 \pm 2.9$  years and the mean gestational age was  $21.0 \pm 8.2$  weeks. There was no significant difference between the two groups in average age and gestational age ( $P > 0.05$ ). White blood cell count and hypersensitive C-reactive protein levels of patients in the pneumonia group and the control group were



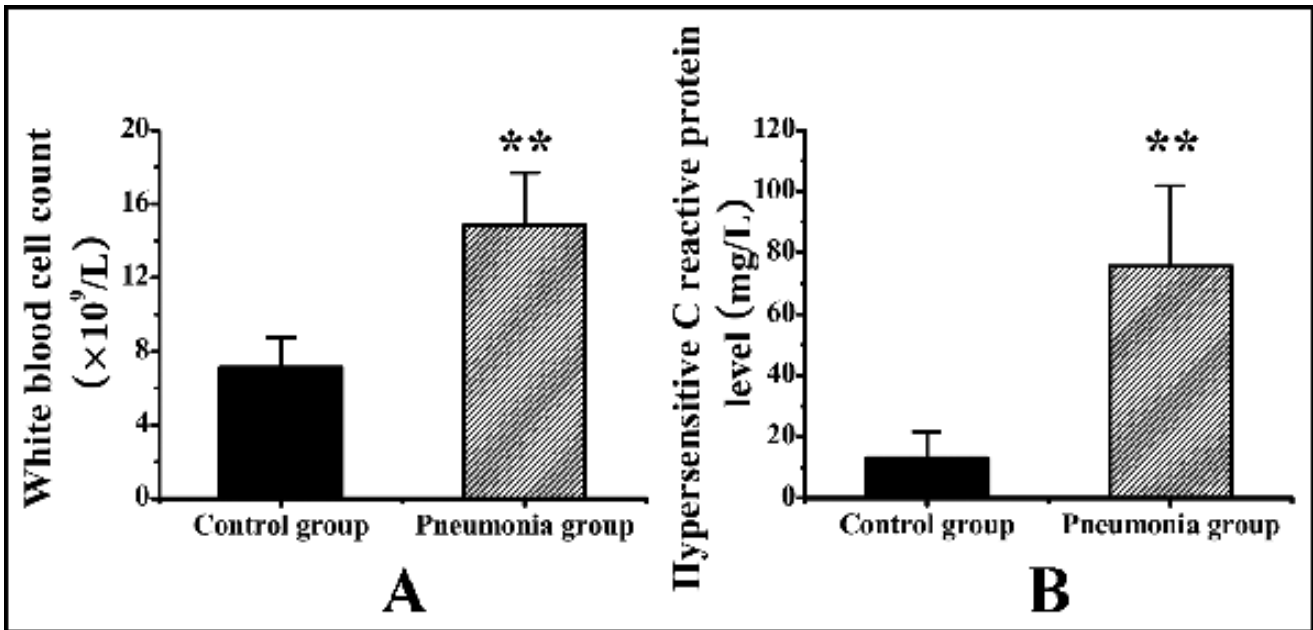
**Figure-3:** Hepatisation with air bronchograms seen by B ultrasound.

compared, and the results are shown in figure 4. It can be observed that the white cell counts were  $14.8 \pm 2.90 \times 10^9/L$  and  $7.1 \pm 1.63 \times 10^9/L$  in the pneumonia and control groups, respectively. The super C-reactive protein level was  $75.6 \pm 26.3$  mg/L and  $13.0 \pm 8.7$  mg/L in the pneumonia and control groups, respectively; moreover, the leucocyte technology and the level of hypersensitive C-reactive protein in the pneumonia group were significantly higher than those in the control group ( $P < 0.01$ ).

As shown in Table-1, there were one (5.6%) and two (11.1%) patients with increased B-line and A-line disappearance, respectively; and pulmonary consolidation and pulmonary pulse were not found in the control group. There were 21 (77.8%), 25 (92.6%), 25 (92.6%), and five (18.5%) patients in the pneumonia group with pulmonary consolidation, increased B-line, A-line disappearance, and pulmonary pulse by LUS, respectively. There was a significant difference in LUS findings between the two groups ( $P < 0.01$ ).

The LUS findings in the pneumonia group, showed Pulmonary consolidation with bronchial inflation sign in 21 out of 27 patients, which presented as hepatisation under B ultrasound with air bronchograms (Figure-2). The small range of infection was manifested as local hepatisation beneath the pleura without obvious air bronchograms (Figure-2); the large range of infection could affect deep lung tissue with obvious air bronchograms (Figure-3). A-line disappearance was noted in 25 (92.6%) patients (Figure-4A, 4b) Increased B-line (at least three lines) was seen in 25 (92.6%) patients (Figure-4A, 4b, 4c).

A total of 25 patients showed A-line disappearance and one patient had increased B-line in the pneumonia and control



Note: figure A shows the difference in white blood cell count between the two groups; figure B shows the difference in the level of hypersensitive C-reactive protein between the two groups. \*\* indicates a significant difference compared to the control group,  $P < 0.01$ .

Figure-4 Comparison of white blood cell counts and high-sensitivity C-reactive protein levels between the two groups.

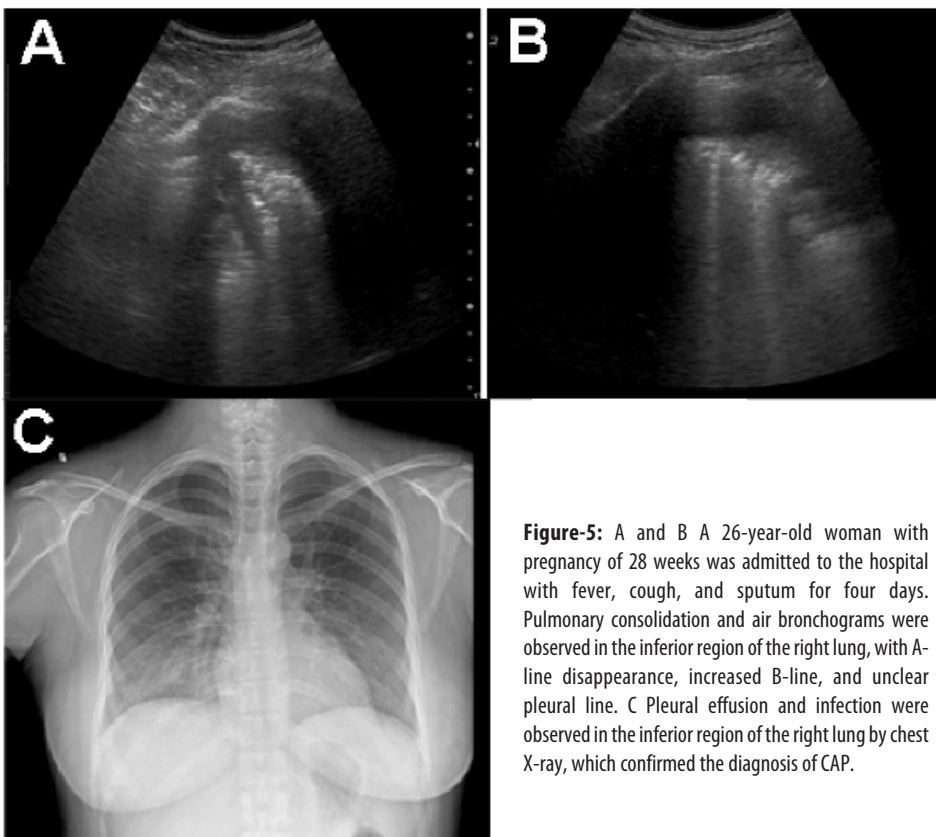


Figure-5: A and B A 26-year-old woman with pregnancy of 28 weeks was admitted to the hospital with fever, cough, and sputum for four days. Pulmonary consolidation and air bronchograms were observed in the inferior region of the right lung, with A-line disappearance, increased B-line, and unclear pleural line. C Pleural effusion and infection were observed in the inferior region of the right lung by chest X-ray, which confirmed the diagnosis of CAP.

groups. The sensitivity and specificity of LUS was 92.6% and 89.5%, respectively. A total of 21 and 0 patient showed pulmonary consolidation and A-line disappearance in the pneumonia and control groups, respectively; the sensitivity and specificity of LUS was 77.8% and 100%, respectively. As shown in table 2, a total of 21 and 0 patient showed pulmonary consolidation, A-line disappearance and increased B-line in the pneumonia and control groups, respectively; the sensitivity and specificity of LUS was 77.8% and 100%, respectively.

As shown in Table-3, the sensitivity and specificity of LUS for diagnosis of CAP was 92.6% and 89.5%, respectively, with the false positive rate, false negative rate, positive prediction, negative prediction, and

accuracy of 10.5%, 3.8%, 82.6%, 94.4%, and 93.3%, respectively. The  $\kappa$  test value was 0.862, indicating good consistency between LUS and chest X-ray.

A total of 17 patients were diagnosed as bronchitis and one as bronchiectasis in the control group. The hospital stay for the pneumonia and control groups was  $5.9 \pm 1.1$  days and  $3.3 \pm 0.9$  days, respectively. The fever remission was in  $3.0 \pm 1.2$  days and  $1.5 \pm 0.6$  days for the pneumonia and control groups, respectively. The cure rate in 14 days was 100% for both groups.

## Discussion

Pneumonia is one of the main causes of morbidity and mortality worldwide. Although *Streptococcus pneumoniae* is the most likely cause in most cases, the environment of acquired pneumonia seriously affects the diagnosis and treatment options. Because pathogens are usually unknown in the early stage, timely use of empirical antibiotics is the cornerstone of pneumonia treatment.

CAP is a relatively common disease worldwide with a high incidence and mortality. The incidence of pneumonia in pregnant women in the United States is about 1 in 1,000, and *streptococcus pneumoniae* can be detected in only 40% to 60% of patients with pneumonia, while this pathogen can be detected in 15% to 20% of CAP pregnant women.<sup>6</sup> And studies have shown that the ventilation method selected for the treatment of severe pneumonia respiratory failure can effectively manage CAP patients in the third trimester of pregnancy.<sup>7</sup> The symptoms of early-stage pneumonia could be masked by other manifestations of pregnancy. Around 20% of pregnant patients were misdiagnosed or had missed diagnosis for pneumonia.

In this study, only 27 of the 45 suspected CAP patients were diagnosed, studies have shown that the major symptoms of CAP in pregnant women included cough and sputum (59.3%), shortness of breath (32.2%), and pleural chest pain (27.1%).<sup>8</sup> The non-respiratory symptoms included nausea, headache, muscle pain, and fever. Physical examination might help to diagnose CAP, however, the sensitivity and specificity was not optimal. Decreased breath sounds, bronchial breathing and dry rales might be detected by auscultation in CAP patients, however, negative finding was also common. Studies have shown that white blood cell count, hypersensitive C-reactive protein, and albumin in patients with CAP are risk factors for CAP diseases, which is consistent with the results of this study that the white blood cell count and the level of hypersensitive C-

reactive protein in pregnant patients with CAP are significantly higher than those in the control group ( $P < 0.01$ ).<sup>9</sup>

At present, LUS is often applied to the diagnosis of CAP disease in children and has achieved good achievements. Boursiani et al. used LUS to diagnose CAP diseases in 69 children. The sensitivity of LUS detection was 92.42%, and the specificity was 100%.<sup>10</sup> In this study, in the diagnosis of CAP patients during pregnancy by LUS, the sensitivity and specificity of LUS for CAP diagnosis were 92.6% and 89.5%, respectively, indicating that LUS can be used in the diagnosis of gestational CAP patients with better sensitivity and specificity. Lorio et al. evaluated the detection difference between LUS and chest X-ray in children with CAP, and found that LUS is a first-line imaging tool that can be used in the clinical diagnosis of CAP diseases.<sup>11</sup> Sperandeo et al. found that the sensitivity of LUS detection in interstitial lung disease was even higher than chest X-ray.<sup>12</sup> In this study, LUS was used for the diagnosis of CAP patients during pregnancy, and the diagnostic false positive rate, false negative rate, positive prediction, negative prediction, and accuracy were 10.5%, 3.8%, 82.6%, 94.4%, 93.3%, respectively. Compared with the results of chest X-ray, the results showed a good consistency. Reisig et al. found that CAP could be diagnosed and followed up with pulmonary ultrasound (LUS) and was comparable to chest X-ray, and LUS could be performed with any abdominal ultrasound device.<sup>13</sup> Krawczyk et al. found that when LUS was used in the diagnosis of patients with acute respiratory failure in pregnancy, 67% of patients had increased B-line and 21% had interstitial syndrome. Therefore, LUS could be used in the diagnosis of patients with respiratory deterioration.<sup>14</sup> Line B is rarely observed in normal lung tissue, usually less than line 3. However, in this study, it found that in 25 pregnant patients with CAP, the number of B-line in the lung tissue increased to 3 or more, and other pulmonary diseases such as pulmonary oedema may also cause the increase or combination of B-line. Therefore, it is speculated that the increase of B-line in the lungs of patients with CAP during pregnancy indicates alveolar interstitial exudation, and concurrent B line may suggest CAP.

LUS is an easy-to-use diagnostic tool that does not involve radiation exposure and has a wide range of applications, especially in situations where X-rays are not available or not appropriate. If LUS is negative and other complications are suspected, chest X-ray or CT examination should be performed.<sup>15</sup>

Pulmonary ultrasound is an effective and cheap tool for the diagnosis of community acquired pneumonia. Similar studies have been reported to explore the value of pulmonary ultrasound in the diagnosis and follow-up of CAP. Lung ultrasound is more sensitive than CXR, and compared with the gold standard CT chest film of CAP diagnosis, the accuracy rate of lung ultrasound diagnosis is 95.0%, the accuracy rate of CXR diagnosis is 81.0%, which confirms the validity of lung ultrasound in CAP diagnosis. With the continuous development of LUS, there are also some in-depth research reports.<sup>16</sup> Because the etiology of community-acquired pneumonia (CAP) is not easy to establish, and lung ultrasound (LUS) has been proved to be a good tool for the diagnosis of CAP, this paper reports and analyzes the role of LUS in the identification of different types of CAP in children. It was found that LUS was particularly suitable for distinguishing bacterial CAP from CAP due to other causes. However, LUS must be interpreted based on clinical and laboratory findings.<sup>5</sup>

There are few guidelines for the treatment of community-acquired pneumonia (CAP) that are more widely accepted. The Nordic countries mainly need macrolides and  $\beta$ -lactams to treat hospitalized non-ICU patients. A great deal of evidence supports the combination therapy. At present and in the future, CAP guidelines are facing challenges such as new antibiotics, the emergence of viruses as the main causes of CAP, new diagnostic models, alternative risk stratification for common cap antibiotic resistant pathogens, and evidence-based management of severe CAP.

## Conclusion

In summary, LUS was more accurate and reliable with high specificity and sensitivity. The examination was easy, non-invasive, and could be performed at bedside, with the advantages of handy and dynamic observation. There was no radiation threat to patients, clinicians and other people in the vicinity. Therefore, LUS can be effectively used for pregnant women with suspected CAP. Good consistency was demonstrated between LUS and chest X-ray for pregnant women with suspected CAP. LUS has the advantages of non-radiation, easy-operation and repeatability, which is more suitable for pregnant women with suspected CAP, and should be further investigated.

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reference list which also contains internet sources. This work has not been submitted to any other journal for consideration.

**Conflict of Interest:** We declare that all contributing authors of this paper have no conflict of interest and all have contributed equally for this research work.

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