Validity of chest ultrasound in the diagnosis of acute chest disorders in children

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Introduction Chest ultrasonography (US) is a promising tool in the evaluation of chest diseases as it is fast, user-friendly, noninvasive, easily reproducible, portable, widely available, inexpensive, and involves no ionizing radiation.

Aim To assess the role of chest US in the diagnosis of acute chest disorders in children comparing it with conventional chest radiographs (CXR).

Patients and methods This was a prospective, observational study, conducted at the Pediatric and Chest Departments of Al-Hussein and Sayed Galal, Al-Azhar University Hospitals, Cairo. Children aged from 1 month to 12 years, suffering from acute respiratory distress were included in this study. Full history taking, clinical examination, CXR, and chest US were performed for each patient. Computed tomography chest was performed in some cases where there was a doubt in diagnosis (e.g. lung abscess, mediastinal mass, and small pneumothorax). The main outcome was the correspondence between chest US findings and the patients' final diagnosis based on history, clinical examination, laboratory results, and radiological finding.

Results A total of 100 patients were included, 66 men and 34 women. Thirty patients had uncomplicated pneumonia, 17 patients had pneumonia complicated with effusion, 13 patients had nonpneumonic effusion, 12 patients had pneumothorax, four patients had lung collapse, 19 patients had acute bronchiolitis, three patients had lung abscess, and two cases had mediastinal masses. Chest US was true positive for the diagnosis in 83% of cases compared with 77% by the CXR (the conventional imaging technique).

Conclusion The chest US is a valid, simple, safe, available, inexpensive method, and comparable to CXR for the diagnosis of acute chest disorders in children.

Recommendation This study recommends administration of chest US as a diagnostic tool in the management of acute chest disorders in children.

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Introduction

For many years, air has been considered an enemy for ultrasound (US), and the lung has been considered an organ not suitable for US examination. Chest radiography (CXR) and computed tomography (CT) scan have considered the routine chest imaging. However, there are some difficulties, as in ICU where various positions are not feasible [1].

Nowadays, US has been proved to be effective in evaluating a wide variety of chest diseases, particularly when the pleural cavity is involved. The advantages of US are that it is a relatively inexpensive, widely available, mobile form of imaging, and free from ionizing radiation [2].

US of the lung is based on the principle that every acute disease reduces lung aeration, changing the lung surface and generating distinct, predictable patterns. This allows the diagnosis of various conditions and the monitoring of therapeutic interventions [3].

With a sensitivity of 100% and a specificity of 99.7%, sonography is more accurate than conventional radiography in the detection of pleural effusion because as little as 5 ml of fluid can be visualized. By contrast, the minimum volume detectable in a posterioanterior radiograph is 150 ml [4].

The principal limitation of chest US is the presence of subcutaneous emphysema that impedes the penetration in depth of the US beam; other factors such as obesity and presence of chest wall hematomas can create varying degrees of obstacles but they never impede the study of the lung [5].

The aim of this study was to prove the validity of chest US in the diagnosis of acute chest disorders in children and to test its sensitivity and specificity in comparison to conventional CXR.

Patients and methods

Study design

This study was a prospective, observational study that was conducted on 100 children (66 men and 34 women). Their ages ranged from 1 month to 12 years. They were recruited from the Pediatric Department of Sayed Galal and Al-Hussein Al-Azhar University Hospitals, during the period between February 2016 and November 2016.

The study protocol was approved by the Ethics Committee of Faculty of Medicine Al-Azhar University and a written consent was taken from the first-degree relatives of all included cases.

Inclusion criteria

(1) Children with signs of respiratory distress such tachypnea, subcostal, intercostal retractions, grunting, or cyanosis.
(2) Age from 1 month to 12 years.

Exclusion criteria

(1) Children contraindicated for exposure to radiation (chromosomal breakage syndromes, e.g. ataxia telangiectasia and fragile X syndrome).
(2) Children with subcutaneous emphysema.
(3) Children with marked obesity.

All included patients were subjected to:

(1) Full history taking stressing on: symptoms of respiratory tract infection before hospitalization, including the onset and duration of cough, fever, apnea, dyspnea, tachypnea, and rhinorrhea.
(2) General and local chest examination.
(3) Complete blood picture with the differential count.
(4) Conventional CXR and CT chest if needed.
(5) Chest US by SonoScape machine (SonoScape SSI-8000 Guangdong, China) at the Chest Department, using a 6-zone lung US imaging protocol similar to that described by Copetti and Cattarossi [6]. Lung US was done immediately after CXR and blindly to its results.

Diagnostic US findings of different chest diseases [1]:

Disease	Chest ultrasound findings
Pneumonia	Consolidation, pleural line irregularities, multiple B-lines, and dynamic air bronchogram
Effusion	Echo-free effusion, floating echoes move with pulse and respiration or septated and loculated pleural effusion
Pneumonia complicated with effusion	Signs of pneumonia+signs of effusion
Pneumothorax	Absent lung sliding, absent B-lines, absent lung pulse, and barcode sign ±lung point sign
Acute bronchiolitis	Subpleural lung consolidation, numerous compact B-lines, and pleural line irregularities
Lung collapse	Consolidation with irregular border and static air bronchogram
Lung abscess	Rounded or oval anechoic lesion, irregular thin wall±septae

Statistical analysis

MedCalc statistical software was used for data analysis. Data were expressed as mean±SD for quantitative parametric measures in addition to both number and percentage for categorized data, χ^2 test was applied for comparison of qualitative data. Sensitivity, specificity, positive predicted value, negative predicted value, and accuracy were calculated for the diagnostic test.

Results

100 patients were included in the study, 66 males and 34 females with mean age 4.4 years. Of 100 patients, 30 patients finally diagnosed as uncomplicated pneumonia, 17 patients had final diagnosis of

Table 1 Distribution of age among patients with respiratory distress

Final diagnosis based on history, clinical and imaging	No or %	Sex		Mean age months (years)	SD months (years)
		Male	Female		
Uncomplicated pneumonia	30	20	10	46.8 (3.9)	42.6 (3.6)
Pneumonia complicated with effusion	17	11	6	55.1 (4.6)	42.4 (3.5)
Nonpneumonic effusion	13	8	5	82.3 (6.9)	47.5 (4.0)
Pneumothorax	12	9	3	6.9 (0.6)	16.8 (1.4)
Collapse	4	2	2	17.9 (1.5)	17.4 (1.5)
Mediastinal mass	2	1	1	110.4 (9.2)	37.3 (3.1)
Lung abscess	3	2	1	47.5 (4.0)	20.6 (1.7)
Bronchiolitis	19	13	6	6.9 (0.6)	16.8 (1.4)
Total	100	66	34	52.41 (4.4)	34.75 (2.9)

This table showed that 66% of cases were men and 34% were women with a mean age of 4.4 years.

Table 2 Chest radiograph results according to final diagnosis of cases

		Chest radiograph results			
		Positive		Negative	
Final diagnosis	No or %	True	False	True	False
Uncomplicated pneumonia	30	26	4	66	4
Pneumonia complicated with effusion	17	14	2	81	3
Nonpneumonic effusion	13	11	1	86	2
Pneumothorax	12	11	0	88	1
Collapse	4	4	0	96	0
Mediastinal mass	2	1	1	97	1
Lung abscess	3	2	0	97	1
Bronchiolitis	19	8	2	79	11
Total	100	77			23

This table shows that chest radiograph was true positive in 77% of cases.

Table 3 Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of chest radiograph in the diagnosis of studied cases

Diagnosis	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Uncomplicated pneumonia	86.67	94.29	86.67	94.29	92
Pneumonia complicated with effusion	82.35	97.59	87.5	96.43	95
Nonpneumonic effusion	84.62	98.85	91.67	97.73	97
Pneumothorax	91.67	100	100	98.88	99
Collapse	100	100	100	100	100
Mediastinal mass	50	98.98	50	98.98	98
Lung abscess	66.67	100	100	98.98	99
Bronchiolitis	42.11	97.53	80	87.78	87

This table shows that chest radiograph has good sensitivity and specificity for pneumonia, effusion, pneumothorax, and lung collapse. NPV, negative predictive value; PPV, positive predictive value.

Table 4 Chest ultrasound results according to final diagnosis of cases

		Chest US results			
		Positive		Negative	
Final diagnosis	No or %	True	False	True	False
Uncomplicated pneumonia	30	28	4	66	2
Pneumonia complicated with effusion	17	16	0	83	1
Nonpneumonic effusion	13	13	0	87	0
Pneumothorax	12	9	1	87	3
Collapse	4	3	1	95	1
Mediastinal mass	2	1	0	98	1
Lung abscess	3	2	0	97	1
Bronchiolitis	19	11	3	78	8
Total	100	83			17

This table shows that chest US was true positive in 83% of cases. US, ultrasonography.

pneumonia complicated with effusion, 13 patients had final diagnosis of non-pneumonic effusion, 12 patients finally diagnosed as pneumothorax, 4 patients had final diagnosis of lung collapse, 19 patients had final diagnosis of acute bronchiolitis, 3 patients had final diagnosis of lung abscess and 2 patients had final diagnosis of mediastinal masses. The chest x-ray was able to detect 77% of cases correctly, with good sensitivity & specificity for uncomplicated pneumonia (86.67% sensitivity & 94.29% specificity), non pneumonic effusion (84.62% sensitivity & 98.85% specificity), pneumothorax (91.67% sensitivity & 100% specificity), and lung collapse (100% sensitivity & specificity), while the Chest U/S correctly diagnosed 83% of cases with better sensitivity & specificity for uncomplicated pneumonia (93.33% sensitivity & 94.29% specificity), pneumonia complicated with effusion (94.12% sensitivity & 100% specificity), non pneumonic effusion (100% sensitivity & specificity) Tables 1–5.

Discussion

The present study was designed to prove the validity of chest US as a diagnostic tool in the diagnosis of

Table 5 Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of chest ultrasound in the diagnosis of studied cases

Diagnosis	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Uncomplicated pneumonia	93.33	94.29	87.5	97.06	94
Pneumonia complicated with effusion	94.12	100	100	98.81	99
Nonpneumonic effusion	100	100	100	100	100
Pneumothorax	75	98.86	90	96.67	96
Collapse	75	98.96	75	98.96	98
Mediastinal mass	50	100	100	98.99	99
Lung abscess	66.67	100	100	98.98	99
Bronchiolitis	57.89	96.3	78.57	90.7	89

This table shows that chest ultrasound has good sensitivity and specificity for complicated pneumonia, effusion, pneumothorax, and lung collapse. NPV, negative predictive value; PPV, positive predictive value.

children with acute respiratory distress who attended the pediatric departments of Al-Hussein and Sayed Galal, Al-Azhar University Hospitals, during the period between February 2016 and November 2016.

This study included 100 infants and children presented with respiratory distress; their ages ranged from 1 month to 12 years; men were 66% while women were 34%.

The predominance of men over women among children and infants with respiratory distress was observed in many studies; Riccetto [7] showed 59.7% males: 40.3% females. Hegazy *et al.* [8] showed 65% males: 35% females among their studied cases. Anatomic differences of the respiratory tract may explain the different prevalence of infections between men and women, as the peripheral airways are disproportionately narrower during the early years of life in men, which may predispose one to lower respiratory tract infections (Falagas *et al.*, [9]).

All studied cases with respiratory distress had confirmed diagnosis relied on history, clinical examination, laboratory results, and radiological findings, where 30% of cases had final diagnosis as uncomplicated pneumonia; 17% of cases had pneumonia complicated with effusion; 13% had nonpneumonic effusion; 12% of cases had pneumothorax; 4% had lung collapse; 19% of cases had acute bronchiolitis; 3% had lung abscess; and two (2% of cases) cases had mediastinal masses.

Similar distribution of cases observed by Elsaeed *et al.* [10], who studied 50 children with pleuropulmonary disorders using US as a diagnostic tool; they found that the majority of cases (46%) had confirmed diagnosis as uncomplicated pneumonia; 16% had parapneumonic effusion; 6% had nonpneumonic effusion; 6% had lung collapse; 4% had abscess; and 4% had pneumothorax.

Furthermore, Rajatonirina *et al.* [11] studied respiratory infections in a pediatric ward, reporting that respiratory infections are a major cause of infectious disease-related morbidity, hospitalization, and mortality among children under 5 years old worldwide, and particularly in developing countries.

Among 30 patients confirmedly diagnosed as having uncomplicated pneumonia in the present study, CXR was true positive in 26 patients with 86.67% sensitivity and 94.29% specificity, compared with 28 patients truly identified by chest US with 93.33% sensitivity and 94.29% specificity of chest US. Also, chest US showed more sensitivity and specificity than CXR in the diagnosis of 17 cases with confirmed diagnosis of pneumonia complicated by pleural effusion, where chest US sensitivity and specificity were 94.12 and 100%, respectively, compared with 82.35 and 97.59% of CXR.

The higher sensitivity and specificity of chest US compared with CXR in the diagnosis of pneumonia reported also by Copetti and Cattarossi [6]; they found that among the studied 60 patients with pneumonia, US was positive for the diagnosis of pneumonia in 100% of patients, whereas CXR was positive in 88.3% of cases; pneumonia was confirmed by CT chest.

Rizk and Mostafa [12] studied 40 patients presented by symptoms and signs of respiratory distress, comparing chest US to CXR results; they found that the sensitivity of chest US in the diagnosis of pneumonia was 85% with a specificity of 96%, compared with the sensitivity and specificity of CXR 67 and 89%, respectively.

Also Sayed *et al.* [13] showed that among the studied 17 cases of pneumonia, lung US showed signs of consolidations in 82.4% of cases, while CXR was positive only in 64.7% of cases.

Similar results also reported by Hegazy *et al.* [8] who studied 19 children with a confirmed diagnosis of

pneumonia. Chest US showed findings consistent with pneumonia in 16 children with a sensitivity of 84.2% and specificity of 100%, whereas CXR was positive for pneumonia in 10 children with a sensitivity of 52.6% and specificity of 100%.

The present study documented the ability of chest US to detect pleural effusion in 13 cases with a sensitivity and specificity of 100% compared with 84.62% and 98.85% (sensitivity and specificity of CXR); also chest US can detect septae in effusion, which cannot be visualized even by CT chest.

The same results were reported by Agmy *et al*. [14] who studied 200 mechanically ventilated patients, comparing three imaging techniques (CXR, lung US, and chest CT); they reported 100% sensitivity and specificity of chest US in detecting pleural effusion compared with 55 and 84% (the sensitivity and specificity of CXR in detecting pleural effusion).

Similar results were also observed by Rizk and Mostafa (2015) who studied 25 patients presented by pleural effusion; three patients had encysted effusion; 15 patients had clear effusion; three patients had turbid effusion, and four patients had septated effusion, three of them with thin septae not detected in chest CT; the sensitivity and specificity of chest US were (95 and 93%, respectively) compared with that of CXR (77 and 83%, respectively).

In the present study, 12 cases confirmedly diagnosed as pneumothorax by chest CT; nine cases were truly identified by chest US with 75% sensitivity and 98.86% specificity, compared with 11 patients truly identified by chest CXR with 91.67% sensitivity and 100% specificity.

In contrast to the present study, Agmy *et al*. [14] reported 100% sensitivity and specificity of chest US in detecting pneumothorax in mechanically ventilated patients compared with 40 and 96% (the sensitivity and specificity of CXR in detecting pneumothorax); the lower sensitivity of CXR in detecting pneumothorax here can be explained by the limitations of A-P CXR film in detecting pneumothorax in mechanically ventilated patients.In the study by Rizk and Mostafa (2015) there were seven patients with confirmed diagnosis of pneumothorax by chest CT, chest US positively identified six of them by a sensitivity and specificity of 85 and 100%, respectively, compared with that of CXR (66 and 97%, respectively).

In the present study, there were 19 patients confirmedly diagnosed as bronchiolitis; 11 of them were truly identified by the chest US with 57.89% sensitivity and 96.3% specificity, compared with nine patients truly identified by CXR with 42.11% sensitivity and 97.53% specificity.

The same finding of the present study was observed by Abdel-Kader *et al*. [15], who studied 25 infants with clinical bronchiolitis comparing the chest US with CXR in detecting bronchiolitis; they found that only 10 infants had positive finding of bronchiolitis by CXR (40% sensitivity) compared with 14 (56%) infants who had positive chest US findings in the form of pleural line abnormalities, confluent B-lines, and/or subpleural consolidations.

The superiority of chest US to CXR in the diagnosis of bronchiolitis reported also by Hegazy *et al*. [8] who studied 32 patients clinically diagnosed as bronchiolitis; 28 (87.50%) of them were diagnosed by chest US as positive for bronchiolitis, while only 25 (78.1%) patients were diagnosed by CXR as positive for bronchiolitis.

In the present study, CT chest confirmedly diagnosed four cases with lung collapse, three cases with lung abscess, and two cases with mediastinal mass; chest US truly identified three of four cases with lung collapse, two of three cases with lung abscess, and one of two cases with mediastinal mass, while CXR was able to detect four cases with lung collapse, two of three cases with lung abscess, and one of two cases with mediastinal mass; so the chest US showed similar sensitivity and specificity to CXR in the diagnosis of these abnormalities.

Similar results were observed by Rizk and Mostafa (2015) in which there were three cases confirmedly diagnosed as mediastinal masses by chest CT; chest US positively identified two of them with 66.67% sensitivity and 97.3% specificity comparable to that of CXR.

Conclusion

The chest US is a valid, simple, safe, available, inexpensive method, and is comparable to chest radiographs for the diagnosis of acute chest disorders in children.

Recommendation

This study recommends administration of chest US as a diagnostic tool in the management of acute chest disorders in children.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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