Bedside Sonographic Diagnosis of Pneumothorax in Pediatric Patients: A Preliminary Report
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Abstract

Background: Development of thoracic ultrasound made it a useful tool for diagnosing respiratory disorders. But it has been rarely described in literatures about the accuracy of sonographic signs specific to pneumothorax. We studied the sonographic findings of pneumothorax in children and examined the patients with chest pain and/or dyspnea in our pediatric emergency department to determine the performance of thoracic ultrasound in children with pneumothorax.

Methods: This is a prospective blinded observational study between 2010 and 2011. Patients less than 18 years of age admitted with chest pain and/or dyspnea to our pediatric emergency department were analyzed. Patients were categorized into two groups: a pneumothorax group and a pneumothorax free (control group). Patients with any lung disorder were excluded as control group. Each patient underwent thoracic ultrasound and chest radiography on the anterior and lateral chest.

Results: Eight patients with pneumothorax and 30 with pneumothorax free were enrolled. The age ranged from 15 to 18 years old. The sensitivity, specificity, negative predictive values of loss of “lung sliding” sign and “lung point” sign in the diagnosis of pneumothorax were all 100%. The sensitivity of “loss of comet-tail sign” was 98%, specificity 40%, negative predictive value 99%.

Conclusion: Thoracic ultrasound is a useful diagnostic tool for children with pneumothorax. An absence of “lung sliding” plus the presence of a “lung point” sign at the anterior chest wall is indicative of pneumothorax. (J Pediatr Resp Dis 2013;9:81-86)

Key words: pediatric, pneumothorax, lung, ultrasound diagnosis

INTRODUCTION

The past decade has seen the rapid development of thoracic ultrasound in the diagnosis of pneumothorax and as such it has become more utilized within the field.¹-⁴ Although pneumothorax is an unusual problem in the pediatric emergency room, it can be life threatening if there is any delay in confirmation. To date, however, there has been little discussion about pneumothorax in pediatric patients, and to the best of our knowledge, no studies have referenced the use of thoracic ultrasound in children with pneumothorax. Accordingly, the diagnosis is still based on essentially clinical findings and chest radiography.

Although computed tomography is the gold standard for the identification of pneumothorax, it may require the transfer of patients to facilities with computed tomography scanners and exposes the patients to high levels of radiation. Chest radiography is not fully sensitive, although it is specific.⁵ This study looks to see if ultrasound could be of any help in this situation. To determine the efficiency of thoracic ultrasound in children with pneumothorax, several sonographic signs can be used. The absence of “lung sliding”, loss of a “comet-tail” sign, and the presence of a “lung point” sign have all been reported to be useful to diagnose and exclude pneumothorax in adults.⁶,⁷ The horizontal artifacts have a reported sensitivity of 95.3-100%, a
specificity of 60-91.1% and a negative predictive value of 100%, and when combined with an absence of lung sliding, a sensitivity and negative predictive value of 100% and a specificity of 96.5%. The ultrasound detection of a comet-tail sign plus a presence of “lung sliding” and the absence of a lung point at the anterior chest wall can discount pneumothorax.

MATERIALS & METHODS

Patients and setting

From January 1, 2010 to December 31, 2011, we conducted this prospective observational study on patients less than 18 years of age admitted with chest pain and/or dyspnea to a tertiary teaching hospital with around 13000 visits per year to the pediatric emergency department. The eligibility criteria and enrollment of the patients are summarized in Figure 1. Thoracic ultrasound was performed in the pediatric emergency room before chest radiography. Our pediatric trauma center is independent of our pediatric emergency department.

The patients were categorized into two groups: a pneumothorax group and pneumothorax-free (control) group. The patients who suffered from chest pain and/or dyspnea were categorized in the pneumothorax group, and all had air in the pleural space on chest radiography. All patients in this group showed clinical improvement after pig-tail insertion. The patients in the control group had no lung disorders on chest radiography, and had improvements in chest pain and/or dyspnea without any invasive therapeutic intervention. A physician specializing in pediatric thoracic ultrasound performed all of the studies.

Radiography

Antero-posterior and lateral chest radiography was performed, and all radiographs were read by physicians in the emergency room. In all studies, the physician who performed the ultrasound examinations was blinded to the results of the chest radiography, and radiologists confirmed the results of the chest X-rays. The presence of air within the pleural space was considered to indicate pneumothorax.

Ultrasound

A Phillips iE33 (Koninklijke Phillips N.V.) S5-1 probe was used. The anterior chest wall was delineated from the clavicles to diaphragm and from sternum to the anterior axillary line, while the lateral wall was delineated from the anterior to posterior axillary line and from the axilla to the diaphragm. Scans were parallel with respect to the ribs over the entire chest on each intercostal space anteriorly, laterally and posteriorly in the cephalocaudal direction. In each case, the sonographic examinations were performed by the same operator.

Basic lung semiology of ultrasound

Pneumothorax is characterized by three features: lung sliding, and comet-tail and lung point signs. Lung sliding is the absence of pleural lung sliding. In normal subjects, pleural sliding is a “to-and-fro” movement or a “sliding” of the visceral pleura against the parietal pleura during respiration. This movement is dynamic and has to be observed in real-time scanning. In cases of pneumothorax, due to air collection within the parietal pleura, the visualization of the visceral pleura is impossible, and therefore, “lung sliding” is not observed. Comet-tail signs are hyperechoic lines that normally arise from the pleural line and extend to the edge of the screen. However, in pneumothorax, air within the pleural space prevents propagation of the sound waves showing the disappearances of such signs, and thus the comet sign is not seen. The lung-point sign occurs at the border of a pneumothorax, and is due to a sliding lung intermittently coming into contact with the chest wall during inspiration. It is helpful in determining the
Figure 2. Loss of sliding of the pleural line. Right: white arrow indicates the pleural line. Normally there is a to-and fro movement of lung sliding, however in pneumothorax the sliding is abolished. Left: time-motion mode allows for observation of lung sliding. A lack of motions was shown with horizontalization of the lung sliding.

Figure 3. Comet-tail sign: white line from the pleural line to the edge of the screen.

Figure 4. Lung point. The point between movement of the pleura and no movement of the pleural line.

actual size of the pneumothorax. These sonographic signs are shown in Figure 2, Figure 3, and Figure 4.

RESULTS

Thirty-eight patients with chest pain/dyspnea who presented to the pediatric emergency department were enrolled, eight of whom had pneumothorax. The sonographic examinations of these eight patients were completed before chest radiography, and their ages ranged from 15 to 18 years. All had chest pain and/or dyspnea without desaturation and without intercostal retraction, and none had hemodynamic instability. No pleural sliding or comet-tail signs were present in any of the eight patients which suggested pneumothorax, and all required pig-tail insertion. All of these eight patients had primary spontaneous pneumothorax, and all showed a clinical improvement after pig-tail insertion.

Thirty hemithoraces were included in the control group, all of which were excluded from having pneumothorax by thoracic ultrasound. The final diagnoses were made according to the findings of chest radiography and the disappearance of clinical conditions with-
out any drug or surgical intervention. In the control group, pleural sliding was noted in all cases, however the lung point sign was absent in all cases. The accuracy of the comet-tail sign, lung sliding and lung point sign are summarized in Table 1, Table 2, Table 3 and Table 4. Overall, the sensitivity, specificity, and negative predictive value of the absence of lung sliding and the lung point sign in the diagnosis of pneumothorax were all 100%. The sensitivity of the loss of the comet-tail sign was 98%, with a specificity of 40%, positive predictive value of 31%, and negative predictive value of 99%.

### Table 1. Overall reliability of comet-tail artifact analysis at the anterior chest wall

<table>
<thead>
<tr>
<th>Group</th>
<th>Comet tail (present)</th>
<th>Comet tail (absent)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumothorax</td>
<td>0</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Pneumothorax free</td>
<td>12</td>
<td>18</td>
<td>30</td>
</tr>
</tbody>
</table>

### Table 2. Overall reliability of lung point analysis at the anterior chest wall

<table>
<thead>
<tr>
<th>Group</th>
<th>Lung point (present)</th>
<th>Lung point (absent)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumothorax</td>
<td>8</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Pneumothorax free</td>
<td>0</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

### Table 3. Overall reliability of lung sliding analysis at the anterior chest wall

<table>
<thead>
<tr>
<th>Group</th>
<th>Lung sliding (present)</th>
<th>Lung sliding (absent)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumothorax</td>
<td>0</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Pneumothorax free</td>
<td>30</td>
<td>0</td>
<td>30</td>
</tr>
</tbody>
</table>

### Table 4. Performance of thoracic ultrasound in children with pneumothorax

<table>
<thead>
<tr>
<th>Signs</th>
<th>Sensitivity%</th>
<th>Specificity%</th>
<th>PPV%</th>
<th>NPV%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absent comet-tail</td>
<td>98</td>
<td>40</td>
<td>31</td>
<td>99</td>
</tr>
<tr>
<td>Absent lung sliding</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Lung point</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Abbreviations: PPV=positive predictive value, NPV=negative predictive value

**DISCUSSION**

Spontaneous pneumothorax is a relatively rare condition in the pediatric population. Although the inclusion criteria of our study included all patients under 18 years of age, the age of children with pneumothorax diagnosed in our pediatric emergency department ranged from 15 to 18 years and all were spontaneous in origin, indicating that the peak age of occurrence is in late adolescence, which supports the findings of another study.

FAST is a term introduced at an international consensus conference in 1996 to describe an integrated, goal-directed, bedside examination to detect fluid in cases of trauma. Extended FAST (e-FAST) also refers to an examination of the chest for pneumothorax in which several subspecialties including anesthesiology, emergency medicine and respiratory physicians have added guidelines regarding the use of thoracic ultrasound, highlighting the importance and the increasingly widespread use of this technique.

The gold standard for identification of pneumothorax is chest computed tomography. However, due to high radiation exposure, the availability and use of contrast, the reference standard in the current study was chest roentgenography. Ultrasonography is a fast, safe, easy and inexpensive method which is preferable because a small pneumothorax may be missed in chest radiography. Recent studies have shown that in patients with trauma-related pneumothorax, ultrasonography is more than twice as sensitive as conventional supine chest radiography for the detection of occult pneumothorax (pneumothorax seen only on CT), with a similarly high specificity of 98%.

In the current study, we performed chest ultrasound for the patients with suspected pneumothorax before chest radiography (all patients subsequently also underwent...
chest radiography) to enable the prospective nature of this study. We then enrolled the patients with confirmed pneumothorax and those confirmed pneumothorax-free to determine the accuracy of thoracic ultrasound.

To the best of our knowledge, this is the first prospective, blinded, observational study of thoracic ultrasound in a pediatric emergency room. The results showed a high diagnostic accuracy for the identification of pneumothorax in children. The sensitivity, specificity and negative predictive value of the absence of lung sliding and the lung point sign were all 100%. These findings are consistent with the studies by Soldati et al.\textsuperscript{16} and Blaivas et al.\textsuperscript{15} which showed the specificity and sensitivity of thoracic ultrasound for the detection of pneumothorax in adult patients to be around 98.1-98.2% and 99.2-100%, respectively. The results of the current study confirm the findings of previous studies,\textsuperscript{7,17} and also include several new observations that provide a more complete understanding of how sonographic findings may serve as a diagnostic tool for primary spontaneous pneumothorax.

There were apparent discrepancies between the specificity of loss of the comet-tail sign and the lung point sign to the findings of previous studies. These discrepancies may be because of differences in study design. In our study, the control group was comprised of patients with hemithoraces without any lung diseases. Earlier studies have reported a higher specificity of the loss of the comet-tail sign (60%) and a lower sensitivity of the lung point sign (66%) than our findings.\textsuperscript{4} We believe that the higher specificity of lung sliding in our study is reliable because it was compared to patients with hemithoraces without any lung disorders. While other studies have found a lower sensitivity for the lung point sign and a higher specificity for the absence of the comet-tail sign,\textsuperscript{4,7} the pneumothorax free group in these studies included patients with other lung disorders such as diffuse alveolar-interstitial syndrome, chronic interstitial syndrome, chronic obstructive pulmonary disease and others. Our results showed that the loss of the comet-tail sign identified pneumothorax in all cases. In contrast, using loss of the comet-tail sign as an indicator in the pneumothorax free group, 18 (60%) patients were falsely identified as having the disease. Twelve (40%) of the cases with hemithoraces had a comet-tail sign, none of whom were found to have pneumothorax. However, an absence of lung sliding in combination with the lung point sign indicated pneumothorax with sensitivity, specificity, positive predictive value and negative predictive values of 100%.

There are some limitations to this study. First, we enrolled a relatively small number of patients (8 in the pneumothorax group and 30 in the pneumothorax-free group). A large-scale study is required to confirm our findings. Second, the performance of ultrasound is operator dependent. In this study the operator was a well-trained pediatrician in thoracic ultrasound. Although, large-scale studies involving a wide variety of physicians in emergency rooms have shown that sonographic evaluation for pneumothorax is as accurate as reference standards,\textsuperscript{18} we recommend that minimally experienced operators should make the diagnostic decision based on a reference standard test. Third, lung ultrasound accessibility may be difficult in some patients due to tissue edema and obesity. Fourth, we did not perform ultrasound in all patients with chest pain and/or dyspnea who visited our pediatric emergency room because only one observer was available.

Screening of patients with chest pain and/or dyspnea is attractive because it is fast, noninvasive and does not involve radiation. Thoracic ultrasound is increasingly being used to detect pneumonia, pulmonary edema, free fluid (intraperitoneal, pelvis, pericardial and pleural effusion) and pneumothorax in adults. We recommend thoracic sonography for children with suspected pneumothorax.

In conclusion, for pediatric patients with chest pain and/or dyspnea who have a high probability of pneumothorax, we recommend performing thoracic sonography despite normal appearing chest radiography. Thoracic ultrasound is an adjunctive imaging modality that does not involve the hazards associated with radiation, but seemingly is better than plain chest radiography.

REFERENCES


