Abnormal Changes of a 12-Lead Electrocardiogram in Male Patients with Left Primary Spontaneous Pneumothorax

Shih-Chung Huang, 1,3† Gen-Min Lin, 1,4† Yi-Hwei Li, 5 Chin-Sheng Lin, 1 Hung-Wen Kao 2 and Chih-Lu Han 6

Background: Typical electrocardiographic (ECG) changes associated with left primary spontaneous pneumothorax (PSP) have previously been well-described. However, there were no reports in the literature about the characteristic of ECG in estimating the severity of pneumothorax.

Methods: From 2003 through 2008, 63 male patients who had left PSP were divided into two groups: 1) large PSP, Light index ≥ 20% (n = 43), and 2) small PSP, Light index < 20% (n = 20). The ECGs of 64 age-matched disease-free men were used as the normal control. Those medical records reviewed that provided data for this study included patient backgrounds, severity of PSP, and 12-lead ECG characteristics.

Results: As compared to the normal controls, left PSP patients had lower body mass index, more rapid heart rate and lower voltages in V3R-V6R. In analyzing QRS voltages, the amplitudes of V2S and V3S were significantly different. As with both V2S < 12 mm and V3S < 9 mm, the sensitivity, specificity and positive predictive value to predict patients who had large left PSP area were estimated at 42% (18/43), 100% (20/20) and 100% (18/18), respectively.

Conclusions: Using the criteria of V2S < 12 mm, V3S < 9 mm and electrical alternans could predict pneumothorax size exceeding 20% in patients who already had left PSP.

Key words: 12-lead electrocardiogram • Male • Primary spontaneous pneumothorax

INTRODUCTION

Primary spontaneous pneumothorax (PSP) is defined as the spontaneous occurrence of air in the pleural cavity in patients without underlying lung disease. It occurs primarily in the young male population, and is left side predominant.1,2 Some experts have stated that invasive procedures such as manual aspiration, chest tube drainage, and thoracoscopic treatment are required if the volume of air occupies more than 20% of the hemithorax in symptomatic patients.3,4 There have been several methods developed for evaluating the size of pneumothorax including computed tomography (CT)-based Collins method and a chest plain film derived Rhea method and Light index.5-7 The Light index could provide a good correlation between the estimated size of pneumothorax from an image study and the actual volume of leaking air.7,8

In clinical practice, a conventional 12-lead electrocardiogram (ECG) in addition to a chest radiograph (CXR)
provides essential information in patients with sudden onset chest pain. With left-sided pneumothorax, the following ECG changes have been described including phasic R wave variations, right ward shift of the frontal QRS axis, diminution of the QRS complex, T-wave inversion, and loss of R waves in the precordial leads.9-13 The presence of these typical ECG findings remind medical practitioners of the presence of left side pneumothorax before a CXR is available.

Although ECG characteristics in left PSP are now well-understood, questions remain about whether a 12-lead ECG could be utilized for predicting the volume of air exceeding 20% hemithorax that subsequently may require invasive treatment. According to the solid angle theorem, the ECG surface potential will decrease as the boundary size is reduced and as the distance to the electrode is widened.14 Therefore, we assumed that the area of pneumothorax is inversely proportional to the voltage of cardiac electrical activation in some leads. Therefore, we conducted a comprehensive analysis of the 12-lead ECG characteristics of male patients with left PSP and its diagnostic value in determining the severity of PSP.

MATERIALS AND METHODS

Study subjects

This retrospective cohort study was conducted in Tri-Service General Hospital, an 1800-bed tertiary referral medical center in Taiwan. New cases of PSP numbering approximately 100-150 per year could be diagnosed in this hospital. Every patient that visited our emergency department (ED) under the impression of pneumothorax received a thorough medical history intake and physical examination. CXR was routinely obtained and 12-lead surface ECG was performed as clinically indicated. From January 2003 to February 2008, male patients with left-sided pneumothorax were retrospectively reviewed at our institution; patients who had available ECG were enrolled. They were further divided into two radiologically defined groups, the first with large PSP, and Light index ≥ 20% (group 3); and the second with small PSP, and Light index < 20% (group 2). The ECGs from 64 age-matched disease-free men provided the normal control (group 1). Patients with hydro-pneumothorax, history of cardiac and pulmonary diseases, isolated diaphragmatic elevation, chest wall deformity and previous lung volume reduction surgery were excluded in this study. The following data were reviewed and analyzed from the ED medical records: patients’ demographic data including age, sex, height, weight, and body mass index, radiological appearance in size of pneumothorax and 12-lead surface ECG characteristics. The Tri-Service General Hospital Institutional Review Board approved the study and waived the requirement for informed consent for this retrospective review of medical records (TSGHIRB09705103).

Radiological studies

All patients underwent posteroanterior CXR in the upright position taken at the time of admission into the ED, which were reviewed by two internists. If a discrepancy existed in the calculations of Light index for left side pneumothorax, the CXR was further reviewed by the radiologist blinded to the results. The Light index was used for measuring the sizes of pneumothorax and the calculated formula is listed below.

\[
\text{Size of PSP (\%) = 100 - \left(\frac{\text{average lung diameter}}{\text{average hemithorax diameter}}\right)^3 \times 100}
\]

- \(\text{Average lung diameter} = \text{average intrapleural distance (AID)}\).
- \(\text{AID} = \frac{\text{maximal apical ID + maximal mid upper ID + maximal mid-lower ID}}{3}\) (Figure 1).

12 lead ECG

To obtain a standard 12-lead ECG, patients were prepared in the supine position. The six limb leads ori-
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ginated from four electrodes placed on the arms and legs bilaterally. They provided the basis for the three standard limb leads (I, II, and III) and the three augmented limb leads (aVR, aVL and aVF). Six precordial leads were placed in order: V1 at the right 4th intercostal space, V2 at the left 4th intercostal space, V3 at halfway between V2 and V4, V4 at left 5th intercostal space, mid-clavicular line, V5 horizontal to V4 at anterior axillary line, and V6 horizontal to V5 at the mid-axillary line. The R wave was measured from the initial positive deflection of ventricular depolarization. The S wave was measured from the first negative deflection of ventricular depolarization that follows the first R wave. Phasic voltage variations meant those rhythmic changes of R wave amplitude over 2mm with respiratory cycles.

RESULTS

Patient and baseline ECG characteristics

Of the total of 630 patients that were retrospectively reviewed, only 108 had an available ECG. Of that reduced number, there were 63 patients with PSP of the left side, 42 patients with right side PSP, and 3 with bilateral PSP. In those patients with left side pneumothorax, all were males: 20 were in group 2 (21.7%), and 43 were in group 3 (68.3%). The normal control group (group 1) consisted of the ECGs of sixty-four age-matched disease-free men. Baseline characteristics of normal subjects and left PSP patients were shown in Table 1. The median age of the 63 diseased patients who were enrolled in the study was 23 years (range 14-41 years old). As compared to the normal controls (group 1), left PSP patients (groups 2 and 3) had lower body mass index and more rapid heart beat rate. As the major end point to compare groups 2 and 3, there were no significant differences with respect to age (22.7 ± 11.5 years vs. 22.9 ± 6.6 years), body height (175.3 ± 6.3 cm vs. 172.6 ± 7.4 cm), body weight (61.8 ± 7.02 kg vs. 59.6 ± 7.89 kg), and body mass index (20.2 ± 2.7 vs. 20.1 ± 3.0). In baseline ECG, group 3 had more rapid heart beat rate than group 2 (82.5 ± 11.0 vs. 70.3 ± 11.8, p = 0.002). Similarly, there were no statistically significant differences between groups 2 and 3 with respect to the PR interval, QRS interval, QT interval, and QTc interval. Axes of P, QRS and T wave as well as the angles between axes of P-QRS and QRS-T were also not different.

Surface 12 lead ECG presentations regarding QRS complex amplitude

Table 2 illustrates the comparison of RS amplitudes in all surface leads among 3 groups. In frontal leads including leads I, II, III, aVF, aVR and aVL, neither voltage of R wave nor S wave was extremely different among the 3 groups. On average, small r waves are prominent at the direction of superior and left leads. As to precordial leads, the presence of phasic R wave variation (electric alternateness) was only present in group 3 (sensitivity: 30% (13/43), specificity: 100% (20/20), positive predictive value: 100%). Notably, the normal controls in group 1 had significantly higher R wave in V3R-V6R than patients in groups 2 and 3. Besides, the amplitudes of V2S and V3S in group 3 were lower than
Table 1. Characteristics and baseline ECG of patients with left side pneumothorax

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group 1</th>
<th>Group 2 Light index ≤ 20% (n = 20)</th>
<th>Group 3 Light index &gt; 20% (n = 43)</th>
<th>p-value‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics</td>
<td>Healthy controls (n = 64)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td>22.49 ± 1.13</td>
<td>22.70 ± 11.50</td>
<td>22.89 ± 6.56</td>
<td>0.980</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>171.66 ± 5.69</td>
<td>175.32 ± 6.27</td>
<td>172.62 ± 7.40</td>
<td>0.290</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>70.78 ± 10.99</td>
<td>61.79 ± 7.02</td>
<td>59.55 ± 7.89</td>
<td>0.675</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.00 ± 3.38</td>
<td>20.18 ± 2.70</td>
<td>20.05 ± 2.97</td>
<td>0.899</td>
</tr>
<tr>
<td>Baseline ECG</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR (per min)</td>
<td>62.69 ± 8.46</td>
<td>70.25 ± 10.99*</td>
<td>82.53 ± 17.75*</td>
<td>0.002</td>
</tr>
<tr>
<td>PR (ms)</td>
<td>153.72 ± 21.13</td>
<td>156.05 ± 30.69</td>
<td>157.09 ± 27.00</td>
<td>0.987</td>
</tr>
<tr>
<td>QRS (ms)</td>
<td>90.90 ± 13.55</td>
<td>90.10 ± 9.53</td>
<td>94.28 ± 12.93</td>
<td>0.443</td>
</tr>
<tr>
<td>QT (ms)</td>
<td>367.46 ± 49.67</td>
<td>364.70 ± 32.38</td>
<td>349.30 ± 37.32</td>
<td>0.290</td>
</tr>
<tr>
<td>QTc (ms)</td>
<td>378.30 ± 30.54</td>
<td>391.65 ± 31.44</td>
<td>403.09 ± 30.74</td>
<td>0.357</td>
</tr>
<tr>
<td>P-axis</td>
<td>50.78 ± 54.57</td>
<td>64.20 ± 16.95</td>
<td>64.35 ± 19.37</td>
<td>0.999</td>
</tr>
<tr>
<td>QRS-axis</td>
<td>57.88 ± 30.93</td>
<td>85.2 ± 42.19</td>
<td>83.84 ± 44.76</td>
<td>0.990</td>
</tr>
<tr>
<td>T-axis</td>
<td>43.68 ± 16.63</td>
<td>58.00 ± 14.92</td>
<td>61.33 ± 15.53</td>
<td>0.723</td>
</tr>
<tr>
<td>P-QRS</td>
<td>13.05 ± 36.85</td>
<td>21.15 ± 50.10</td>
<td>19.49 ± 44.44</td>
<td>0.988</td>
</tr>
<tr>
<td>QRS-T</td>
<td>16.98 ± 30.08</td>
<td>27.35 ± 46.11</td>
<td>22.51 ± 48.05</td>
<td>0.896</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD. BMI, body mass index; cm, centimeter; HR, heart rate; kg, kilogram; ms, millisecond; P-QRS, angle between P and QRS axis; PR, PR interval; QRS, QRS interval; QRS-T: angle between QRS and T axis; QT, QT interval; QTc, corrected QT interval.

p-values were derived from Tukey’s pairwise multiple comparison procedure; * p < 0.05, † p < 0.01, and ‡ p < 0.001 were used for comparison between the healthy control group and the two pneumothorax groups; i.e. Light index ≤ 20% vs. control, and Light index > 20% vs. control. * Exact p-values are shown for comparison between Light index ≤ 20% and Light index > 20% groups.

Table 2. Analysis of RS amplitude from 12-lead surface ECG in left side pneumothorax patient

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group 1</th>
<th>Group 2 Light index ≤ 20% (n = 20)</th>
<th>Group 3 Light index &gt; 20% (n = 43)</th>
<th>p-value‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal leads (mm = 0.1 mV)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IR</td>
<td>4.48 ± 2.25</td>
<td>2.88 ± 1.39</td>
<td>2.81 ± 2.37</td>
<td>0.994</td>
</tr>
<tr>
<td>IIR</td>
<td>10.97 ± 4.14</td>
<td>11.78 ± 4.30</td>
<td>9.77 ± 4.88</td>
<td>0.220</td>
</tr>
<tr>
<td>IIIR</td>
<td>7.26 ± 4.66</td>
<td>9.53 ± 4.75</td>
<td>7.59 ± 4.48</td>
<td>0.273</td>
</tr>
<tr>
<td>aVFR</td>
<td>9.04 ± 4.23</td>
<td>10.23 ± 4.82</td>
<td>8.51 ± 4.56</td>
<td>0.331</td>
</tr>
<tr>
<td>aVLr</td>
<td>0.94 ± 1.08</td>
<td>0.73 ± 0.64</td>
<td>0.86 ± 1.41</td>
<td>0.902</td>
</tr>
<tr>
<td>aVRr</td>
<td>0.16 ± 0.27</td>
<td>1.05 ± 1.23</td>
<td>0.74 ± 1.03†</td>
<td>0.338</td>
</tr>
<tr>
<td>IS</td>
<td>1.10 ± 1.13</td>
<td>1.50 ± 1.66</td>
<td>1.16 ± 0.89</td>
<td>0.531</td>
</tr>
<tr>
<td>IIIS</td>
<td>1.02 ± 1.19</td>
<td>1.78 ± 2.02</td>
<td>1.57 ± 1.57</td>
<td>0.866</td>
</tr>
<tr>
<td>IIIIS</td>
<td>0.90 ± 1.25</td>
<td>1.05 ± 1.20</td>
<td>1.13 ± 1.31</td>
<td>0.972</td>
</tr>
<tr>
<td>afVS</td>
<td>0.84 ± 1.59</td>
<td>1.30 ± 1.42</td>
<td>1.19 ± 1.21</td>
<td>0.954</td>
</tr>
<tr>
<td>aVLS</td>
<td>2.56 ± 1.99</td>
<td>3.90 ± 2.26*</td>
<td>3.05 ± 2.43</td>
<td>0.326</td>
</tr>
<tr>
<td>aVRs</td>
<td>7.34 ± 2.17</td>
<td>6.58 ± 2.66</td>
<td>5.93 ± 3.46*</td>
<td>0.664</td>
</tr>
<tr>
<td>Precordial leads (mm = 0.1 mV)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V1R</td>
<td>2.52 ± 1.47</td>
<td>2.43 ± 2.26</td>
<td>3.45 ± 2.62*</td>
<td>0.160</td>
</tr>
<tr>
<td>V2R</td>
<td>6.03 ± 3.04</td>
<td>5.50 ± 4.10</td>
<td>5.27 ± 3.68</td>
<td>0.966</td>
</tr>
<tr>
<td>V3R</td>
<td>10.25 ± 5.20</td>
<td>5.68 ± 4.07*</td>
<td>5.80 ± 4.03†</td>
<td>0.994</td>
</tr>
<tr>
<td>V4R</td>
<td>17.68 ± 4.87</td>
<td>7.43 ± 6.21</td>
<td>6.29 ± 4.50†</td>
<td>0.678</td>
</tr>
<tr>
<td>V5R</td>
<td>16.89 ± 4.94</td>
<td>7.93 ± 4.94</td>
<td>6.96 ± 4.87†</td>
<td>0.753</td>
</tr>
<tr>
<td>V6R</td>
<td>12.73 ± 4.34</td>
<td>7.88 ± 4.24</td>
<td>6.76 ± 4.54†</td>
<td>0.616</td>
</tr>
<tr>
<td>V1S</td>
<td>9.06 ± 4.17</td>
<td>9.83 ± 4.46</td>
<td>9.62 ± 8.33</td>
<td>0.991</td>
</tr>
<tr>
<td>V2S</td>
<td>13.58 ± 5.02</td>
<td>18.88 ± 5.27†</td>
<td>13.80 ± 9.07</td>
<td>0.017</td>
</tr>
<tr>
<td>V3S</td>
<td>8.84 ± 5.09</td>
<td>13.43 ± 6.96†</td>
<td>8.70 ± 5.69</td>
<td>0.007</td>
</tr>
<tr>
<td>V4S</td>
<td>4.02 ± 3.37</td>
<td>5.98 ± 5.04</td>
<td>4.75 ± 3.89</td>
<td>0.474</td>
</tr>
<tr>
<td>V5S</td>
<td>2.08 ± 2.14</td>
<td>2.35 ± 2.20</td>
<td>2.42 ± 2.09</td>
<td>0.993</td>
</tr>
<tr>
<td>V6S</td>
<td>0.97 ± 1.04</td>
<td>1.33 ± 1.26</td>
<td>1.40 ± 1.49</td>
<td>0.976</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD; mm, millimeter; mV, millivolt.

p-values were derived from Tukey’s pairwise multiple comparison procedure; * p < 0.05, † p < 0.01, and ‡ p < 0.001 were used for comparison between the healthy control group and the two pneumothorax groups; i.e. Light index ≤ 20% vs. control, and Light index > 20% vs. control. * Exact p-values are shown for comparison between Light index ≤ 20% and Light index > 20% groups.
those amplitudes in group 2 (13.8 mm vs. 18.9 mm, \( p = 0.017 \) and 8.7 mm vs. 13.4 mm, \( p = 0.007 \), respectively). There were no statistically significant differences between groups 2 and 3 regarding voltage of R wave in all precordial leads from leads V1 to V6 and that of S wave in V1, V4, V5 and V6.

**Positive correlation of Light index to V2S and V3S**

Figure 2A showed ROC curve to measure the probabilistic forecasts discriminated between group 2 and group 3 with respect to V2S. The area under ROC curve was maximally estimated to 76.6% if the amplitude of V2S < 12 mm was chosen as the cutoff point to predict group 3. The sensitivity was 58.1% (25/43), the specificity 90.0% (18/20) and the positive predictive value 92.6% (25/27). Figure 2B demonstrated the cumulative percentage curves against V2S voltage of patients in group 2 (n = 20, red square) and group 3 (n = 43, colorless circles). The vertical dash line was at the level of V2S = 12 mm. Figure 2C showed ROC curve to measure the probabilistic forecasts discriminated between groups 2 and 3 regarding V3S. The area under ROC curve was maximally estimated to 71.8% if the amplitude of V3S lower than 9 mm was chosen as the cutoff point to predict group 3. The sensitivity was 55.8% (24/43), the specificity 75.0% (15/20) and the positive predictive value 82.8% (24/29). Figure 2D draws cumulative percentage curves against V3S voltage of patients in group 2 (n = 20, red square) and group 3 (n = 43, colorless circles). The vertical dash line was at the level of V3S = 9 mm. Moreover, using both V2S < 12 mm and V3S < 9 mm for predicting Light index >20% (group 3) versus Light index < 20% (group 2), the sensitivity was 18/43 = 41.9%; the specificity was 20/20 = 100%; positive predictive value was 18/18 = 100% (data not shown in Figure 2).

**Analysis of subgroups of patients with V2S < 12 mm and V3S < 9 mm**

Table 3 revealed that case numbers were distributed equally in group 3 with V2S < 12 mm, 32% (8/25) having pneumothorax area within 20-40%, 32% (8/25) having pneumothorax size within 40-60%, and 36% (9/25) hav-

![A](image1.png) ![B](image2.png) ![C](image3.png) ![D](image4.png)

**Figure 2.** (A) ROC curve of V2S to differentiate the patients in groups 2 and 3. The maximal area under curve (AUC) was 76.6% when 12 mm and less was chosen as the cutoff-point in V2S. (B) Two cumulative percentage curves against V2S voltage of patients in groups 2 and 3. (C) ROC curve of V3S to differentiate the patient in groups 2 and 3. The maximal area under curve (AUC) was 71.8% when 9 mm and less was chosen as the cutoff-point in V3S. (D) Two cumulative percentage curves against V3S voltage of patients in groups 2 and 3. ROC, receiver operating characteristic.
ing pneumothorax size > 60%. Meanwhile, only one pa-
tient in group 2 (10-20%) had pneumothorax size close
to 20%. In sharp contrast, case numbers of group 3 in-
creased proportionally to greater pneumothorax sizes if
V3S < 9 mm, with 25% (6/24) having pneumothorax area
within 20-40%, 33% (8/24) having pneumothorax size
within 40-60%, 42% (10/24) having the largest pneumo-
thorax sizes. And five patients in group 2 (10-20%) were
close to the volume of 20% in pneumothorax.

**DISCUSSION**

It is generally accepted that radiological study is ex-
clusively the “gold standard” used to diagnose patients
with pneumothorax. Our study reconfirmed this com-
mon knowledge for PSP patients who are young and
have low body mass index in comparison with age-
matched healthy persons. Additionally, we first reported
the 12-lead ECG features in patients with left-sided PSP
by Light index classifications. The presence of phasic R
wave variation (electric alternateness) and rapid heart-
beat rate in ECG is specific for left PSP patients with
higher Light index. In the pneumothorax group, our
study also found a trend that the direction of the heart
axis is not only a clockwise rotation but also downward
deviated. These are reflected by diffuse low voltage (0-3
mm) of R wave in left-superior leads (I, aVL, aVR) and
dominant R waves (8-12 mm) in right-inferior leads (II,
III, aVF). From our study, the phenomenon of phasic R
wave variation only existed in the group 3 (13/43). One
possible explanation is that air with an insulator effect
easily moves to the apical aspect of the pleural cavity in
the supine position which may cause loss of R wave in
corresponding leads on the body surface (Figure 3).

With the air expanding in size, the heart lacks the lung
parenchymal support and “swims” in accordance with
rhythmic cardiac and respiratory cycles leading to elec-
trical alternateness in the group 3 (Figure 4).

In analyzing the difference of ECG between groups 2
and 3, there are many variables to discuss. Firstly, the
heart rate in group 3 is more rapid than that in group 2.
The reactive tachycardia could take place in patients
with a larger area of pneumothorax due to pain,
hypoxia, a rise of catecholamine level and enhanced
sympathetic tone. The heart rate in an ECG of pa-
tients with left PSP rarely achieves the definition of
“tachycardia” (over 100 beats per minute). 2. Second,
the extra-pulmonary air is redistributed to the ante-
orial-cardiac area thereby it increases the resistance on
the lateral leads when the volume expands. However, in
left anterior leads (V2-V3), the electrodes are closer to
the heart and receive the greatest cardiac electrical po-
tential (Figure 3). It would reflect the change of air vol-
ume based on the solid angle theorem. The result of our
study is consistent to our hypothesis that a significant
difference was present in left anterior leads of V2S and
V3S between groups 2 and 3.

![Figure 3](image_url)

**Table 3.** Patient numbers of subgroups in amplitude of V2S and V3S below 12 mm (1.2 MV) and 9 mm (0.9 MV) respectively

<table>
<thead>
<tr>
<th>Light index</th>
<th>V2S (mm)</th>
<th>V3S (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 2</td>
<td>Group 3</td>
</tr>
<tr>
<td>0.0-0.1</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>0.1-0.2</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>0.2-0.4</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>0.4-0.6</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>0.6-1.0</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Overall</td>
<td>18</td>
<td>2</td>
</tr>
</tbody>
</table>
According to ROC curve analysis, it is clear that neither V2S (58.1%) nor V3S (55.8%) was sensitive enough in determining the size of PSP. When voltage < 12 mm in V2S and voltage < 9 mm in V3S both existed, the extent of pneumothorax could be accurately predicted with a high positive predictive value up to 100%.

However, these findings were restricted in their clinical implications for a low sensitivity to detect left PSP and the majority of patients having pneumothorax (83%) without ECG. The baseline profiles and the severity of pneumothorax of patients without ECG were not known. Therefore, it is not rational to apply the current results to those without ECG. In addition, some ECG characteristics of left-sided PSP described in previous case reports were not observed in our patients such as the changes of ST segment and QRS morphology.17,18

Finally, our studies have several limitations. First, ECG may be affected by a variety of factors such as patients’ body position and the location of the electrodes.19,20 Second, the time interval between ECG and chest – X ray was not standardized in our study. A comprehensive and prospective study should be undertaken to provide additional information.

In conclusion, using the criteria of V2S < 12 mm, V3S < 9 mm and phasic electrical alternans (black arrow) were noted in the patient with Left PSP (Area = 39%) at Figure 4B.

Figure 4.  (A and B) The 12 lead ECG were obtained from two of our PSP patients (13% vs. 39% area of left PSP), the finding of V2S < 12 mm, V3S < 9 mm and phasic electrical alternans (black arrow) were noted in the patient with Left PSP (Area = 39%) at Figure 4B.
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