Intraoperative identification of persistent left superior vena cava with intracavitary electrocardiogram during venous port insertion: A report of eight cases

Yogesh Jheengut and Boqiang Fan

Abstract
Persistent left superior vena cava is a rare congenital anomaly, occurring in 0.3% to 0.5% of general population and up to 10% in patients with congenital heart disease. This anomaly is usually discovered incidentally during central venous catheterization from left side. Since 2015, we have identified eight cases of persistent left superior vena cava out of a total of 2637 patients who had left sided venous port insertion in our department. The persistent left superior vena cavae were identified with the aid of intracavitary electrocardiogram. The characteristic finding was an initial negative P-wave (in lead II), followed by a biphasic P-wave pattern during catheter insertion. All the ports worked properly, with a total catheter dwelling time of 2586 days (range: 96–756 days, mean: 323.25 days), and no catheter-related complication was observed. However, because of the paucity of clinical evidence, we should still be prudent in the long-term use of venous ports in persistent left superior vena cava.

Keywords
Persistent left superior vena cava, venous port, intracavitary electrocardiogram

Introduction
Persistent left superior vena cava (PLSVC) is the most common congenital anomaly of thoracic venous system, occurring in 0.3% to 0.5% of the general population and up to 10% in patients with congenital heart disease.1,2 It is usually asymptomatic and is detected incidentally during procedures like cardiac pacemaker implantation,3,4 chest imaging,2,5 and central venous catheterization.6–9 In venous catheterization, PLSVC is usually confirmed by postoperative imaging. Given the paramount importance of tip position to venous ports, it is crucial to identify PLSVC intraoperatively. Here, we report a specific intracavitary electrocardiogram (IC-ECG) pattern recognized during port insertion from left side in eight patients with PLSVC.

Case series
From November 2015 to October 2019, 2637 patients underwent chest port insertion from the left side in our department. The left side was chosen due to local conditions, which precluded right chest for catheterization or port chamber placement, such as breast surgery, radiotherapy, large metastatic lymph nodes at right neck root, and compression or stenosis of right innominate vein. The catheters of eight patients (six females, two males, age: 31–59 years, average age: 44.8 years) were inserted into PLSVC. None of them were known to have the anomaly before the procedure. Four patients had their ports removed uneventfully after completion of therapy, two patients died

Department of Oncology, The First Affiliated Hospital of Nanjing Medical University, Nanjing, China.

Corresponding author:
Boqiang Fan, Department of Oncology, The First Affiliated Hospital of Nanjing Medical University, No. 300, Guangzhou Road, Nanjing, Jiangsu, China.
Email: bq_fan@139.com
of disease with the port in their body, and two patients are still using their ports (last follow-up on 28 October 2019; Table 1).

**Procedures**

Routine informed consent for port insertion was obtained from each patient or by their responsible party. All procedures were performed under local anesthesia (10 mL of lidocaine 1% with adrenaline 1:200000). No prophylactic antibiotic was used. The patient was placed in supine position on the operation table with the head turned to right side. The neck, chest, and shoulder area were sterilized with 0.5% chlorhexidine in 70% (v/v) alcohol solution and draped in a customary manner. After injecting local anesthesia, the pocket for port chamber was made at second rib level. The internal jugular vein or axillary vein was accessed under ultrasound (US) guidance. The column of saline method was adopted for catheter tip positioning. The RA (right arm) electrode was connected to the catheter through a cable, and the P-wave in lead II (right shoulder–left leg) was evaluated dynamically with pushing or pulling the catheter. P-wave in lead III was used as reference. The final catheter length was determined by maximal P-wave in lead II.

**IC-ECG findings and recognition of PLSVC**

The IC-ECG waveform was similar in all eight patients but were different from what was expected as in the right sided superior vena cava (SVC) catheterization. When the catheter was inserted at about 15 cm, instead of the normally expected rise in the amplitude of the P-wave, there was an increasing negative deflection of the P-wave (Figure 1(a)). As the catheter was advanced further, the negative deflection increased and reached its maximum (Figure 1(b)). Very soon, the P-wave became biphasic, and then the negative deflection decreased and reached its minimum (Figure 1(c)). The change of waveform could be repeated as the catheter was re-inserted. On routine post-procedural chest X-ray (CXR) examination, the catheter was found to course down along the left side of mediastinum (Figure 2). Then chest computed tomography (CT) was carried out to confirm the presence of PLSVC (Figure 2). Based on the maximal negative P-wave criteria, all the tips were in the lower part of PLSVC.

**Discussion**

PLSVC is a well-recognized congenital anomaly of chest venous system. There are numerous reports on central catheters inserted into this vein, including central inserted central catheters (CICCs), dialysis catheters, peripherally inserted central catheters (PICCs), and ports. The anatomical aspect of this anomaly is described in detail elsewhere and is not the main topic of this report. In this report, we mainly discuss the intraoperative IC-ECG findings in PLSVC and its related clinical aspects. Catheter tip location is of paramount importance to central venous catheters, especially long-term devices. Several methods have been applied for this purpose, including X-ray, US, and ECG. Intraoperative fluoroscopy is the traditional modality for tip positioning. However, the availability, cost-effectiveness, and exposure to radiation limit the widespread use of fluoroscopy. Actually, the 2016 version of INS (the Infusion Nurse Society) guidelines advocates the avoidance of fluoroscopy during port insertion, except in difficult cases. Post-procedural CXR was also adopted for confirmation of catheter tip. This is nevertheless not amenable for port, because the adjustment of catheter, inevitably, needs another surgery as well as increased intraoperative risks. Tip positioning with US is attractive, as it allows the procedure to be performed faster and it does not subject the patient to radiation. At present, two routes of US are adopted: transesophageal echocardiography (TEE) and transthoracic echocardiography (TTE). Both TEE and TTE can identify the existence of PLSVC. Although TEE allows precise recognition of anatomical variances as well as the position of the catheter tip, it cannot be routinely adopted because of its invasiveness. TTE is noninvasive and has a high specificity for ruling out malposition. There are still disadvantages with this method, including relatively low sensitivity and only rough estimation of the tip position (intra-atrial vs extra-atrial). Direct visualization of catheter tip with TTE is sometimes difficult due to its small size and poor echogenicity. Thus, the role of TTE for precise tip positioning remains to be elucidated.

The IC-ECG is also easy to perform and is well established. This method utilizes the inserted guidewire or catheter as an intracavitary electrode, and by which the characteristic P-wave is recorded. If the tip is positioned in the pleural space or in the arterial system, a false “atrial” P-wave may be present. However, this is extremely rare with column of saline technique. False negative may be related to inappropriate placement of the electrodes and actually can be excluded during the procedure with careful examination. The electrocardiographic characteristics of PLSVC have been described by several surface ECG studies. Left axis deviation of P-wave in lead II or lead III is the usual finding. Ito-Hagiwara et al. found that a negative or positive/negative P-wave morphology in lead II or lead III suggested the presence of a PLSVC. Theoretically, IC-ECG has an advantage over surface ECG by the amplification effect, due to the closer placement of electrode to the origin of electrical signal. Moreover, the P-wave change may be explained partly by the relative normal origin of impulse and the direction of observation. In normal right sided SVC, the electrical vector of the heart is
Table 1. Characteristics of the patients and their catheters.

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<td>51</td>
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<td>Breast cancer</td>
<td>Breast cancer</td>
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<tr>
<td>Total chemotherapy cycles</td>
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<td>18</td>
<td>20</td>
<td>6</td>
<td>6</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
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<td>Med Comp</td>
<td>Med Comp</td>
<td>B. Braun</td>
<td>Med Comp</td>
<td>Med Comp</td>
<td>Med Comp</td>
<td>Perouse</td>
<td>Med Comp</td>
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<tr>
<td>Catheter length (cm)</td>
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<td>24</td>
<td>20</td>
<td>21</td>
<td>25</td>
<td>21</td>
<td>19</td>
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<tr>
<td>Catheter external diameter (Fr)</td>
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<td>6.6 Fr</td>
<td>6.5 Fr</td>
<td>6.6 Fr</td>
<td>6.6 Fr</td>
<td>6.6 Fr</td>
<td>7 Fr</td>
<td>7 Fr</td>
</tr>
<tr>
<td>Procedure timeb (min)</td>
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<td>11</td>
<td>25</td>
<td>10</td>
<td>12</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Catheter functionc (aspiration and injection)</td>
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<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
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<tr>
<td>Catheter dwelling time (days)d</td>
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<td>96</td>
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<td>None</td>
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NSCLC: nonsmall cell lung cancer.

*aMaintenance cycle: routine catheter flush after finish of chemotherapy.
*bProcedure time: from start of anesthesia to finish of skin closure.
*cAspiration: aspiration of blood; injection: infusion of liquid.
*dDetermined as removal date, or death of the patient, or last follow-up.
directed toward the exploring electrode, resulting in a positive deflection of P-wave in lead II. While in case of PLSVC, the electrical vector is directed away from the exploring electrode, and therefore produces a reversed waveform. Similarly, this type of waveform change can also be observed in IC-ECG guided port insertion through femoral vein in normal individuals.35 Abnormal sites of origin of atrial depolarization (e.g. the coronary sinus node) and abnormal atrial pathways may also contribute to this characteristic P-wave.33 Hence, this method depends on a recognizable P-wave, which is the only contraindication of this method.10 By our experience, even a pacemaker ignited P-wave could produce the typical waveform change as described above.

Currently, no consensus has been reached regarding the optimal position of the catheter tip in PLSVC. The tip should generally be placed outside the atrium.1,19 Thrombosis within the coronary sinus36 or atrium37 may be fatal and is usually related to dialysis catheters,37–39 which may need atrial thrombectomy. Although very rare, intraoperative complications like arterial puncture, mechanical damage to vessel wall, air embolism, and cardiac arrhythmia cannot be obviated. Butt et al.40 reported a case of cardiac tamponade caused by mechanical damage of a CICC inserted into PLSVC. Kawasaki et al.41 reported a case of dialysis catheter–related venous thrombosis, which was developed 4 h after insertion. Moreover, complications, such as catheter malfunction secondary to catheter malposition, venous thrombosis, catheter-related blood stream

Figure 1. IC-ECG pattern during catheter insertion in PLSVC patients: Arrow indicates (a) a small P-wave in lead III and a small negative P-wave in lead II, (b) increased negative deflection, and (c) a biphasic P-wave.

Figure 2. Post-procedure chest X-ray and corresponding chest CT image. Large arrow indicates the tip of port catheter. Small arrow indicates the catheter is inside the PLSVC. Arrow head indicates right sided SVC of the same patient.
infection, and possible vessel wall erosion, are major obstacles to long-term use, especially for dialysis catheters.13,42,43 Of note, about 10% of the PLSVC drains into left atrium, which increases the risk of paradoxical arterial embolism, either from thromboemboli or air embolus.1,19 Although several reports suggested the feasibility of chemotherapy with a catheter in PLSVC,12,19,44,45 we should still be prudent, because of the paucity of evidence. In fact, we closely monitor every patient once a PLSVC was identified and venous port inserted.

Conclusion

PLSVC is a rare congenital anomaly, which may cause problems or confusion in left sided catheterization. Since most PLSVCs are confirmed afterward, and the catheter tip may be incorrectly placed without any intraoperative imaging methods, it is extremely important to identify this venous anomaly during the procedure. Our series showed the feasibility of IC-ECG for recognition of the PLSVC intraoperatively, along with catheter tip positioning by the specific waveform. Although all the eight patients in our series used their ports without any complications, we should still be prudent in its use, due to the paucity of evidence especially in long-term situation. Generally, once a catheter is inserted into a PLSVC and before starting to use the catheter, a comprehensive consideration should be made regarding the anatomy of the specific patient, purpose of catheterization, type of catheter, tip of catheter, and duration of treatment.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

Because venous port insertion is a routine procedure in our hospital and all the patients were unknown of their anatomical anomalies, no prior agreement was obtained from our Ethical Committee. However, informed consent for the procedure was obtained from every patient.

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ORCID iD

Boqiang Fan https://orcid.org/0000-0003-4758-1597

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