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Evidence-Based Nursing Optimization for Catheter Tip Positioning in PICC Insertion in Patients with Persistent Left Superior Vena Cava

Qian Wang, Yaran Zhang, Haiqing Huang, Ziwei Xu, Xinxin Wang, Chenli Zhang, Shuqi Wang, Bo Xu*

Outpatient Department, Beijing Arion Cancer Center, Beijing 102600, China

**Author to whom correspondence should be addressed.*

Abstract: *Objective:* To explore the evidence-based nursing optimization strategy for catheter tip positioning during peripherally inserted central catheter (PICC) insertion in patients with persistent left superior vena cava (PLSVC). *Methods:* For one ovarian cancer patient with PICC malposition in the coronary sinus (CS) due to PLSVC, multi-modal imaging techniques were integrated to accurately locate the catheter tip. The catheter position was adjusted based on evidence (withdrawing 5 cm), and a standardized nursing process was established, including personalized health education, catheter fixation and displacement monitoring, complication monitoring, establishment of a specialized disease information archive system, and formulation of a follow-up plan. *Results:* The catheter tip was successfully withdrawn from the coronary sinus (at the T8 level) to the middle and lower part of the PLSVC (at the T6 vertebral level), and the catheter functioned normally after adjustment. No complications such as arrhythmia or thrombosis occurred during the 332-day chemotherapy period. *Conclusion:* The PICC tip in PLSVC patients should be positioned in the middle and lower part of the PLSVC (at the T5–T7 vertebral level). This new standard can effectively avoid CS-related complications. The integration of multi-modal imaging techniques and evidence-based nursing management are key to ensuring safe infusion.

Keywords: Persistent left superior vena cava; Peripherally inserted central catheter; PICC; Nursing

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1. Introduction

Persistent left superior vena cava (PLSVC) is a common congenital anomaly of systemic venous development, with an incidence of approximately 0.3–0.5% in the general population [1]. When it coexists with the right superior vena cava, it is called double superior vena cava (DSVC). The incidence of PLSVC is significantly higher in patients with congenital heart disease, reaching 2–10% [2]. Most individuals with PLSVC have no obvious clinical symptoms and are usually accidentally discovered during central venous catheter insertion, cardiac pacemaker implantation, or cardiothoracic surgery. In approximately 90% of cases, PLSVC drains into the right atrium

through the dilated coronary sinus (CS) [3]. This anatomical variation poses challenges for left upper extremity PICC insertion. If the catheter tip mistakenly enters the coronary sinus, infusion of high-concentration or irritating chemotherapeutic drugs may lead to serious consequences. From November 2021 to August 2025, our department completed more than 1,300 PICC insertions, among which 1 PLSVC patient was identified. This article aims to detail the diagnosis, treatment, and nursing process of this case, in order to provide references for peers.

2. Case report

2.1. Basic information

(a) Patient

Female, 55 years old.

(b) Chief complaint

"Postoperative chemotherapy for ovarian cancer"

(c) Diagnosis

Ovarian malignant tumor (clear cell carcinoma, Stage IV). Admitted to the hospital on July 10, 2024, scheduled to receive the first cycle of TC regimen (paclitaxel + carboplatin) chemotherapy.

To establish a long-term venous access, the patient underwent ultrasound-guided PICC insertion in the outpatient department of our hospital.

2.2. Pre-insertion assessment

2.2.1. Clinical assessment

The patient was in good general condition with stable vital signs, clear consciousness, and high compliance. Preoperative examinations such as blood routine, coagulation function, and electrocardiogram were all within normal ranges, and there were no contraindications to PICC insertion. The informed consent was signed.

2.2.2. Vascular assessment

The patient reported a preference for the right lateral decubitus position. To improve sleep quality and comfort, the left upper extremity was selected for catheter insertion after communication. Ultrasound assessment showed that the left basilic vein had a good inner diameter, smooth vessel wall, unobstructed blood flow, no thrombosis, and no obstacles in the puncture path, meeting the puncture conditions.

2.2.3. Body surface measurement

The patient was unknown to have a double superior vena cava before catheter insertion. The length was measured from the intended puncture point along the venous direction to the right sternoclavicular joint and then downward to the third intercostal space, with the measured catheter insertion length being 43 cm. The arm circumference of both upper extremities (10 cm above the elbow crease) was 27 cm, showing no difference.

2.3. Insertion process and tip localization

2.3.1. Puncture and catheter advancement

A 4F single-lumen PICC catheter (Bard, USA) was used, and successful puncture was performed in the left upper arm basilic vein under ultrasound guidance. When the catheter was advanced to 39 cm, "elastic resistance"

different from the conventional resistance was encountered, rather than the hard resistance caused by touching the vessel wall or venous valve. After adjusting the abduction angle of the patient's left arm to 60 degrees, the catheter could be slowly advanced to the predetermined length of 43 cm. After the operation, blood return was unobstructed, there was no resistance when flushing with normal saline, and the patient had no complaints of discomfort such as chest tightness or palpitations.

2.3.2. Preliminary imaging localization (chest X-ray)

Due to the abnormal hand feeling during intraoperative catheter advancement, a bedside chest posteroanterior X-ray examination was performed immediately after catheter insertion. The image showed abnormal course of the PICC catheter: instead of traveling to the right along the conventional path from the left subclavian area, the catheter descended vertically along the left edge of the aortic arch and the left contour of the heart, with the tip reaching deep into the cardiac contour, and its projected position was at the level of the 8th thoracic vertebra (T8). This characteristic image highly suggested the presence of a persistent left superior vena cava (PLSVC).

2.3.3. Accurate imaging localization and diagnosis (chest contrast-enhanced CT)

To clarify the exact relationship between the catheter tip and cardiac structures and determine whether it had entered the coronary sinus, after urgent communication with the attending physician, the patient was arranged to undergo a chest contrast-enhanced CT scan (see **Figure 1**). The results of CT angiography clearly diagnosed double superior vena cava malformation with the presence of PLSVC. The right superior vena cava was approximately 6 cm in length and 11 mm × 13 mm in diameter, while the left superior vena cava was approximately 7 cm in length and 15 mm × 18 mm in diameter. The PLSVC descended along the left side of the thoracic cavity, finally draining into the significantly dilated coronary sinus, which then enters the right atrium through the opening of the coronary sinus. CT showed that the PICC catheter tip had entered the coronary sinus along this path and then into the right atrium, with the tip located at the level of the T8 vertebra.

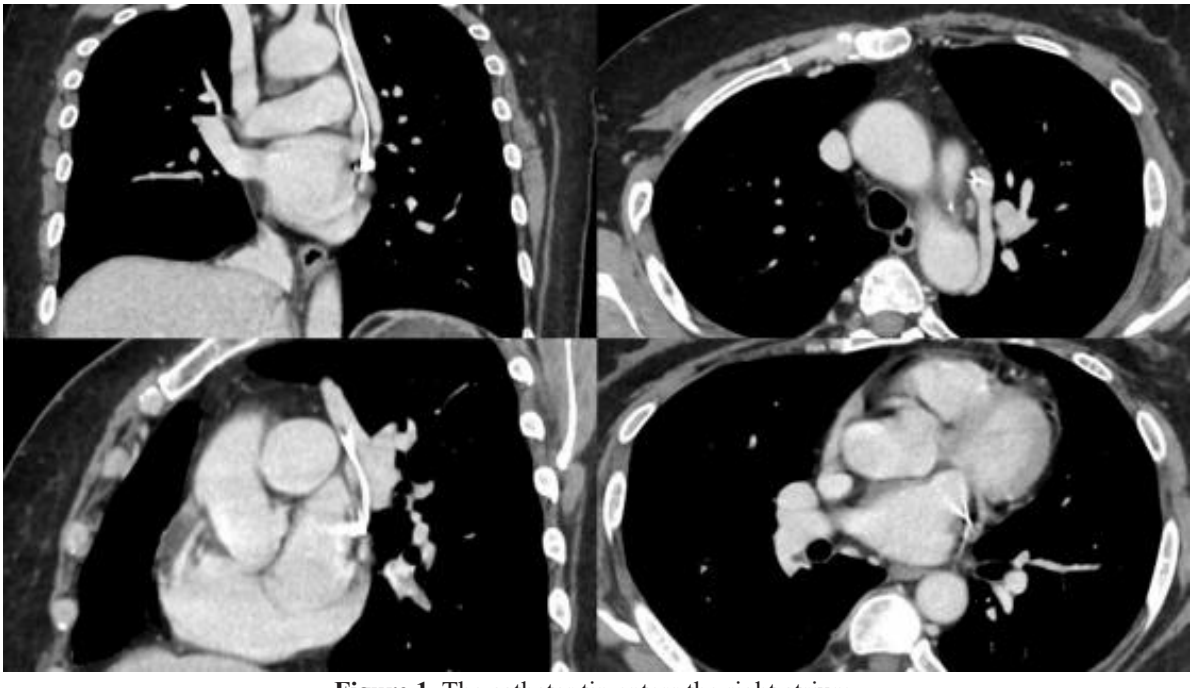


Figure 1. The catheter tip enters the right atrium.

2.3.4. Evidence-based adjustment of catheter tip position

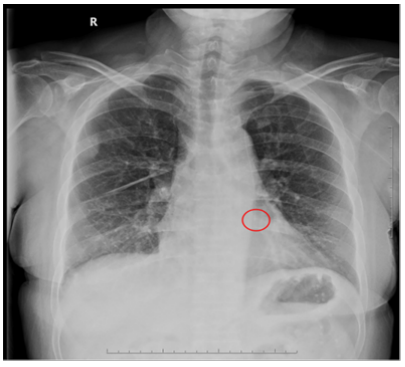
Studies have indicated that for patients with a persistent left superior vena cava (PLSVC), the optimal position for the tip of a peripherally inserted central catheter (PICC) should be in the middle-lower segment of the PLSVC itself (not fixed at the T6–T7 level) [4,8], i.e., before the entrance of the coronary sinus. This position not only ensures the blood flow dilution effect of central venous infusion but also minimizes stimulation and damage to the coronary sinus and intracardiac structures. If the catheter tip is placed inside the coronary sinus, the risks are extremely high, including as follow.

(1) Direct stimulation of the coronary sinus wall by chemotherapeutic drugs, which may lead to chemical phlebitis and arrhythmia

(2) Alteration of the pressure inside the coronary sinus, inducing angina pectoris, myocardial ischemia, or even myocardial infarction

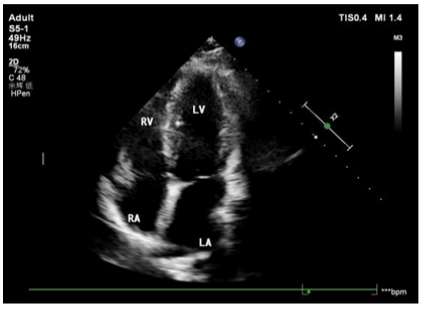
(3) Increased risk of coronary sinus thrombosis

Based on the CT positioning results; the catheter position was adjusted immediately. Under sterile conditions, the PICC was withdrawn 5 cm outward. An immediate bedside chest radiograph was performed, confirming that the catheter tip had retracted to the level of the T6 vertebra, located in the middle-lower part of the PLSVC. To avoid radiation exposure from CT scans for the patient, a bedside echocardiogram was also requested. Both the apical four-chamber view and subxiphoid two-chamber view of the echocardiogram showed no PICC echo in the right atrium, indicating that the catheter tip was away from the high-risk coronary sinus area. After adjustment, the catheter length was 38 cm, and both blood return and flushing functions of the catheter were normal (see **Figure 2**).

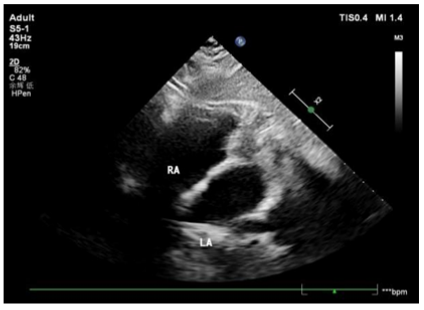


The catheter tip is located at the T8 level.

The catheter tip is located at the T6 level.



Apical four-chamber view shows no visualization of the PICC tip.



Subxiphoid two-chamber view shows no visualization of the PICC tip.

Figure 2. The location of catheter and PICC tip.

2.4. Catheter retention criteria for persistent left superior vena cava (PLSVC)

Based on the venous drainage site and associated malformations, PLSVC is clinically classified into 4 types: Type I (accounting for 90%) refers to PLSVC draining into the right atrium via the coronary sinus, with normal hemodynamics and no shunt; Type II PLSVC is based on Type I, with a shunt between PLSVC and the left atrium, resulting in partial right-to-left shunting; Type III PLSVC drains directly into the left atrium, with right-to-left shunting; Type IV PLSVC is directly connected to the left pulmonary vein. Anatomically, Type I has normal function due to unchanged hemodynamics; the other three types, however, have right-to-left shunting, causing part of the venous blood to flow into the left atrium and mix with oxygenated blood, resulting in a congenital malformation similar to anomalous pulmonary venous connection. After the catheter tip enters the persistent left superior vena cava, the decision on whether to retain the catheter is made based on the results of relevant examinations to determine the type, course, and whether the lumen diameter of the left superior vena cava is appropriate. Therefore, catheters can be retained for Type I PLSVC (draining to the right atrium) with a lumen diameter ≥ 15 mm, cases where the lumens of the bilateral superior vena cava are similar, isolated PLSVC, and those with a large lumen diameter confirmed by ultrasound [4]. In this case, the patient was confirmed by CT to have Type I PLSVC with a left lumen size of 15 mm × 18 mm, meeting the safety standards.

3. Core nursing strategies

3.1. Integrated application of multimodal imaging technologies in diagnosis and localization

3.1.1. Chest X-ray

It is the most basic and rapid preliminary screening tool. If an abnormal path of the catheter (inserted on the left side) running vertically downward along the left edge of the mediastinum is detected, further examinations should be initiated immediately.

3.1.2. Contrast-enhanced CT

It is the gold standard for confirming the anatomical course of persistent left superior vena cava (PLSVC) and accurately evaluating the three-dimensional spatial relationship between the catheter tip, coronary sinus, and right atrium [5]. In this case, CT examination played a key role in confirming the diagnosis and guiding subsequent adjustments, with the catheter tip placed in the middle and lower part of PLSVC (T5–T7).

3.1.3. Intracavitary electrocardiogram (IC-ECG) technology

Studies have confirmed that intracavitary ECG (IC-ECG) is the gold standard for real-time catheter placement and localization [6]. During catheterization, the position of the catheter tip in the middle and lower part of PLSVC can be judged in real time by monitoring changes in the P wave morphology (broad and inverted P wave) on the electrocardiogram.

3.1.4. Ultrasound

In addition to guiding puncture, cardiac ultrasound is also of great value in diagnosing PLSVC. By injecting microbubble contrast agent into the left arm vein, the dilated coronary sinus can be observed to opacify first, followed by the entry of bubbles into the right atrium, this is a typical sign for diagnosing PLSVC complicated with coronary sinus drainage. In this case, bedside ultrasound showed no PICC (peripherally inserted central

catheter) tip in multiple cardiac cavity sections, ensuring that the catheter tip was far away from the venous sinus.

3.1.5. Electromagnetic navigation & intracavitary electrocardiogram (EN-IC-ECG)

The EN-IC-ECG localization technology is an innovative PICC placement method. By integrating real-time position tracking of the electromagnetic navigation system and P wave morphology monitoring of intracavitary electrocardiogram, it significantly improves the accuracy and safety of catheter tip localization. The electromagnetic navigation technology uses the principle of electromagnetic fields to construct a 3D model of the catheter's path, which can dynamically display the position and direction of the catheter tip in the blood vessel in real time. Once the system detects leftward displacement of the catheter (into PLSVC) or deviation from the predetermined path (such as accidental entry into the brachiocephalic vein or internal jugular vein), it will immediately prompt the operator to make adjustments. The PICC tip localization technology combining electromagnetic navigation and intracavitary electrocardiogram can timely correct ectopic placement during catheterization, thereby enabling timely detection of vascular malformations and prevention of ectopic placement [7,8].

In the PLSVC diagnostic criteria, contrast-enhanced CT serves as the basis for confirmation, while IC-ECG technology and contrast-enhanced ultrasound play key auxiliary roles through real-time localization and blood flow visualization, respectively. Additionally, electromagnetic navigation combined with intracavitary electrocardiogram can real-time judge the path of the catheter tip. Together, these technologies optimize diagnostic efficiency and clinical outcomes.

3.2. Refined post-catheterization care and risk management

3.2.1. Personalized health education

After successful PICC insertion, in addition to routine PICC care education, it is necessary to use anatomical diagrams to explain the special vascular structure of Persistent Left Superior Vena Cava (PLSVC) to patients and their families in detail, so that they understand why strict monitoring of the exposed length of the catheter is required and why special symptoms such as palpitations need to be vigilant. Instruct patients to seek medical attention immediately if they experience chest tightness, palpitations, or limb swelling. Inform them that this information is crucial for any future treatment requiring central venous access or cardiac intervention.

3.2.2. Catheter fixation and displacement monitoring

Due to the vertical course of PICC in PLSVC and the tip being close to the cardiac activity area, changes in patient position, coughing, respiratory movements, etc., may cause the catheter tip to shift inward and slip into the coronary sinus again. Therefore, the StatLock catheter securement device must be used for firm fixation. The exposed length of the catheter should be accurately measured and recorded daily, and the StatLock should be replaced weekly. Any changes need to be vigilant.

3.2.3. Complication monitoring

Focus on monitoring cardiovascular symptoms related to coronary sinus stimulation. During chemotherapy infusion, use ECG monitoring to closely observe whether the patient has palpitations, chest tightness, and changes in heart rate and rhythm. Although no arrhythmia was found in this patient during the subsequent 332 days of use, the risk always exists, and monitoring cannot be ignored.

3.2.4. Establishment of a specialized disease information file system

This measure is very important. The file content includes: patient identification information, PICC diagnosis (with CT report and images), PICC-inserted upper limb, catheter model, final insertion depth and body surface scale, final tip CT positioning, ultrasound image report, bilateral arm circumference, cardiovascular disease history, family history, etc. In addition, a prominent warning label of "Persistent Left Superior Vena Cava" should be set in the electronic medical record system to remind all subsequent medical staff.

3.2.5. Establishment of follow-up plan

(1) Conduct timely follow-up after catheterization

With the first follow-up within 24 hours to assess catheter function and the exposed scale of the puncture site.

(2) Routine follow-up

Once a month if there is no abnormality; studies have pointed out that the risk of thrombosis increases after PICC catheterization, so the follow-up frequency should be increased to once a week when the patient is in an anticoagulant or hypercoagulable state (D-dimer > 500 μg/L), and intervention should be carried out at any time if problems are found [9].

(3) Follow-up content

Catheter length, exposed scale, presence of redness, swelling, itching or pain at the puncture site, presence of swelling in the catheter-inserted limb, catheter patency test, arm circumference measurement, complication screening (recheck ultrasound every 3 months to rule out thrombosis), and patient complaints.

4. Discussion and conclusion

4.1. Identification is the key

When placing a catheter in the left upper extremity, any abnormal "soft resistance" or "elastic feel" should be regarded as a potential sign of vascular variations such as persistent left superior vena cava (PLSVC), and forceful catheter advancement must be avoided.

4.2. Accurate localization is required

Once PLSVC is suspected, X-ray screening must be performed initially, and enhanced computed tomography (CT) or contrast-enhanced cardiac ultrasound is preferred for confirmation and precise localization. Chest X-ray alone may not accurately distinguish whether the catheter tip is in the lower segment of the PLSVC or has entered the coronary sinus.

4.3. Necessity of multidisciplinary consultation

The 2024 guidelines of the Infusion Nurses Society (INS) recommend that the tip of a peripherally inserted central catheter (PICC) should be located in the lower 1/3 of the superior vena cava (SVC) or near the cavoatrial junction (CAJ). However, the optimal position of the PICC tip for patients with PLSVC (a vascular variation) has not been clearly defined. Some studies suggest that the optimal position for the PICC tip in PLSVC patients is at the level of the lower edge of the 5th thoracic vertebra, rather than the traditional CAJ [10]. Conventional

body surface measurement methods are ineffective in this context. When an abnormal position of the PICC tip is encountered, timely multidisciplinary consultation can help determine the vascular course and lumen size through imaging diagnosis, enabling individualized adjustments under the premise of ensuring safety. Studies have found that echocardiography (especially transthoracic echocardiography) is a very effective and non-invasive method to confirm the catheter's position in the coronary sinus [4]. When doubts exist, the risk of complications is high, or the most precise information is needed, CT angiography is the most reliable diagnostic tool. Magnetic navigation combined with intracardiac electrocardiography (ECG) can real-time observe the direction of the catheter tip, but there is currently a lack of reported data on PICC placement in patients with PLSVC.

4.4. Upgrade of nursing management

PICC nursing for PLSVC patients is an "upgraded" version, requiring stricter displacement monitoring, more targeted complication observation, and more in-depth health education.

4.5. Knowledge sharing is essential

Establishing disease-specific records and setting up warning signs to translate the experience from individual cases into important institutional measures to ensure patients' long-term medical safety.

4.6. Pre-insertion assessment

In addition to routine clinical assessment content, the assessment of cardiovascular disease history and family history should be added, including inquiries about whether the patient has congenital heart disease or a family history of vascular malformations (e.g., double superior vena cava).

Through standardized nursing and evidence-based analysis of this rare case, we not only successfully ensured the patient's safe infusion for 332 days and avoided complications caused by the catheter entering the coronary sinus but also accumulated valuable experience for our department and other medical institutions in handling similar situations. This reflects the professional value of clinical nurse specialists in addressing complex vascular access issues.

5. Conclusion

In conclusion, positioning the PICC tip in the mid-lower PLSVC (at T5–T7) is recommended as a new standard to prevent complications. Ensuring safe infusion relies on the integration of multi-modal imaging and evidence-based nursing management.

Disclosure statement

The authors declare no conflict of interest.

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