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Modified Insertion of a Peripherally Inserted Central Catheter: Taking the Chest Radiograph Earlier

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Placement of the tip of a peripherally inserted central catheter in the lower third of the superior vena cava is essential to minimize the risk of complications. Sometimes, however, the catheter tip cannot be localized clearly on the chest radiograph, and repositioning a catheter at bedside is difficult, sometimes impossible. A chest radiograph obtained just after the catheter is inserted, before the guidewire is removed, can be helpful. With the guidewire in the catheter, the catheter and its tip can be seen clearly on the radiograph. If the catheter was inserted via the wrong route or the tip is not at the appropriate location, the catheter can be repositioned easily with the guidewire in it. Between January 1, 2007, and May 31, 2009, 225 catheters were placed by using this method in our department. Of these, 33 tips (14.7%) were initially malpositioned. The tips of all these catheters were repositioned in the lower third of the superior vena cava by using this method. No catheter was exchanged or removed. The infection rate for catheter placement did not increase when this method was used. This modification facilitates accurate location of the catheter tip on the chest radiograph, making it easy to correct any malposition (by withdrawing, advancing, or even reinserting the catheter after withdrawal). (Critical Care Nurse. 2011;31:64-69)

Vascular catheters facilitate hemodynamic monitoring and infusion of vasoactive medications and hypertonic solutions into the central circulation. The use of vascular catheters is one of the most important and essential interventions in critical care units.

Use of a peripherally inserted central catheter (PICC) is one of the options. Traditionally, PICCs have been placed by physicians. Bedside insertion of PICCs by specially trained nurses is now common in many medical centers. PICCs have been suggested as an alternative to standard central venous catheters, as PICCs have lower risk of adverse events, including pneumothorax, neurovascular injury, bloodstream infections and, rarely, cardiac tamponade, but fulfill the requirements for multilumen central venous access and hemodynamic monitoring. Results of clinical studies indicate that a central location for the PICC tip is essential to minimize the risk of complications such as phlebitis, venous thrombosis, cardiac arrhythmias, and cardiac rupture.

Position of the PICC Tip
The best location for the tip of a PICC is the lower third of the superior vena cava (SVC), close to the junction of the SVC and the right atrium. The SVC is the second largest vein in the body, about 7 cm long and 2 cm in diameter, and has no valves. With its tip in this location, the catheter can float freely within the vein lumen and lie parallel to the vessel wall without impinging on the wall. Solutions infused through the SVC will be diluted by rapid blood flow. The 3 pathophysiological factors that lead to thrombus formation are injury of the endothelium of
the vein, circulatory stasis, and hypercoagulability. When the catheter tip lies outside the SVC, vein curvatures, junctions, venous valves, and smaller vein diameter increase the possibility of contact of the catheter tip with the vein wall. This contact disrupts the endothelial cell layer of the tunica intima, exposes the basement membrane, and triggers the clotting process. Smaller vein diameters indicate smaller amounts of blood flow, leading to increasing irritation from some chemical solutions, such as high-concentration potassium chloride solution. Thus the mechanical irritation of the vessel at the catheter tip is compounded by the chemical irritation from the solution being infused. The vessel wall irritation results in endothelial trauma and vessel wall inflammation, triggering a thromboplastic response. Blood flow stasis often accompanies these changes, resulting in vessel thrombosis. The blood clot that forms around the catheter can extend into the central veins toward the right atrium and rarely may be a source of pulmonary embolism. If the catheter tip is in the right atrium, pericardium, or the lower part of the SVC, it can come in contact with the myocardium. Catheter tips in these locations can lead to cardiac arrhythmias, cardiac rupture, or cardiac compression complications.

We describe our experience in modifying the procedure for inserting a PICC to enable physicians or specially trained critical care nurses to optimize placement of the catheter tip before the guidewire is removed or the catheter is cut.

**Shortcomings of the Standard Procedure for PICC Insertion**

As described in the instructions for use of the Groshong PICC, the brief standard procedure for PICC insertion includes 10 steps (Table 1). Following this standard procedure, a PICC was placed by using external landmarks and approximate measurement at the bedside. The tip placement was confirmed by chest radiography after the guidewire was removed and the catheter was cut, but before the catheter was secured.

On the fluoroscopic monitor or on the radiograph, the lower third of the SVC, the best location for the PICC tip is the area no more than 2 cm below the image of the main right bronchus. Because the external measurement can never exactly duplicate the internal venous anatomy, tip malposition is relatively frequent with bedside placement of PICCs. Sometimes the tip of the PICC is not in the SVC, and sometimes the tip of PICC is in the SVC but not in the best spot, in the lower third of the SVC. When using the sternal notch and the third intercostal space as landmarks, nurses have a 65% to 70% success rate of placing the catheter tip in the lower third of the SVC on the first try. A blindly placed PICC initially may have a nonoptimal position of the PICC tip that requires additional manipulation. If a “long” catheter is being used; that is, if a catheter tip is in the right atrium or in the right ventricle or beyond, which happens less often, tip placement can be corrected by withdrawing the catheter. Conversely, if the catheter is “short,” that is, if the tip is located

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**Table 1** Standard procedure for insertion of peripherally inserted central catheters

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Site selection</td>
</tr>
<tr>
<td>2.</td>
<td>Length determination: For placement in the superior vena cava, measure from the planned insertion site over to the sternal notch, then down to the third intercostal space</td>
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<tr>
<td>3.</td>
<td>Preflushing catheter</td>
</tr>
<tr>
<td>4.</td>
<td>Site preparation</td>
</tr>
<tr>
<td>5.</td>
<td>Venipuncture</td>
</tr>
<tr>
<td>6.</td>
<td>Catheter insertion</td>
</tr>
<tr>
<td>7.</td>
<td>Suture wing attachment and removal of the guidewire</td>
</tr>
<tr>
<td>8.</td>
<td>Modification of catheter length and connection attachment</td>
</tr>
<tr>
<td>9.</td>
<td>Placement verification: verify location of catheter tip on radiograph</td>
</tr>
<tr>
<td>10.</td>
<td>Securing the catheter</td>
</tr>
</tbody>
</table>

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in the upper or middle third of the SVC or in the innominate veins, tip placement may be corrected by advancement only if the catheter has not been cut too short to reach the lower third of the SVC; otherwise, placement can be corrected only by insertion of a new catheter. Finally, the tip of the catheter may be inadvertently positioned in the internal jugular vein or in other thoracic veins (eg, internal mammary vein, azygos). In these cases, the catheter position must be corrected by withdrawing the catheter first and then reinserting it. Withdrawing a catheter without a guidewire from the vein is easy, but advancing or reinserting the long, thin, soft, and hollow catheter is difficult and usually impossible in clinical practice. Trerotola et al report that about 58% of attempts to correct malpositioning at the bedside failed and the catheter could be positioned correctly only by insertion of a new catheter.

Another problem that we observed is that although the PICC is radiopaque, some catheter tips cannot be localized clearly on a standard posteroanterior chest radiograph because the high density of the sternum and the thoracic vertebrae causes marked attenuation of the X-rays (Figure 1). One hundred chest radiographs taken after a PICC was placed were interpreted by 2 radiologists to determine the position of the catheter tip; the 2 radiologists were discrepant in localization of the PICC tip in 41% of the radiographs, and 4% had the annotation “difficult to identify the position of the tip” although the 2 radiologists’ localizations of the PICC tip were similar.

**Modification of PICC Insertion**

In order to place the catheter tip in the best spot and to minimize problems, time, and costs related to repositioning these catheters, the staff in our department modified the insertion practice. Just after PICC insertion, before the guidewire was removed and the catheter was cut, a chest radiograph is taken to identify where the catheter was inserted, the approximate size of the catheter, the route taken, and the location of the catheter tip. If the catheter was malpositioned, it can be advanced or reinserted easily with the guidewire in it (Figure 2).

**Figure 1** Standard posteroanterior chest radiograph shows peripherally inserted central catheter (PICC, arrows) but the tip of the PICC cannot be localized clearly because of the high density of the sternum and thoracic vertebrae, which causes marked attenuation of X-rays.

**Figure 2** Chest radiographs obtained at bedside with portable radiographic equipment after insertion of a peripherally inserted central catheter (PICC) in a 44-year-old man with non–small cell lung cancer. **A,** The PICC was inserted via the wrong route and the tip of the PICC (arrow) was in the right internal jugular vein; the inset shows a magnified view of the route and the tip of the PICC (arrows). After the patient’s posture was changed, the catheter was withdrawn and reinserted with the guidewire in it at bedside. **B,** Another chest radiograph shows the PICC (arrow) with its tip in the lower third of the superior vena cava.
This modification of the PICC insertion procedure offers 3 advantages: (1) the tip of the PICC can be seen more clearly on the chest radiograph with the metal guidewire still in place; (2) the catheter can be withdrawn and reinserted easily (much like the first insertion) with the guidewire in it; and (3) the guidewire can help prevent the catheter from kinking inside the vessel during repositioning.

Cost-effectiveness is another concern. The most commonly used PICCs in China, the Groshong (Bard Access Systems, Salt Lake City, Utah) and the Blue FlexTip (Arrow International Inc, Reading, Pennsylvania), are expensive (about $220 per catheter) and the cost of a digital chest radiograph is about $20 in China. As described before, about 58% of attempts to correct PICC malpositioning at the bedside were unsuccessful and the catheter had to be exchanged. We wonder if use of this modification in insertion procedure can reduce the rate of catheter exchange when correcting malpositioned catheters.

Clinical Application of This Modification

A preliminary study was conducted to determine the feasibility and potential complications of this modification in the procedure for PICC insertion.

Materials and Patients

Single-lumen Bard Groshong PICC (Bard Access Systems) 4F catheters are used in our patients. From January 1, 2007, to May 31, 2009, all suitable patients in our department had PICCs placed by using this method. This modification was approved by the scientific and ethics committee of our hospital, and informed consent was obtained from all the patients.

PICC Insertion

In clinical operation, the 2 modifications made to the PICC insertion process were to (1) take the chest radiograph earlier and (2) take additional measures to prevent infection. The revised procedure for PICC insertion is shown in Table 2.

The following demographic information was collected and recorded: sex, age, indication for PICC, site of insertion, date of PICC insertion, tip location after insertion and for malpositioned tips, results of attempts to correct malposition, and the nature and timing of complications.

Results

Between January 1, 2007, and May 31, 2009, 225 PICCs were placed by using this method in our department. Of these, 33 tips (14.7%) were initially malpositioned (not in the lower third of the SVC). That incidence of malposition is similar to the incidences reported in other studies. Malpositioned tips were located in the upper or middle third of the SVC, the ipsilateral subclavian vein, the right atrium, the ipsilateral internal jugular vein, and the axillary vein. In 1 case, the tip was coiled in the SVC (Table 3). Malposition was corrected by advancing the catheter in 23 cases (69.7%), withdrawing the catheter in 5 cases (15.2%), or reinserting the catheter after withdrawing it in 5 cases (15.2%; Figure 3). The tips of all the PICCs in these patients were placed in the lower third of the SVC. No catheter was exchanged or removed. The short-term rate of infective
complications (within 5 days after insertion) was 3.1%, no greater than the rate for PICCs inserted in our department before this method was used (4.34%; between August 1, 2004, and November 31, 2006). The incidence of short-term infective complication is similar to rates reported in other studies.40,41

Discussion

In our study, malpositioned PICC tips were located in the upper or middle third of the SVC, the ipsilateral subclavian vein, the right atrium, the ipsilateral internal jugular vein, the axillary vein, and coiled in the SVC. The tip locations and incidences are similar to those reported in other studies.32,38,39 These reports show that about 58% of malpositions were corrected with catheter exchange, and 83% were corrected by repositioning the catheter in the interventional radiology division under imaging guidance.32,38,39 In this study, we demonstrated a modification of PICC insertion: taking the chest radiograph earlier, which makes it easier to correct malpositions at the bedside, with high success rates and without catheter exchange.

To place the tip of a PICC in the proper location, Pittiruti et al41 reported an electrocardiographic method of determining the terminal location of the tip during insertion of the PICC. This method uses the changes in the P wave of the electrocardiogram to monitor the tip of the PICC during insertion. But in situations where the P wave is not present or not readable (atrial fibrillation, atrial flutter, marked tachycardia, pacemaker-driven rhythm), that method cannot be used. Still other devices can help locate the tip of a PICC, such as the Sherlock Tip Location System42 and the Electromagnetic Detection System,41 but these private devices are expensive and the operator needs special training.31,42,43 On the other hand, radiographic confirmation of the tip location cannot be omitted even if the PICC was inserted with the help of all these devices. According to the Infusion Nurses Society’s 2006 standards of practice,39 locations of all central catheter tips shall be determined radiographically and documented before the start of the prescribed therapy.

This modification may increase the risk of infection because the patient must be transported to the radiology department for chest radiography. This limitation can be overcome by protecting the patient from contamination of the insertion site when the insertion procedure is interrupted and during transport. Third, this study is retrospective; the clinical availability and the potential complications of the modification deserve further investigation in large-scale prospective randomized controlled studies.

Implications for Nurses

For nurses who are inserting PICCs, the implications are the same as those for physicians: (1) the need to be vigilant about protecting the patient from contamination of the insertion site when the insertion procedure is interrupted and during transport and (2) monitoring carefully for infection and any of the other possible complications of PICCs, such as phlebitis and venous...
thrombosis, after insertion. Nurses must demonstrate strict adherence to hand hygiene practices and aseptic technique, using maximum hand hygiene and aseptic technique and using maximal sterile barrier precautions during the procedure.

Physicians and critical care nurses must collaborate to ensure that standards of practice related to PICC insertion and ongoing management are established and followed by all staff.

Conclusion

We introduced a modification of the practice for PICC insertion: take a chest radiograph before removing the guidewire and cutting the catheter to determine the route that the catheter took and the location of the catheter tip. Our practice indicates that this modification facilitated accurate location of the tip of the PICC on chest radiographs and made it easier to correct such malposition (by withdrawing, advancing, or even reinserting the catheter after withdrawal). The clinical availability and the potential complications of this modification deserve further investigation in large-scale studies.

References

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