



Novel Catheter Positioning System for Intravenous Central Lines: A Report of 1 Hospital's Experience

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Abstract

Background: Malpositioned peripherally inserted central catheters (PICCs) can create serious complications. Confirmatory chest radiographs, the standard method for certifying proper central-catheter tip position, are sometimes imprecise and unreliable. James A. Haley Veterans' Hospital tested an advanced electronic positioning system for central lines that could hypothetically reduce malpositions. Little data has previously been published about this technology.

Methods: Before the positioning system could be approved for use at the hospital, efficacy data had to pass reviews by multiple individuals/entities. The hospital's PICC team initially conducted a 2-week trial of the vascular positioning system, using it on 28 patients. Permission was granted to continue using the new system and to request acquisition of the technology. Use of confirmatory radiographic images continued during this further evaluation.

Results: The overall malposition rate during the first 12 months of system use was reduced by about half—a statistically significant finding. The system could be used optimally with 594 of 834 placements (71.2%) at an accuracy rate of 98.5%. The system could be used suboptimally (eg, with patients who have pacemakers) for 240 of the 834 placements, at an accuracy rate of 84.6%. The overall malposition rate was 5.5%—about half the 10.8% rate seen during the 12-month period before system use.

Conclusions: The statistically significant results, from the largest data set reported at 1 site using the system, were judged sufficient to switch to using the system instead of confirmatory radiographic images when the system indicated correct PICC placement in the heart's cavoatrial junction. The malposition rate with the system continues to improve as the PICC team gains experience in using the system. Additional study is needed on this and other positioning systems.

Keywords: catheter positioning system, Doppler, ECG, malposition, PICC

Background

When patients need vesicant or irritant medications, nutrients, or other fluids administered over a long period, a central venous line (CVL)—either a central venous catheter (CVC) or peripherally inserted central catheter (PICC)—is normally chosen for the task. Of the >5 million CVLs inserted in the United States annually,¹ a

significant and growing percentage are PICCs. The placement procedure for PICC can present risks to patients that on rare occasions are severe. We report 1 hospital's initial experience with efforts to reduce risks associated with improper PICC placement. It is believed to be the most extensive data so far reported on positioning system technology (ARROW VPS Vascular Positioning System, Teleflex, Inc, Research Triangle Park, NC).

A PICC insertion originates in a peripheral vein such as the cephalic vein, basilic vein, or brachial vein. The catheter is then guided through the venous system to its ultimate destination: the lower one-third of the superior vena cava (SVC) cavoatrial junction (CAJ). It is true that the overall complication rate for PICC insertions is low, but some complications do

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<http://dx.doi.org/10.1016/j.java.2014.05.003>

Published by Elsevier Inc. on behalf of the ASSOCIATION FOR VASCULAR ACCESS.

occur during the insertion process with enough frequency to be worth noting:

- Hemorrhage, vascular spasm, and arterial puncture are among the most common vascular complications.²
- Nerve-related complications may occur, including injury to the peripheral nerves and brachial nerve plexus.²
- Cardiac tamponade, air embolism, hemothorax, hydrothorax, and thoracic duct injury may occur during PICC insertions, although the risk is low because the insertion site is farther from the central circulation system.²
- Malposition of the catheter can cause potential dangers that often stem from a combination of the potentially harmful nature of some intravenous (IV) fluids if misdirected, and the critical functions of the anatomy involved. Malposition can also lead to the complication of venous thrombosis because of the chronic irritation engendered by a malpositioned tip.³
- Finally, occlusive complications and their downstream effects such as infiltration and extravasation can result from catheter tips malpositioned too high in the SVC.⁴ Occasionally after a difficult insertion in which a PICC is unable to be threaded into the SVC, the catheter might be left in place so that the patient has access to IV fluids, medications, and blood draws, even though the catheter is known to be short. Leaving the malpositioned device in place in such a case is a temporary solution while vascular access personnel wait for an interventional radiologist to place a tunneled catheter.

For many years the standard method of certifying proper central-catheter tip position has been the use of confirmatory chest radiograph. This method is imprecise and unreliable, with different radiologists often reaching different conclusions about the same image. Not infrequently, the tip position cannot be identified in a radiograph with any degree of confidence.^{3,5,6} Recently, advanced electronic positioning systems for central lines have emerged that are designed to guide CVC insertions. If they perform as intended, these systems could potentially help reduce the incidence of catheter placement-related complications. Unfortunately, there is only minimal data published on the efficacy of these devices.

At James A. Haley Veterans' Hospital (JAHVH) in Tampa, FL, our PICC team decided to conduct a trial of a central line positioning system (Vascular Positioning System [VPS], Teleflex, Inc), with the dual goal of improving the malposition rate of PICC line insertions and reducing delay-of-therapy while waiting for PICC tip position to be confirmed following insertion. The 2-person PICC team at our hospital inserts all PICC lines, including for the Spinal Cord Injury Unit and the Community Living Center (formerly called the Nursing Home Care Unit). The team inserts approximately 1,000 PICC lines per year. During the 12 months before using the VPS, the team inserted 1,032 PICC lines with a malposition rate of 10.8%. The malpositions encompassed 40 lines terminating in the right atrium, 46 terminating in the jugular vein, and 25 lines terminating in another vessel.

Teleflex, Inc, provided no financial support for the trial. The hospital was allowed to use the device for 2 weeks without charge before having to make a decision to purchase it. Teleflex also provided free training on the device and made technical staff available during regular business hours for telephone and in-person consultation and troubleshooting.

JAHVH is a tertiary care facility classified as a Clinical Referral Level 1 Facility. It has 415 beds, including 100 beds in its Spinal Cord Injury Unit, 118 beds in its Community Living Center, and 33 Domiciliary beds. Its patient population is primarily adult men and the average age of enrolled veterans is 61 years.

Project and Methods

Before implementing new central line vascular access technology, JAHVH, as at any institution, required a number of steps involving various individuals and entities. The internal review board determined that approval was not needed for this project. The central line positioning system was demonstrated in front of the PICC team, the assistant chief of radiology, and the PICC Program director. The radiology department was included as part of the evaluation because buy-in by this department was needed if a chest radiograph was to be eliminated in these circumstances.

The positioning system uses a combination of Doppler ultrasound and intravascular electrocardiogram. The latter provides a P-wave, which represents the spread of electrical activity over the atrium. The positioning system displays a green arrow directing the clinician to keep advancing when correct placement has not yet been reached but the catheter is moving in the proper direction (ie, with the flow of blood toward the heart). A yellow triangle appears on the screen to indicate that the catheter tip is possibly against the vessel wall or has retracted inside the catheter, and that the catheter should be pulled back and redirected. If an orange circle appears, this is an indication that the clinician should stop advancing the catheter because it is moving against the flow of blood. As with the yellow triangle, the catheter should be pulled back and redirected at this signal.

A steady blue bull's eye appears on the positioning system screen to indicate correct placement in the lower one-third of the SVC and the CAJ, which is the optimal final tip location according to guidelines from the Association for Vascular Access and Infusion Nurses Society.^{7,8}

The positioning system is still useful when a blue bull's eye cannot be obtained. This circumstance may occur when a patient has a pacemaker or has a diagnosis of atrial fibrillation, which is the most common irregular heart rhythm. In the presence of atrial fibrillation or pacing, a P-wave cannot be obtained, and nurses have to rely on the Doppler signal alone. When a blue bull's eye is not achieved, a confirmatory radiograph is required.

The device was initially tested for 2 weeks on 28 patients. During that time, the team achieved 18 blue bull's eyes (indication of proper tip position), 17 of which were confirmed by radiograph for location of the tip in the CAJ. One of the 18 placements was determined to be in the atrium. Of the other 10 cases where a green arrow was achieved (indicating the catheter was moving in the proper direction toward the heart and with the flow of blood), 9 placements were in the SVC

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