A randomized, controlled trial evaluating postinsertion neck ultrasound in peripherally inserted central catheter procedures

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LEARNING OBJECTIVES

1. Describe the procedure for locating a catheter tip by ultrasound.
2. Explain the indications for use of these catheters.
3. Use this information in a clinical setting.

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Objective: **Insertion of peripherally inserted central catheters (PICCs) at the bedside may result in tip malposition. This study was designed to evaluate whether the addition of ultrasound (US) inspection of the ipsilateral neck provides immediate recognition of PICCs in aberrant position facilitating catheter reposition before completion of the procedure.**

Design: **Randomized, controlled trial.**

Setting: **University-affiliated hospital.**

Patients: **Totally, 300 patients ordered for PICC placement.**

Interventions: **Patients were randomized to either postinsertion US inspection of the ipsilateral neck (intervention, n = 151) or to usual practice (control, n = 149). In the intervention group, catheters detected by US to be traveling within the ipsilateral internal jugular vein (IJ), were further adjusted before procedural completion. All procedures included US localization of the peripheral vein and postprocedural chest radiograph to assess catheter tip position. The primary end point was defined as the rate of PICC tip malposition in the ipsilateral IJ as detected by postprocedure chest radiograph. The secondary end point was procedure duration.**

Measurements and Main Results: **In the control arm, 140 of 149 PICC placement attempts (94%) were completed, including 11 procedures with catheter tips terminating in the ipsilateral IJ (7.9%). In the intervention arm, 142 of 151 attempts (94.7%, $p = 0.98$) were completed; one procedure resulted in a catheter tip in the ipsilateral IJ (0.7%, $p = 0.007$). Eleven intervention procedures included successful PICC repositioning during the initial procedure based on US detection of malposition. The median duration of the procedure in the control group was 8 minutes (6–10.5 minutes) and increased to 9.0 minutes (7–11 minutes) in the intervention group.**

Conclusions: **Bedside PICC placement morbidity can be reduced via US inspection of the ipsilateral neck for PICC tip malposition in the IJ. This modality can guide catheters to be successfully repositioned during the initial procedure. (Crit Care Med 2009; 37:1217–1221)**

KEY WORDS: peripherally inserted central catheter; ultrasound; malposition; central venous catheter; internal jugular vein

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Vascular access in both hospitalized and ambulatory patients is commonly needed for intravenous infusion of medications, blood products, and parenteral nutrition as well as for phlebotomy. The peripherally inserted central catheter (PICC) provides effective short-term and intermediate-term intravenous access, and confers several advantages over other central venous catheters: bedside insertion under local anesthesia, a low risk of major hemorrhage, and no risk of pneumothorax. However, investigations have questioned the performance and safety of PICCs vs. central venous catheters. Prospective studies of inpatients demonstrated similar rates of catheter-related bloodstream infections for both catheter types (1, 2). Additionally, increased rates of complications with PICCs have been documented, including catheter malposition, phlebitis, and thrombosis (3).

Despite the uncertain cost–benefit ratio, increasing demand for PICCs has led to the development of venous access teams that specialize in the bedside placement of such catheters (4–6). These services permit expeditious placement of the devices with a concomitant reduction in the demand on the interventional radiology division; however, the shift in environment limits the tools available for the procedure.

Procedural success, via improved venipuncture accuracy, has improved with the availability of portable ultrasonography (5, 7–9). However, fluoroscopic guidance for tip positioning is generally not used by PICC teams operating at the bedside thus, tip malposition continues to be problematic, worsening the catheter's complication profile. Although extensively debated, the recommended tip position for PICCs is in the distal third of the superior vena cava (SVC) or close to the junction of the SVC and right atrium (10). This tip location allows the catheter to float freely within the vein lumen and lie parallel to the vessel wall, resulting in a considerable reduction in such complications as venous thrombosis, venous perforation, and catheter-related bloodstream infection (11, 12).

Previous observational studies have demonstrated that catheter tip malposition can occur commonly with rates of 10% to more than 60% (4, 13–18). One type of malposition frequently encountered is the passage of the catheter from the peripheral vein into the ipsilateral internal jugular vein (IJ) (Fig. 1). The byproduct of such malposition is at least a second procedure, including catheter withdrawal, resuturing, and repeat chest radiograph (if the infused solution is amenable to a midline catheter). Alternatively, if the SVC position is mandated, such as with parenteral nutrition or chemotherapy, the catheter must be changed over a wire or a new catheter must be placed—markedly increasing the burden on both the patient and the operator.

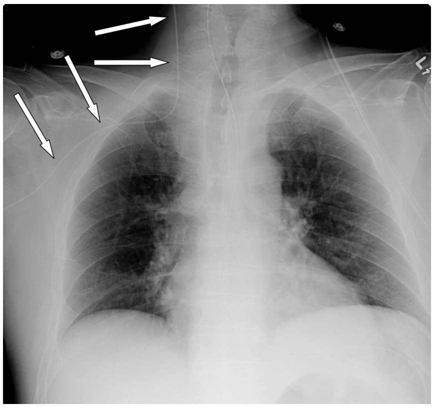

Figure 1. Chest radiograph demonstrating right peripherally inserted central catheter coursing through the ipsilateral internal jugular vein (malposition). Arrows demonstrate the course of the catheter.

We propose to evaluate the role of postinsertion neck vein ultrasound in evaluating the position of a PICC line. Ultrasound use may permit more rapid identification of catheters malpositioned in the ipsilateral IJ and afford readjustment of the catheter before completion of the initial procedure.

MATERIALS AND METHODS

Patient Population

The University of Chicago Institutional Review Board approved the study protocol, and verbal informed consent was obtained from participants. Study personnel screened adult patients (≥18 years) referred for placement of a PICC line via the institution's procedure service. Patients were excluded only if appropriate informed consent was not feasible or if they had undergone previous PICC line insertion at the institution.

Randomization

Patients were randomly assigned in a 1:1 manner to placement with ipsilateral neck ultrasound or standard practice using a computer-generated, permuted-block randomization scheme.

Figure 2. B-mode ultrasound image of an internal jugular vein (transverse view) with a peripherally inserted central catheter line within the vessel lumen. Arrow points to the echogenic intraluminal catheter. Note the shadow effect (hypoechoic signal) distal from the catheter highlighting its presence.

Study Protocols

Types of Catheters

All catheters were made of silicone and manufactured by Boston Scientific (Glen Falls, NY). The sizes included single-lumen catheters of 18 gauge (4F) or double-lumen catheters of 16 gauge (5F).

Insertion Technique. PICC insertion technique has been described in detail by others (19). All procedures used a uniform ultrasound device (Sonosite TITAN; Sonosite; Bothell, WA) equipped with a 5–10 MHz linear array transducer to image the peripheral vein for catheter entry. All operators used B-mode (two-dimensional) ultrasound in a transverse view to visualize the vein, proximate artery, and optimal access site, and to guide venipuncture in real time. Catheter introduction was established using the Seldinger technique. Catheter length was trimmed based on measurements from the site of venipuncture to 1–2 cm below the suprasternal notch to meet the goal of catheter position within the SVC (applied universally, regardless of catheter indication). Previously described maneuvers to avoid tip malposition (e.g., turning the head toward the insertion

Table 1. Characteristics of the study population

	Insertion Technique		
	Control (n = 149)	Neck Ultrasound (n = 151)	p Value
Female, n (%)	76 (51%)	80 (53%)	0.82
Age (mean yrs ± SD)	52 (39–65)	50 (41–59)	0.23
Right arm accessed, n (%)	79 (53%)	85 (56%)	0.41
Indication for catheter placement, n (%)			0.20
Total parenteral nutrition	23 (15%)	32 (21%)	
Antibiotic	92 (62%)	78 (52%)	
Other medication	34 (23%)	41 (27%)	
Unable to access	9 (6%)	8 (5%)	0.98

side and tilting the chin to the chest, digital pressure applied to the ipsilateral supraclavicular fossa) were used in all patients (14, 18, 20).

Ultrasound Surveillance. In the intervention group, on completion of the line insertion, before breaking the sterile field, the ultrasound examination was performed. B-mode ultrasound using a 5- to 10-MHz linear array transducer was used to visualize the course of the IJ in the transverse view. The IJ was recognized by the one or more of the following features: compressibility, nonpulsatile nature, and distensibility by Valsalva or Trendelenberg position. Catheters were recognized as echogenic in the otherwise hypoechoic (blood) contents of the IJ, commonly paired with catheter-related shadow artifact (Fig. 2).

This ultrasound evaluation was facilitated by either of the following: 1) the procedure nurse repositioning the sterile barrier to permit the operator to use the nondominant hand to scan the neck outside of the sterile field, or 2) the nurse (experienced in ultrasound application) scanning the ipsilateral neck beneath the sterile field with the operator viewing the images. If the catheter was found in the IJ and the first option was selected, the ultrasound probe was left off the sterile field and the operator regloved and gowned. Then, for all patients with a visualized catheter within the IJ (using either option of detection), the operator withdrew the catheter and reattempted proper positioning (including head turn, chin tuck, and digital occlusion maneuvers) (14, 18, 20). No limit was placed on the number of repositioning attempts. If the catheter was not observed in the neck, the drapes were removed.

All patients underwent a postprocedural chest radiograph to confirm catheter tip location.

Data Collection. Procedural details, including patient demographics, catheter type, site selection, procedural duration, and details of repositioning attempts were recorded by the procedure service nurse. Procedural duration was defined as the time from administration of the local anesthetic (after sterile barriers established) to the removal of the sterile field (equipment setup was identical between the two groups). The gold standard for tip location was the postprocedural chest radiograph, interpreted by a pulmonologist blinded to study group assignment and cross-referenced against the formal radiology interpretation (also blinded to the study group).

Assessment of End Points and Follow-Up. The primary end point was defined as the rate of PICCs in the ipsilateral IJ malposition as detected by postprocedure chest radiograph. The secondary end point was the duration of the procedure.

Statistical Analysis

On the basis of a pilot study, we expected ~10% of PICCs to be in an aberrant position in the ipsilateral IJ in the control group. Thus, we calculated that a sample size of 300 patients would be needed to detect a reduction in incidence of such a malposition from 10% to 1% within the experimental group with 80% power and a two-sided significance level of 0.05.

Data were analyzed using an intention-to-treat approach. Nonparametric data were analyzed with Mann-Whitney *U* tests. These data are presented as median values (with 25th and 75th percentiles). Nominal data were analyzed by chi-square analysis with Yates's continuity correction or by Fisher's exact test, as appropriate.

RESULTS

Patients/Procedures. From October 2004 to March 2006, 338 patients were eligible for enrollment. Twenty-eight patients were excluded for an inability to obtain informed consent and ten patients had a PICC placed previously at the institution. Totally, 300 patients were enrolled: 149 patients were randomly assigned to the intervention group ("neck ultrasound") and 151 to the control group.

Demographic information, procedural detail, and chest radiographs were available for all 300 patients enrolled; procedural duration data were available in 140 of 149 control patients and 141 of 151 intervention patients. The two groups were similar with respect to baseline demographics, indication for line placement, and ability to accomplish venipuncture and catheter threading (Table 1). Venipuncture and catheter threading was accomplished in the initial PICC procedure in 94% of the control patients (140 of 149) and 95% of the intervention patients (142 of 151, $p = 0.98$).

Outcomes. In the control arm, 11 of the 149 attempted PICCs resulted in the ipsilateral internal jugular vein malposition (7.4%) compared with 1 of the 151 threaded PICCs in the intervention group (0.7%, $p = 0.003$). Notably, 11 catheters in the intervention group were initially positioned in the IJ; therefore, the rates of initial IJ cannulation were strikingly similar between groups (control = 7.4%; intervention = 7.3%, $p = 0.97$). However, all 11 intervention group catheters detected to be in the ipsilateral IJ position were capable of being successfully repositioned to the SVC during the initial procedure. All 12 patients (11 control, 1 intervention) with postprocedural ipsilateral IJ position required a second procedure (or more) to correct the initial malposition.

In the control arm, 53 of the 149 line attempts (36%) met criteria for malposition vs. 39 of the 151 lines (26%, $p = 0.07$) in the intervention arm. There was no difference between groups in the rate of aberrant catheter position in a vein proximal to the SVC (control 21% vs. intervention 18.5%, $p = 0.62$) (see Table 2 for details of each position).

The duration of the procedure in the control group was a median of 8 minutes (6–10.5 minutes) and increased to a median of 9.0 minutes (7–11 minutes) in the intervention group.

DISCUSSION

Malposition of PICCs placed at the bedside is a well-recognized phenome-

Table 2. Peripherally inserted central catheter position after initial procedure

	Insertion Technique		
	Control (n = 149)	Neck Ultrasound (n = 151)	p Value
Superior vena cava	87 (58.4%)	104 (68.9%)	0.06
Ipsilateral IJ malposition	11 (7.4%)	1 (0.7%)	0.003
Other proximal vein	31 (20.8%)	28 (18.5%)	0.62
Subclavian vein	13 (8.7%)	11 (7.3%)	0.65
Brachiocephalic vein	14 (9.4%)	13 (8.6%)	0.81
Axillary vein	4 (2.7%)	4 (2.6%)	>0.99
Distal position[a]	11 (7.4%)	10 (6.6%)	0.80
Unable to access	9 (6.0%)	8 (5.3%)	0.81

IJ, peripherally inserted central catheter.
[a]Distal position: defined as right atrium and beyond. All values described: n (%).

non. Although the antecubital route to the central venous circulation is widely regarded as being safer than other vascular access sites, noncentral localization of the catheter tip is common. In a study of attempted central venous cannulations via the antecubital route, catheters were observed with fluoroscopy to determine catheter tip location (14). Successful central placement occurred on the first attempt in only 54%—the second most common cause of noncentral location was migration of the catheter tip into the IJ (18%). Elevated incident rates of this specific malposition have been reported in multiple published studies of bedside PICC placement, ranging from 3% to 37% (4, 14, 15, 17, 21–23).

Fortunately, maneuvers to minimize internal jugular vein cannulation during PICC placement have been previously reported, enhancing the potential significance of postinsertion neck ultrasound as a screening test. Four interventions have been described: 1) head rotation to the side of cannulation, 2) application of digital pressure to the ipsilateral supraclavicular fossa, 3) continuous slow saline injection during catheter advancement, and 4) the use of a flexible J-wire (14, 18, 20, 24, 25). The initial two procedures can be applied empirically in all procedures, yet current bedside PICC protocols without fluoroscopy provide no immediate feedback for the recognition of catheter malposition in the IJ or the success of a repositioning attempt using one of the four mentioned manipulations. Standard procedures necessitate an interim chest radiograph with demonstration of tip malposition. Once accomplished, a second procedure is necessitated, risking increased patient discomfort from multiple manipulations and increased operator time and equipment expense.

In this study, we demonstrated that patients in both study groups experienced a similar rate of PICC procedures resulting in initial ipsilateral IJ cannulation (~7%). However, the utilization of ultrasound surveillance in the intervention group detected 11 of 12 such malpositioned catheters, and operators were able to manipulate all recognized malpositioned catheters into appropriate position within the context of the initial procedure. This simple intervention added no cost to the patient, used already available equipment, and conferred an additional minute to the duration of the initial procedure. This additional minute seemingly pales in comparison to the burden (on both patient and operator) for a second procedure. This technique may be used similarly for catheters inserted by the axillary or subclavian route (26).

In practice, ultrasound visualization may be less than optimal or impossible based on obstacles such as tracheostomy securements, bandages, and morbid obesity. Anecdotally, operators within the study noted that a static observation of the vein did not always suffice. Catheter manipulation at entry site ("jiggling") during ultrasound surveillance helped to highlight the presence or absence of the catheter's position in the jugular vein (particularly when an ipsilateral internal jugular venous catheter was already present).

Neck ultrasound surveillance did miss a single catheter in the jugular malposition. Review of this case demonstrated that the catheter had only a minimal extension into the jugular vein, and was likely missed by an incomplete evaluation of the most proximal portion of the jugular vein. Therefore, we advise careful attention to ultrasound surveillance that extends to the level of the thoracic inlet to confirm the absence of a jugular venous catheter.

Although all catheters were intended for placement in the SVC, a reasonable number in both groups ended with catheter positions in veins proximal to the SVC. Potentially, some of these catheters may have been introduced into the IJ if further advancement were accomplished, resulting in different rates of the primary outcome. Of note, however, there was no difference in rates of "proximal vein placement" between groups.

The variability in tip position (demonstrated in Table 2) highlights the reasoning for ongoing debate regarding optimal central venous catheter positioning (11, 12). Complications are associated with all tip positions—distal insertions (SVC and intracardiac-positioned catheters) risk tip perforation with resultant pleural injury or tamponade (27–29), whereas proximal catheters (proximal SVC and above) are associated with increased rates of thrombosis (30–32). In this study, we adopted the recommendations of the National Association of Vascular Networks (10). Although ultrasound can help to identify catheters in a noncentral locale (IJ [this study]; subclavian or axillary veins [not tested in this study]), the confirmation of tip location will still require advanced imaging (either chest radiograph or an image intensifier).

One limitation of this study was that we did not track line infection rates between groups. Potentially, repositioning a catheter after manipulation of the sterile field for ultrasound detection may result in an increased risk of infection; however, patients with an ipsilateral IJ catheter tip not recognized by ultrasound would require a second procedure: either changing the PICC over a wire or a new catheter placement. This study was not designed to answer the rates of infection between these two approaches.

In practice, providers placing PICC lines may want to prep and drape to expose both the insertion site and ipsilateral neck. In theory, even greater information may be derived by more extensive ultrasound (including axillary and subclavian surveillance for catheter coiling).

The decision to use a PICC line (over a central venous catheter) should include a careful evaluation of risks and benefits for the individual patient, and should not be selected based on the advantages of PICC team availability and unsubstantiated concepts of PICC safety. Should a PICC be appropriate, ultrasound can help to identify catheter malposition.

CONCLUSION

In summary, the simple application of postprocedural neck ultrasound surveillance can result in fewer patient procedures (including radiation exposure, equipment cost, operator time, and demand for repositioning within the interventional radiology suite). We believe that PICC providers already using ultrasound guidance for venipuncture should apply this technique universally in standard bedside PICC placement procedures.

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