A Retrospective Look at Tip Location and Complications of Peripherally Inserted Central Catheter Lines

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In 1982, Southern Regional Medical Center in Riverdale, Ga, instituted a program for selected intravenous nurses to insert and manage peripherally inserted central catheters (PICCs). At present, approximately 125 to 150 PICCs are inserted annually by eight experienced IV nurses. In this retrospective study, the authors review medical record data on PICC insertions that occurred between January 1987 and December 1991. The optimal tip location is defined as the superior vena cava (SVC) and an anterior-posterior one-view chest x-ray is performed to confirm tip location. This study focuses on the initial location of the PICC and actions taken to correct the initial tip placement if not in the SVC. Medical records were reviewed for complications including mechanical phlebitis, infections, ruptured catheters, clotted catheters, or vein thromboses. The frequency of these complications, their prevention, and management are discussed.

Today, the use of peripherally inserted central catheters (PICCs) is surrounded by many clinical controversies. Cannula tip location and the need for a chest x-ray are two of the major questions. Our policies mandate a cautious approach to minimize any risk associated with these devices. In the current cost-conscious environment, we decided to undertake this study to assess our existing PICC program.

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In 1982, the intravenous team began a carefully controlled program allowing IV nurses with *advanced* levels of experience to insert PICCs. These nurses had been practicing IV therapies for between 3 and 5 years. At that time, only one nursing study and a few medical studies had been published regarding the use of these devices.[1–4] During the past few years, several articles have appeared detailing the efforts of Clayton General Hospital.[5–7] While the name of the facility has changed, its PICC program and patient population have remained constant, and nurses still perform insertions. Southern Regional Medical Center is a 367-bed suburban regional hospital with 44 full-time employees (FTEs) on the IV team. We provide coverage 24 hours a day, 7 days a week. During the study period, eight IV nurses inserted PICC lines; all eight nurses were CRNIs.

At the time our PICC program began, the National Intravenous Therapy Association (NITA)

Standards of Practice, written in 1981, stated "Central catheters that are inserted through a peripheral vein and peripheral arterial catheters should be treated as a peripheral catheter. The proper frequency for changing these catheters is not known."[8] Some could interpret this to mean that PICCs should be changed every 48 to 72 hours. Our program included a quality assurance monitoring process to document the efficacy of our practice and to support this perceived deviation from 1981 Standards.

The current *Intravenous Nurses Standards of Practice*, available for the last 15 months of this study period, includes information about PICC lines mentioned in five standards including site selection, cannula selection, cannula site preparation, cannula placement, and cannula removal.[9] Information in each one of these standards is important; however, for the purpose of this study, we concentrated on the cannula placement standard. Particularly important are the statements about not altering the tip integrity of the device and confirming the tip location by x-ray before using the line to deliver any prescribed therapy.

Our practice includes a few key points supporting the standard. The superior vena cava (SVC) is considered the best tip location because rapid blood flow through the SVC allows for maximum hemodilution of the infusate. The cannula will also have a greater chance of laying parallel to the vein wall.[10] Impingement of the cannula tip on the tunica intima can cause intimal injury leading to thrombus formation.

A single-view anterior-posterior chest x-ray is performed on each patient to confirm tip location. The IV nurse accompanies the patient to the radiology department and checks the film to assess tip placement. If correction is necessary, we confer with the radiologist about the manipulation needed to correct placement. A second chest x-ray is performed only after extensive cannula movement.

Study Purpose and Methods

For the purpose of this study, we identified four criteria to investigate:

1. The frequency of correct tip location on initial placement;
2. The success of repositioning by the recommended methods;
3. The frequency of complications during dwell time; and
4. The successful management of these complications.

We began the study process by compiling a list of patients with PICC lines from old monitoring records. A tool for collecting data was created that included patient information, insertion date, initial tip location, corrective actions, complications, nursing management and results, date, and reasons for removal. We also recorded whether or not the patient was discharged to home care with the catheter in place. Medical records were reviewed and forms completed. This process yielded 158 data sheets for analysis.

From the IV team statistics for 1987 through 1991, we were able to find the number of PICCs inserted by month. We found no pattern by month, year, or season. The number inserted per year ranged from 188 in 1987 to 94 in 1990.

The device used during this study period was a 16-gauge silicone elastomer catheter, 20 inches in length, with a 14-gauge introducer (Intrasil, Travenol, Inc., Deerfield, Ill).

Table 1. Patient Information

	Value	N
Average age, years (range)	48 (1.4–91)	157
Height, feet & inches (range)	5'8" (4'11"–6'4")	118
Weight, pounds (range)	159 (18–293)	120
Previous IV therapy, days (range)	7 (0–26)	150
Sex (male/female)	98/59	157

Note: N represents the number of data sheets reporting this information.

Patient Information

Patients in this study covered a wide range of ages, heights, and weights. The figures for height do not reflect the height of one 15-month-old child. Sixty percent of patients were men and 40% were women. (Table 1)

Of the patients studied, 65% suffered from infectious diseases, including osteomyelitis, cellulitis, and other wound infections. (Table 2) Many types of cancer, gastrointestinal diseases, and orthopedic

Table 2. Patient Diagnoses

Diagnosis	N	(%)
Infectious processes	104	65
Cancer, multiple types	22	14
Orthopedic disorders (excluding osteomyelitis)	9	6
Gastrointestinal diseases	8	5
Other	15	10
Total	158	100

problems excluding osteomyelitis, represented another 25%. The remaining 10% carried diverse diagnoses such as multiple sclerosis, chronic obstructive pulmonary disease, and cerebrovascular accidents. Many patients in the total sample had secondary diagnoses of diabetes.

Results

We studied specific veins used for insertion. The majority of cannulas were placed into the left arm. Of the 93 left-arm insertions, 54 were inserted into the basilic vein and 36 into the cephalic vein, with three remaining undocumented. Of the 65 right-arm insertions, 38 were basilic, 22 were cephalic, and 5 were undocumented. (Fig. 1)

The initial location of the cannula tip on the first chest x-ray was examined regarding the specific vein used for insertion. Our insertion procedure requires extending the patient's arm at a 90° angle from the body, with the head turned to the ipsilateral side and the chin touching the chest. This position straightens the curve in the subclavian and narrows the angle between the jugular and subclavian veins.[11] This positioning should guide

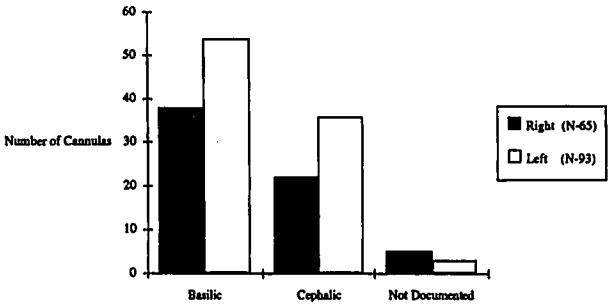

Figure 1. Location of insertion sites.

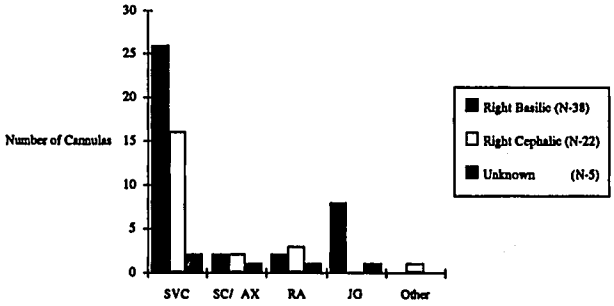

Figure 2. Tip location from right-arm insertions.

the cannula into the SVC; however, this maneuver is not always successful.

From the right basilic vein, 26 (or 68%) were advanced to the SVC on first placement. The remaining 32% in this group advanced into other locations including the subclavian, axillary, and jugular veins, and right atrium. (Fig. 2) From the right cephalic, 16 (or 73%) went into the SVC. The remaining 27% went into the subclavian, axillary or right atrium, and one passed into a small peripheral vein. From the left basilic, 38 (or 74%) went into the SVC on first insertion, with the remaining 26% into the other locations. From the left cephalic, 29 (or 80%) were placed into the SVC and the remaining 20% into the other locations. (Fig. 3)

Another way to assess approximate catheter length to be inserted is to measure externally from the venipuncture site to the level of the third rib, or about the level of the SVC. Venous pathways vary greatly from one individual to another and the external measurement is not an exact predictor of the internal pathway. Figure 4A shows the axillary/subclavian vein with a very high arch, while Figure 4B displays the same veins in a more horizontal position.

The number of venous valves in the axilla, shoulder, and base of the neck can affect tip location after initial insertion. *Grant's Atlas of Anatomy* documents the presence of 40 valves in the region.[12] These valves can send the cannula into

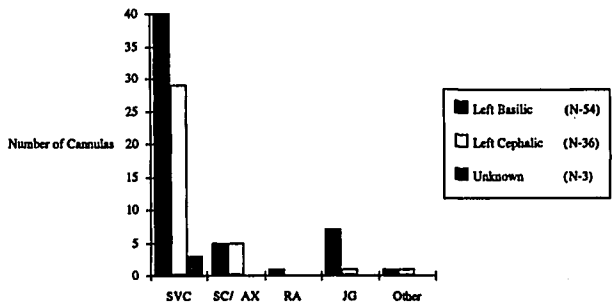

Figure 3. Tip location from left-arm insertions.

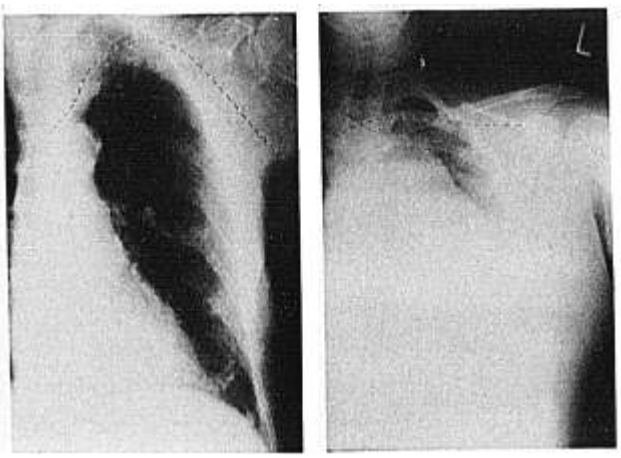

Figure 4. Individual differences in axillary-subclavian vein configurations.

unanticipated locations even with the best patient positioning and the most experienced nurses performing the procedure.

A total of 42 cannulas (34%) were malpositioned on first insertion. (Fig. 5) Chest x-rays were obtained with the guidewire still in place. Occasionally, removing the guidewire was the only procedure necessary. The blood flow on a soft silicone elastomer cannula will cause it to fall into the SVC. Eleven of these were successfully repositioned by removing only the guidewire or by partially withdrawing and re-advancing the cannula. A sterile field was maintained during both procedures. Subsequently, a second chest x-ray was obtained to confirm tip location.

Placing the patient in a semi-Fowlers position will encourage the tip to fall. A rapid push of 10 ml normal saline can also be performed to reposition the tip. We performed this procedure successfully in 2 of 5 patients.

In 11 patients, cannulas in the subclavian or axillary vein could not be repositioned using these techniques. We allowed these cannulas to remain in place without any further manipulation. These

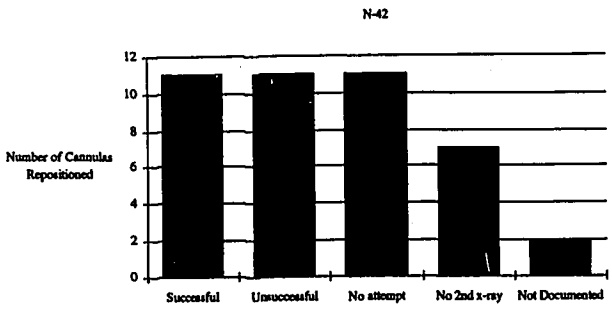

Figure 5. Results of repositioning cannula after first x-ray.

tip locations were carefully noted on the patient care profiles and these catheters were used exclusively as peripheral lines.

We did not attempt to manipulate another 11 cannulas in this group. These cannulas were inserted from the left side, or the patients involved were more than 6 feet tall, making a 20-inch cannula too short to reach the SVC. Other factors such as shunts draining into the SVC or large chest tumors prevented advancement of the cannula. A few patients in this group had endocarditis, and the infectious disease physicians requested that the cannula tip *NOT* be located in the SVC. Again, these were used only as peripheral lines.

Seven of the 42 patients did not require repeat chest x-rays, because manipulation only involved withdrawing the cannula a few centimeters. This group included cannulas that were advanced into the right atrium on first insertion. A measurement was taken from the x-ray to determine how much cannula should be retracted to position the tip in the correct location. Because a second chest x-ray was not obtained, this group was analyzed separately from the first group of eleven successfully repositioned cannulas. However, these seven were considered to be correctly positioned after withdrawal. The remaining two patients were discharged before the second x-ray could be taken.

Only the patients still hospitalized during the dwell time could be analyzed to study complications and their management. Of 158 patients, 78 remained in the hospital during the entire dwell time of the cannula; 79 were discharged to home care. One patient was discharged but returned to the outpatient clinic daily for infusions and cannula care.

Of the discharged patients, some remained in the hospital for several days after cannula insertion. Some patients in this group did experience some complications after insertion and have been included in the total sample when all complications were analyzed.

We have divided complications into two categories: 1) complications that resolved completely with treatment, and 2) those that did not resolve and required cannula removal. The first group consisted of 23 patients; the second group consisted of six patients.

Early-stage mechanical phlebitis accounted for 18 (or 78%) of the resolved complications. Usually at least twice in an 8-hour shift, experienced IV nurses carefully observed patients during the entire dwell, especially during the first week. On average, it took 4 days from insertion for this phlebitis to

Table 3. Reasons for Cannula Removal (78 Patients Remaining Hospitalized)

Therapy ended	54
Patient expired	10
Cannula migrated out of vein	3
Another device needed	2
Accidentally removed	2
Clotted, malfunctioning pump	1
Developed cannula-related complications	6

occur, with complete resolution documented within 3 days after the treatment began.

Other complications included four patients with mild transient edema or soreness without other symptoms of phlebitis, and one clotted catheter. Heat application resolved the mild edema and soreness within 24 hours. The clotted catheter was opened using a urokinase declotting procedure.

Six cannulas were removed because of unresolved problems. One patient with phlebitis was treated for approximately 20 hours without improvement. Because of suspected infection, the catheter was discontinued and cultured. However, the results of both catheter tip and blood cultures were negative after 48 hours. No other patients showed any signs or symptoms of cannula-related local infection or septicemia.

One clotted cannula was discontinued without documented efforts to declot. One ruptured cannula or a small hole in the cannula was detected when clear fluid leaking from the insertion site was discovered. When the cannula was retracted, a saline flush revealed the leak.

One patient developed a vein thrombosis, documented by the physician, even though the initial tip location was in the SVC. Two other cases of edema and leaking from the site occurred, resulting in cannula removal. Both tips were located in the subclavian/axillary region.

All reasons for cannula removal were examined in the 78 patients who remained in the hospital during the entire dwell time. (Table 3). Seventy percent of these catheters were removed at the end of therapy, the primary reason for removal. Only six (7.7%) were removed for complications related to cannula performance as described above.

In the group of hospitalized patients, dwell time ranged from 1 to 74 days, with an average dwell time of 16 days. The Kaplan-Meier Product Limit Estimator, another way of calculating dwell time, is the median time to catheter-related failure, usually expressed as the point when 50% of the study catheters would have failed had all catheters been allowed to dwell until failure. In this study, we did not have enough catheters to reach a 50% failure rate. At dwell day 74, we had a 12% failure rate, or an 88% functioning rate.

Discussion

Even with the best patient positioning and experienced nurses performing the procedure, PICCs do take various venous pathways. Malpositioning occurred in between 20% and 30% of our insertions. Insertions made into the left cephalic vein were associated with 20% of incorrect tip locations, the lowest frequency. The right basilic vein had the highest frequency of incorrect tip locations (32%). Variations from the normal anatomical venous pattern and venous valves could provide one explanation. Other studies have reported similar findings on malpositioned cannula tips. Our results validate those findings.[11,13]

Repositioning the tip was successful in 43% of the cannulas in our study. Complete knowledge of the patient's medical history, size, and required therapy can have an impact on the choice of devices. When disease processes prevent or contraindicate placing a cannula tip in the SVC, a midline catheter can be chosen. If the patient is more than 6 feet tall and central venous tip location is required, a cannula longer than 20 inches is usually needed.

Of the 158 patients studied, 14.5% experienced complications that were resolved with proper management. The clinical symptoms of early-stage mechanical phlebitis include tenderness, heat, redness, and edema along the path of the cannula, occurring in the first week after insertion. Treatment was accomplished by applying continuous heat at approximately 105°F with an electronically controlled pad. Rest and elevation of the extremity was also encouraged. Treatment should begin immediately after observing the first symptom of phlebitis and should continue until inflammation completely subsides. The patient can perform minimal daily activities. However, we encourage them to keep the heating pad on continuously.

Blood clots inside the cannula can be dissolved with a thrombolytic enzyme such as urokinase. An amount of urokinase equaling the internal volume of the cannula is carefully instilled inside the lumen and allowed to remain for 10 to 15 minutes.

Then, if aspiration is still not possible, the procedure may be repeated.

Cannula materials such as silicone elastomer can develop perforations when excessive pressure is exerted with small syringes. Any flushing should be performed slowly and carefully with the patient's arm fully extended. If any resistance is met, the flush should be stopped and the cause of the resistance determined. Perforated cannulas may be exchanged over a guidewire, a practice recognized by the INS *Standards of Practice* as a nursing act.

Conclusion

Presently, few studies have been conducted investigating the complications associated with the midclavicular tip location. We have experienced great success with SVC placement and consider it as the safest tip location for the patient. Therefore, we will continue to emphasize SVC placement for cannula tips.

Reinforcing statements in the INS *Standards of Practice,* the Central Venous Catheter Working Group, an advisory body to the FDA, recommends that a chest x-ray be obtained initially and be rechecked periodically during the device's dwell time. Because soft cannulas can move from one venous location to another, no specific time interval is suggested presently for repeating the x-ray.[14,15] The radiology department could be asked to confirm cannula location when chest x-rays are obtained for other medical reasons.

Early assessment of the venous access needs of each patient will identify candidates for PICC lines early in their course of treatment. This practice will reduce the waste of other peripheral veins and allow PICC placement before good insertion sites have been used for other purposes.

Education for this program centers around three groups of caregivers: 1) those who identify patient candidates early in the course of treatment, 2) those who insert the device, and 3) those who provide nursing care and manage complications. In our facility, nurses on the IV team perform all three activities for patients on the general nursing units. In the specialty units, the primary care nurse identifies patient candidates and performs nursing care; however, the IV nurse does the actual insertion. Continuous education is necessary. Early detection of problems and proper management can increase the life of the cannula. Outcomes will include improved management of the patient's IV therapy and increased patient satisfaction.

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