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Optimizing the patient positioning for PICC line tip determination

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Abstract Central venous catheters (CVCs) are used for both emergent and long-term vascular access for the infusion of numerous therapeutic agents such as chemotherapy, parenteral nutrition, antibiotics, and analgesics, as well as for temporary hemodialysis or hemoperfusion [1]. Current standard of care dictates that CVC insertion should be followed by an immediate chest radiograph to confirm appropriate position [2]. Radiographic confirmation of central venous line placement is important because it is not possible to determine CVC tip position clinically. Although many catheter tips can be localized on the standard frontal radiograph, there are occasions when a second radiograph is necessary to localize the position of the CVC tip accurately [3]. We hypothesized that a right posterior obligue chest radiograph would more consistently enable the catheter tip to be seen as it reduces the superimposition of mediastinal structures. One hundred chest radiographs taken in an anteroposterior (AP) projection and 100 chest radiographs taken in a right posterior oblique (RPO) projection after a peripherally inserted central catheter (PICC) line placement at UCI Medical Center from June 2000 to November 2002 were read by two radiologists. Forty-one percent of AP readings were discrepant and 4% had the annotation ''difficult to identify the position of the tip'' although the identification of tip position was similar. Fifty-five percent of AP readings were in agreement with no note of any difficulty. Eighteen percent of RPO readings were discrepant and 2% had the annotation ''difficult to identify the position of the tip'' although the identification of tip position was similar. Eighty percent of RPO readings were in agreement with no note of any difficulty.

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Introduction

Central venous catheters are defined as venous access lines whose tips terminate in the superior vena cava (SVC) or inferior vena cava (IVC), regardless of insertion site. These vessels are preferred due to their large lumen size and high flow. Peripherally inserted central catheter (PICC) lines are appropriate for both short- and long-term use, ranging from 10 days to several months. Timely delivery of an appropriate concentration of medications is crucial in emergency situations such as sepsis or septic shock. PICC line placement is performed at the bedside by physicians or specially trained PICC line nurses using the basilic or cephalic veins. Advantages of PICC lines are low insertion cost, elimination of risk of postinsertion pneumothorax, reduced risk of infection, and easy removal. However, maintenance requirements of daily heparin flushing and sterile dressing changes are necessary [4]. In 1988, more than 3 million CVCs were placed, and the procedure is generally considered safe [5].

Catheter-related complications are estimated to occur in 5–20% of cases [4]. The potential emergent complications of malplaced catheters include: hematoma, pneumothorax, arteriovenous fistula, brachial plexus or phrenic nerve palsy, air embolism, infectious complications, venous thrombosis, septic thrombophlebitis, chylothorax, SVC syndrome, limb swelling, hydrothorax, hemothorax, mediastinal hemorrhage, cardiac injury, cardiac tamponade, vascular perforation, looping of the catheter, catheter occlusion, CVC fragment emboli, arrhythmia, and misplaced or migrated CVCs. In addition, catheter insertion into a pericardiophrenic vein can induce a fatal hydropericardium.

Among these complications, the most commonly noted problem is malposition of the catheter tip [1, 5, 6,

7]. Consequently, the Food and Drug Administration has published guidelines and warnings as to the recommended techniques for catheter insertion and follow-up care [8]. These emphasize among other things the importance of obtaining a portable chest radiograph immediately after catheter placement to confirm optimal tip positioning [1, 4]. The recommended tip position for a CVC is in the distal portion of the SVC or at the SVC and right atrial (RA) junction [9]. Increased incidence of catheter dysfunction and complications were noted when catheter tips are located outside these preferred sites. These complications include: venous thrombosis, venous perforation, and catheter-related bloodstream infection. Moreover, the location of the catheter tip has been documented to affect catheter patency. Tips located higher in the SVC reportedly showed an increased rate of occlusive complications [9]. Catheters that migrate into smaller veins, such as the internal jugular or azygos, which are used for infusion of hyperosmolar and irritating drugs, may also cause thrombophlebitis and subsequent thrombosis [10].

CVC tip malposition is very common in all hospital services and settings, and can be recognized by chest radiography; postprocedural chest X-rays are helpful. In 1993, LaFortune, utilizing chest X-rays, was able to detect a 26% postinsertion malposition rate of PICC lines and supported the importance of postinsertion tip verification [9]. Radiographic clues to correct placement include: (1) a right-sided catheter that has not crossed the midline; (2) a catheter path that is inferiorly oriented toward the junction of the RA and the SVC; and (3) the absence of sharp angles in the catheter's path [11]. The most common sites of malposition noted are, in order of prevalence: RA, left brachiocephalic vein (LBCV), and right jugular vein (RJV) [8]. If a review of the chest X-ray confirms that the catheter tip is positioned outside of the SVC, removal and replacement or repositioning of the catheter may be required [1, 9].

Many patients needing PICC line placement are critically ill, and the chest X-rays obtained to evaluate the catheter tip position are of the portable variety; these factors further limit detection of the tip due to the effect of magnification and variations in radiographic technique [9]. If the tip is not seen on the initial portable chest X-ray, a second radiograph with different technique has to be obtained. This increases the cost of medical care and delays the administration of the necessary medicine. the aim of the present study was to develop a method that more reliably identifies the catheter tip position on the first radiograph.

Materials and methods

After receiving institutional review board approval, all PICC line placements performed by a specially trained registered nurse at UCI Medical Center in Orange, California, from June 2000 to November 2002 were reviewed. Some chest radiographs were taken in an AP projection and some were taken in a RPO projection. The technical guidelines for the RPO radiograph were to rotate the patients approximately 15–20°; however, several patients were rotated approximately 45°. One hundred consecutive AP films and 100 consecutive RPO films were pulled for analysis. Two staff radiologists read each film individually and independently and recorded the exact location of the PICC line tip as shown on the film, the projection in which the radiograph was taken (AP or RPO), and whether the location of the tip was too difficult to read. After reviewing the literature and CT scans of a chest, the staff radiologists came to consensus definitions as follows: left and right internal jugular veins drain the head and join the respective subclavian veins to form the brachiocephalic (BC) vein at the medial head of the clavicle; left and right subclavian veins begin at the lateral margin of their respective first rib and join the internal jugular vein to form the BC vein at the medial head of their respective clavicles; left and right BC veins begin at the medial end of their respective clavicles and join to form the SVC at 1 cm above the top of the azygos vein; the radiographic SVC/RA junction is located at the "waist line" of the heart; SVC extends from 1 cm above the top of the azygos vein to 2.9 cm below the radiographic SVC/RA junction; and the RA begins 3 cm below the radiographic SVC/RA junction [3, 11]. Although the radiographic SVC/RA junction is still considered SVC anatomically, the reading of the tip at this radiographic marker was incorporated to enhance the precision of the radiologists' reading of the tip position.

Once the data collection was completed, discrepancies between the two radiologists' readings of the catheter tip and the difficulty category of tip readings were calculated. Subsequently, the two groups (AP vs RPO) were compared with regard to the agreement factor. The agreement factor was determined by whether or not the two radiologists agreed on the location of the catheter tip. If they agreed, an agreement coefficient value of 1 was assigned. If they did not agree, a value of 0 was assigned. If they agreed but had difficulty in reading the tip position, the assigned value was 0.5. If they disagreed and had difficulty, the assigned value was still 0. The statistical significance was calculated using the Mann–Whitney test. The data are considered nonnormal. Hence, a nonparametric test was used to calculate their statistical significance. A probability value below 0.001 was taken to show statistical significance.

Results

Forty-one out of 100 AP films (41%) had discrepant readings and 4 out of the 100 films (4%) were noted as difficult to read for the tip although they were similarly read by both radiologists. Fifty-five AP films (55%) were similarly read by both radiologists without any difficulty. Of the 41 films that were differently read by the radiologists, 24 were noted as difficult to read for the tip. Eighteen of the 100 RPO films (18%) had discrepant readings and 2 of the 100 films (2%) were noted as difficult to read for the tip although both radiologists read them similarly. Eighty RPO readings (80%) were similarly read by both radiologists without any difficulty. Seven out of 18 films that were differently read by the radiologists were noted as difficult to read (Table 1).

Table 1 Comparison of two radiologists' readings of 100 anteroposterior and 100 right posterior oblique radiographs taken to determine central venous catheter tip position

	AP	RPO
Same reading without difficulty	55	80
Discrepant readings	41	18
Difficult to read tip	4	2

In general, the exams that led to difficulty and discrepancy were underpenetrated for the mediastinum (on the toe of the characteristic curve of the film).

The mean agreement for AP was 0.5550 and mean agreement for RPO was 0.8000. Using the Mann-Whitney test, the data comparing the two groups was determinded to be statistically significant with $p < 0.001$.

Discussion

Placement of CVCs has become ubiquitous in the modern intensive care unit. CVCs allow reliable, painless, and repeated entry into the venous system and are widely used for both emergent and long-term administration of life-supporting fluids, parenteral nutrition, administration of antibiotics, vasoactive medication, chemotherapeutic agents, hemodialysis, periodic blood sampling, and others [1, 2, 4, 5, 10]. Routine chest radiographs help confirm tip position and the absence or presence of malposition and other complications [2]. The purpose of verifying CVC tip position is to (1) identify appropriate tip placement, (2) rule out malposition, and (3) confirm acceptable tip position for medication administration. Malposition of catheter tips can occur either at the time of the initial insertion or at any time during the indwelling period. The catheter can easily become misdirected and end up in a smaller vessel, such as the mammary vein, or the catheter can extend across to the contralateral subclavian or up into the jugular instead of heading down into the SVC. A misplaced catheter may damage the underlying vein and has the potential to reduce access sites for any future needs. In addition, the occurrence of spontaneous migration has been linked with catheters whose initial tip terminates in the upper third of the SVC. One study identified left-sided catheter placement as associated with a significantly higher incidence of catheter-related thrombosis [9]. Consequently, it is recommended that left-sided placement should be avoided except where right-sided placement is contraindicated. Much evidence suggests that tip termination deep within the SVC offers increased hemodilution of the infusate and less trauma to the vessel wall, thereby reducing the incidence of catheter-related complications [1, 3, 9].

In order to avoid the complications of a malpositioned PICC line tip, our radiology department has historically performed postprocedural portable AP chest X-rays. However, with AP films, the position of the PICC line tip was not always reliably identified. Although the AP film is better for determining and localizing parenchymal lesions, the specific question of the PICC line tip position that prompted the exam could not always be answered. Frequently, the patient had also had an AP film that day prior to the insertion. Hence, a second radiograph with different radiographic technique or patient position had to be obtained to clearly determine the position of the PICC line tip. This meant that the patient was exposed to additional radiation, the availability of the PICC line for use was delayed, and the medical charges increased by $272 for the second radiograph.

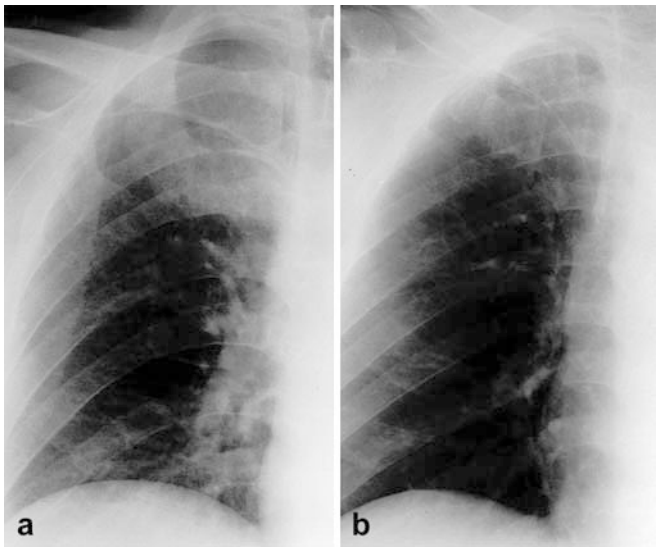

Fig. 1a, b Postprocedural chest X-rays of a patient with a PICC line placement: **a** anteroposterior projection, **b** right posterior oblique (RPO) projection. The line appears to have a sharper angle into the superior vena cava and the tip is more clearly visualized in the RPO film

In an effort to enhance the reliability of identifying the PICC line tip on the first radiograph, our study compared 100 AP films and 100 RPO films. As suspected, RPO films exhibited the PICC line tip with more clarity as it lessens the superimposition of mediastinal structures, thus enhancing the reliability of the radiologists' readings. Out of 100 RPO films reviewed by two staff radiologists, 80 films (80%) were read in the same way without any difficulty, as against 55 of the 100 AP films (55%). Out of the 100 AP films reviewed, 41 (41%) were differently read by the two radiologists: for example, one radiologist identified the tip as being in the SVC, while the other radiologist identified the same tip as being in the RA. In comparison, only 18 RPO films (18%) were differently read by the two radiologists.

Thus, our study results indicate that chest radiographs taken in the RPO position yield images in which the PICC line tip position is more reliably identified. To demonstrate this, postprocedural chest X-rays of a patient with a PICC line placement taken in both the AP projection (Fig. 1a) and the RPO projection (Fig. 1b) are presented. In the AP view, the PICC line is seen below the medial head of clavicle and positioned in the upper half of the SVC at the level of the aortic knob. In the RPO view, the PICC line is also seen below the clavicle and positioned in the upper half of the SVC at the level of the aortic knob. However, with the rotation, the line appears to have a sharper angle into the SVC and the tip is more clearly visualized.

In our study, there were a few points of improvement. After the first 30 films were read, we realized that each radiologist had a slightly different interpretation of the landmarks of the anatomic SVC/RA junction and BC/SVC junction. On the basis of a CT scan of a sample chest and the literature, the radiologists agreed the exact anatomic positions of SC, BC, SVC/BC junction, SVC, RA, and radiographical SVC/RA junction. The first 30 films were then reread according to clear anatomic and radiographic position guidelines. Another point of improvement was the differences in the radiographic technique. Depending on the technician, some AP films were not perfect but were taken with slight rotation, and some RPO films did not adhere to the guidelines of 15–20° rotation. Since this study was performed, we have switched to computed radiography (CR) and now read our images on a picture archiving communication system (PACS) which allows a greater exposure latitude. The switch to PACS allows us to manipulate light images to bring out catheter tip position. However, if the image is too light, PACS cannot salvage the exam. Since many institutions have not yet switched to CR and PACS, we believe the results of this study are still relevant.

Conclusion

Our study comparing AP versus RPO chest radiographs in determining the postprocedural position of a PICC line tip indicates that the tip is more reliably read on RPO films. Although many AP films were consistently read, many more RPO films were read in the same way by two radiologists. Hence, RPO is the better projection for identifying the postprocedural position of a PICC line tip on a chest radiograph.

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