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Influence of guide wire removal on tip location in peripherally inserted central catheters (PICCs): a retrospective cross-sectional study

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ABSTRACT

Objectives The aim of this study was to identify the prevalence of peripherally inserted central catheter (PICC) malposition and the influence of guide wire removal on tip location in PICCs and determine whether related factors, including age, sex, side of insertion and brand of catheter, influence the PICC tip location.

Setting Single-centre research institute in China recruiting patients from the hospital.

Participants A total of 837 adult patients with inserted PICCs were recruited from October 2016 to May 2017.

Interventions This was a cross-sectional study aiming to identify the prevalence of PICC malposition and the influence of guide wire removal on tip location in PICCs. A linear regression model and a variance of factorial design analysis were performed. The PICC tip location was documented on a postinsertion chest X-ray. Multivariable analyses were performed based on the following related factors: age, sex, side of insertion and brand of catheter.

Results The tip location moved a mean of 17.4 mm among the 837 included patients. The prevalence of PICC malposition was 83.6% (700/837), while 16.4% (137/837) of PICCs remained in correct location. The mean movement caused by guide wire removal without an adjusted tail end was (–1.95±26.90) mm. The difference between tail end adjustment movement and actual tip position movement in each PICC was (33.0±17.1) mm in type C, which was significantly higher than the findings for type A (12.8±13.3) mm and type B (12.9±12.7) mm.

Conclusions PICC malposition is a frequent event. Different catheter brands were associated with different ranges of movement in tip location after guide wire removal. The age and sex of the patients and the insertion side did not influence the extent of movement.

Strengths and limitations of this study

- ► This is the first study investigating the influence of guide wire removal on tip location in peripherally inserted central catheters.
- ► The difference in tip position movement was compared accurately by an objective positioning method based on X-ray examination.
- ► Insertion sites and vein choices may have affected the results.
- ► The sample sizes among the groups were not equal, which might have influenced the final results.

INTRODUCTION

Peripherally inserted central catheters (PICCs) play a fundamental role in intravenous therapy and treatment. PICCs have a wide range of applicability in different patients, including paediatric and elderly patients, patients with chronic or acute diseases, patients undergoing surgery or chemotherapy and patients who need parenteral nutrition and medication, such as antibiotics and fluids.[1–4]

The correct location of the catheter tip must be guaranteed to provide a good therapeutic effect and reduce the occurrence of adverse events.[5] The general consensus is that the tip of any central line should lie in the lower third of the superior vena cava–right atrium (SVC–RA) junction.[6 7] A poorly located tip can delay the patient's treatment and result in the generation of additional resource costs. Malposition rates vary widely, ranging from 2.3% to 76%.[5 8 9] Malposition can not only affect the usefulness of the catheter but also expose the patient to potential complications, including venous thrombosis and cardiac arrhythmia.[10 11] Malposition can involve passage of the PICC into the internal jugular vein, into the contralateral subclavian vein, or curling within the subclavian back toward the insertion site.[12] The overall complication rates for the malposition of PICCs range from 35% to 65%.[13]

It is increasingly recognised that it is critical to place the central tip in a correct location.[14] Several tip location technologies are available. Usually, PICCs are inserted using

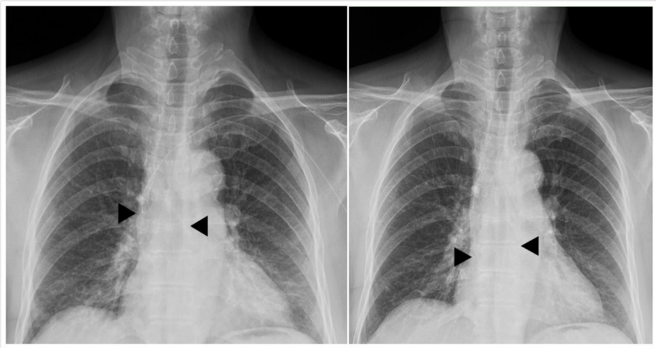

Figure 1 Position of anatomical landmark for measurement and tip location of peripherally inserted central catheters.

ultrasound to find a suitable vein to access, while anthropometric algorithms are used to measure the PICC, and head and shoulder movement are monitored to guide the PICC tip to the correct location. Several studies have demonstrated that bedside ultrasound can be useful for identifying catheter tip malposition.[15 16] Therefore, a postinsertion chest X-ray is required. ECG is another way to confirm tip location. P-wave amplitudes will be highest when the catheter is in the optimal location: at the SVC–RA junction. PICC insertion guided by intraoperative fluoroscopic visualisation is a precise method but is cost-expensive and resource-expensive.

In our clinical practice, confirmation of the tip location revealed that the removal of the guide wire has an effect on tip location. Additionally, the location of the catheter tip was very different between its location after the first postinsertion chest X-ray (after the guide wire was used to guide the catheter) and its location after the second postinsertion chest X-ray (after the guide wire was removed).

The purpose of this study was to evaluate the influence of guide wire removal on tip location in PICCs and determine whether related factors, such as age, sex, side of insertion (left or right) and brand of catheter, affect the difference between the tail end adjustment movements and actual tip location movements caused by guide wire removal in each PICC.

METHODS

All patients provided written informed consent.

Patients were recruited from the community through advertisement by the Harbin Medical University Cancer Hospital. Patients who were 18 years of age and older with inserted PICCs were identified as potential eligible patients. Subsequently, the research nurses asked the patient and their informal caregiver for their willingness to participate in the study and to provide written informed consent. If the participant lacked the capacity to consent, the informal caregiver was asked to act as a personal consultee. The personal consultee determined whether he or she believed that participation in the study would be in accordance with the values and interests of the individual and subsequently signed the patient's informed consent form. After the informed consent forms were obtained, the related information was recorded by research nurses. Patients with complications, such as artery puncture, blood vessel penetration, bleeding, nerve injury, pneumothorax and cardiac arrhythmia, were excluded.

This study included 837 patients who underwent PICC insertion. Digital images containing PICCs were retrospectively collected from the picture archiving system in our institution. All of the patients with inserted PICCs from October 2016 to May 2017 were included. In our institution, PICCs are placed using anthropometric algorithms to predict the length of the inserted catheter. The length of the prepuncture point to the right chest lock joint down to the third rib is the predicted length of the inserted catheter. The appropriate length was estimated by measuring the distance between the site of insertion and the second right intercostal space. The patients were supine with the arm abducted at 90° with the elbow straight. The inserted vein was the basilic vein at the upper part of the elbow joint. The central tip location was confirmed by a postinsertion chest X-ray. Each image was captured while the patient was breathing spontaneously, and the patients were not required to control their respiration. All chest X-rays were taken in an anteroposterior projection. The lower third of the SVC–RA junction was defined as the standard position for the central tip. The upper edge of the seventh thoracic vertebra was defined as an anatomical landmark for measuring the movement (figure 1). After the first postinsertion chest X-ray was obtained, the required adjustment was calculated by evaluating the movement between the upper edge of the sixth thoracic vertebra and the position at which the central tip was located. Nurses adjusted the tail end of the catheter and removed the guide wire before obtaining the second postinsertion chest X-ray. If the central tip location was just at the upper edge of the sixth thoracic vertebra level after the first postinsertion chest X-ray, the nurses simply removed the guide wire. The patient position, operator proficiency and strength and speed of removal of the guide wire could affect the position of the PICC tip. To reduce intraoperator variability, catheter placement and guide wire removal were performed by the same group of seven professional PICC nurses, four PICC nurses with national qualifications and three PICC nurses with provincial qualifications. Two doctors separately evaluated the X-ray data; if the difference in evaluated data was <5 mm, the average of the two data points was taken; if the difference in the evaluated data was >5 mm, a third doctor resolved the disagreement. Catheter tip movement was measured using the basic draw functions available in Picture Archiving and Communication Systems (PACS). The range of tip location motion observed between the first and second postinsertion chest X-rays and the range of tail end adjustment were documented in millimetres. We recorded all data in the direction of the foot as a positive number and all data in the direction of the head as a negative number. Movement was defined as the absolute difference between PICC tip locations.

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In this study, the age and sex (male or female) of the patient, the side of insertion (right or left) and the brand of catheter were documented. Based on age, the patients were divided into young (18–44 years old), middle-aged (45–64 years old) and aged (over 65 years old). We defined the single-lumen PICC composed of silicone PowerPICC (Bard Access Systems, Salt Lake City, Utah USA) as type A, the single-lumen PICC composed of silicone (Cathicoid, Branden) as type B and the double-lumen PICC composed of polyurethane PowerPICC (Bard Access Systems) as type C. A linear regression model was used to evaluate the range of movement among the groups with regard for tail end adjustments in the movement of the catheter, guide wire removal and the actual position of the central tip.

A four-way analysis of variance factorial design was performed for all of the measurements using SAS V.9.4. Age, sex, the side of insertion and the brand of catheter were non-repeating variables.

Patient and public involvement

Patients were not involved in the design of the study.

RESULTS

A total of 837 patients were included (436 women and 401 men). The patients ranged in age from 18 to 86 years old. A total of 126 were young, 524 were middle-aged and 187 were aged. A total of 415 PICCs were inserted into the right arm and 422 into the left arm. In all, 521 patients received a type A PICC, 291 patients received a type B PICC and 25 patients received a type C PICC (online supplementary table S1).

It was observed that the prevalence of PICC malposition was 83.6% (700/837), while 16.4% (137/837) of PICCs remained in the correct location (the tip of the PICC in the lower third of the SVC–RA junction). The maximum range of movement of each PICC, as measured by the central tip location, ranged from 0 mm to 147.8 mm, and the mean range of tip location movement was 17.396 mm per PICC (table 1). The mean range of the difference between the tail end adjustment movements and the actual tip position movements for each PICC was 13.422 mm. The linear regression model showed that actual tip position movement (mm)=–2.59 + 8.12×the tail end adjustment movement (mm) (table 2).

The brand of catheter had a significant influence on the range of movement of the central tip location when PICCs inserted from types A, B and C were compared (p<0.001). The difference between the tail end adjustment movement and actual tip position movement for each PICC was 33.0±17.1 mm for type C, which was significantly higher than that calculated for type A (12.8±13.3 mm) and type B (12.9±12.7 mm; table 3). The length of the SVC in Chinese people is 50–70 mm,[17] and one-third of the SVC corresponds to approximately 15–23 mm; thus, movement of the tip position by more than 15 mm is recognised as both statistically and clinically meaningful.

The mean (SD) of the difference between the tail end adjustment movement and actual tip position movement was –7.96±20.21 mm for the young, –3.76±15.83 mm for the middle-aged and –5.94±19.39 mm for the aged (p=0.26). The mean (SD) of the difference between the tail end adjustment movement and actual tip position movement was –4.53±17.01 mm for the left arm, –5.66±18.26 mm for the right arm (p=0.33),–0.34±20.08 mm for men and –5.05±17.59 mm for women (p=0.85). In 262 patients with unadjusted tail ends, the mean (SD) movement caused by guide wire removal was –1.95±26.90 mm (p<0.001). There were no significant differences in the range of movement of the central tip location when PICCs were compared

Table 1 Medians of PICC tip location moving length and insertion length in millimetres

	Median (mm)
First time insertion length	370
Final insertion length	370
Tail end adjusted length	0
Tip location moving length	–1.33

PICC, peripherally inserted central catheter.

Table 2 Results of the linear fixed effects regression model

Variable	df	Estimate	SE	P value
Model intercept	1	–2.5964	0.6462	<0.001
Adjusted length of PICCs	1	8.1186	0.3573	<0.001

PICCs, peripherally inserted central catheters.

Table 3 Mean and maximum tip location movements in millimetres for the three brands of catheters

	Type A	Type B	Type C
Left mean	–0.37	–0.48	3.43
Left max	–15.78	–5.01	4.90
Right mean	–0.31	–0.33	2.02
Right max	–5.89	–13.47	6.95
Male mean	–0.06	–0.25	2.42
Male max	–15.78	–5.57	6.95
Female mean	–0.51	–0.68	2.41
Female max	–7.03	–13.47	5.24
Young mean	–0.59	–0.53	2.99
Young max	4.29	–13.47	5.39
Middle-aged mean	–0.24	–0.35	2.26
Middle-aged max	–15.78	–5.57	6.95
Aged mean	–0.43	–0.49	2.10
Aged max	6.85	–5.01	5.24
Total mean	–0.34	–0.41	2.42
Total max	–15.78	–13.47	6.95

Table 4 Results of analysis of variance of the factorial design model

Variable	df	F	P value
Sex	1	0.95	0.33
Side	1	0.03	0.85
Brand	2	27.83	<0.001
Age	2	1.36	0.26

according to the abovementioned related influencing factors (table 4).

DISCUSSION

The results of our study show that a range of movement occurs when we remove a guide wire. The brand of the catheter was related to the range of movement of the tip location. The age and sex of the patient and the side of insertion did not significantly affect the movement of the tip location during the removal of the guide wire. Exactly why the central tip location of the PICC changes during the removal of the guide wire is not clear. It may be that patients requiring PICCs are vulnerable and heterogeneous according to many factors, such as medical history, treatment and individual differences.

In our study, we focused on the age and sex of the patients, the side of insertion and the brand of catheter used. Age and sex may influence fat tissue and muscle mass, which vary greatly between men and women. The amount of soft tissue may be a predictor of the degree of dislocation.[18]

Currently, there is a lack of definite evidence related to arm selection. Several studies have favoured the right side.[19 20] However, a study by Minkovich *et al* showed that a left-sided approach might be more suitable because it produced a lower incidence of malposition.[21] Another multivariate logistic regression analysis revealed that the risk of adverse events related to malposition was higher when the catheter was inserted in the right than in the left upper limb.[22] However, in our study, we found that the side of insertion had no influence on the movement of the tip location.

The PICC material greatly affects treatment outcomes. Several studies have shown that catheter-related infection is closely related to catheter materials.[23 24] The risk of infection is higher for silicone catheters than for polyurethane catheters. A recent study by Ong *et al*[25] compared two groups that were different primarily regarding the material in the catheters used and the design of the valves. They concluded that proximal valve polyurethane PICCs were more durable than were distal valve silicone PICCs and that they had a significantly lower incidence of complications, especially catheter-related infections and phlebitis. The number of lumens may influence the stiffness of catheters. O'Brien *et al* found that single-lumen PICCs reduced complications and costs.[26] The number of lumens may also influence the degree of dislocation. A recent study by Cho *et al* showed that single-lumen PICCs moved more than that observed for double-lumen or triple-lumen PICCs.[18] In our study, the type C brand of catheter, a double-lumen PICC made of polyurethane, moved more than that observed for single-lumen PICCs made of silicone.

The gold standard is to perform a postinsertion chest X-ray to check the tip location and to guarantee that no pleuropulmonary complications have occurred as a result of the procedure.[27] Thus, in our study, we used postinsertion chest X-rays as the standard to check tip location. Recently, several studies have shown that ECG technology can be used to place the PICCs in the correct location.[28–30] ECG technology relies on changes in the patient's P waves because changes in the morphology of the P wave can be used to identify the tip of the PICC. The P wave starts to increase when the tip of the PICC approaches the sinoatrial node and reaches its maximum height at the cavoatrial junction. The P wave will start to invert if the tip of the PICC goes into the right atrium, indicating that the PICC was inserted too far. The tip is assumed to be in an ideal location for the PICC when the ECG shows a maximal P wave without any inversion or negative deflections.[31] Rossetti *et al* reported that ECG technology was up to 95.8% as effective as X-rays.[32] Because ECG technology is relatively cheap and provides instant, real-time confirmation of tip location, it has been recommended for routine use in clinical practice. However, the effect of guide wire removal on tip location may also influence the ECG technology in a manner similar to that observed in patients in whom the tail end of the catheter was not adjusted in our study. Therefore, we studied the influence of guide wire removal on tip location and eliminated other interference factors. Further research is needed in this area.

LIMITATIONS

The limitations of our retrospective study include potential selection biases that may have affected the results. We had a small sample size in the group treated with the type C brand; therefore statistical analysis was less powerful for this group. The sample sizes among the groups were not equal, which might have influenced the final results. More insertion sites and vein choices were not included (such as the lower part of the elbow joint, the cephalic vein and the brachial vein). Operator-induced bias could not be eliminated because of the large number of patients recruited for this study. Selection bias may still have been present even though we used blind selection in the initially accessed arm. All data were collected from a single institution, which may affect the generalisability of our results.

CONCLUSIONS

PICC malposition is a frequent event (83.6%). During the removal of the guide wire, PICCs moved an average of 17.4 mm (range: 0–14.8 mm). The mean movement caused by guide wire removal without tail end adjustment was −1.95±26.90 mm. The age and sex of the patients and the side of insertion did not influence the extent of movement caused by guide wire removal. Different brands of catheters were related to the range of movement observed for tip location after guide wire removal.

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Contributors DW and FN were the guarantors for the study and affirm that this manuscript is an honest, accurate and transparent account of the study being reported. HG, MY, YL and LX were investigators on the study and collected the data. HC, JL and XD performed the statistical analysis. YL wrote the first draft of the manuscript. HL, LW, YW and CY conceived the study and wrote the first draft of the protocol. KY and CW contributed to study design, interpretation of results and manuscript writing and reviewed the final manuscript prior to submission. All authors had full access to all of the data in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis.

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Competing interests None declared.

Patient consent for publication Not required.

Ethics approval Regional Ethics Committee of Harbin Medical University Cancer Hospital approval was obtained for this retrospective study. The approval reference number is KY2018-02.

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