Is Routine Chest X-ray After Ultrasound and Intracavitary Electrocardiogram Guided Peripherally Inserted Central Catheter Insertion Choosing Wisely? A Population-based Retrospective Study of 2857 Patients With Cancer

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Research

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Abstract

Background: In China, routine chest X-ray (CXR) is generally required for peripherally inserted central venous catheters (PICC) to determine the position of the catheter tip. The aim of this study is to assess the value of a routine post-procedural CXR in the era of ultrasound and intracavitary electrocardiography(IC-ECG) -guided PICC insertion.

Methods: A retrospective population-based cohort study was conducted to review the clinical records of all patients who had PICCs in the Venous Access Center of Beijing Cancer Hospital between January 1, 2019 and June 30, 2020. The incidence of catheter misplacement after insertion was measured. A logistic regression analysis was performed to examine potential risk factors associated with PICC-related complications and a cost analysis to assess the economic impact of the use of CXR.

Results: There were 2,857 samples from 2,647 patients included. The overall incidence of intraoperative and postoperative catheter misplacement was 7.4% (n=210) and 0.67% (n=19), respectively. There was a high risk of postoperative catheter misplacement when the left-arm was chosen for placement (OR: 10.478; 95% CI: 3.467-31.670; p<0.001). The cost of performing CXR for screening of PICC-related complications was $23,808 per year, and that of using CXR to diagnose one case of catheter misplacement was $1253.

Conclusion: This study confirms that misplacement of PICCs guided by ultrasound and IC-ECG is rare and that postoperative CXR is very costly. In our setting, routine postoperative CXR is unnecessary and not a wise option.

Background

Peripherally inserted central venous catheters (PICCs) are critical to the treatment and care of cancer patients, especially in the chemotherapy and nutritional support treatment of this population. With the increasing application in clinical practice, PICCs-related complications are ever more common. Improper position of the catheter could cause discomfort and pain to the patient and lead to serious consequences, such as loss of catheter utility[1] or increased risk of deep venous thrombosis incidence[2]. Different methods have been suggested to control the position of the catheter during and after insertion. In our hospital, chest X-rays (CXR) are routinely applied as the standard process to determine the position of the tip of PICCs after operation.

The use of ultrasound[3] and intracavitary electrocardiography (IC-ECG) to locate the tip of PICCs[2, 4–6] was reported to significantly reduce the risk of PICC-related mechanical complications, improve patient's safety, and reduce the incidence of related venous thrombotic events (VTE). In this setting, the use of CXR seems to be superfluous, while there is insufficient evidence to change practice. One major limitation is that IC-ECG method to determine the position of the catheter tip is relatively new and there is a lack of research reporting the associated risk of PICC-related misplacement. Another is the absence of an

utine postoperative CXR is sufficiently cost-effective.

In this study, we performed a retrospective study in a Chinese cohort to clarify the incidence of PICC-associated misplacement at our hospital, followed by a cost analysis to study the use of postoperative CXR as a screening test to exclude PICC-associated misplacement.

Methods

Subjects

This retrospective study examined the clinical records of all adult patients with PICCs in the Venous Access Center of Beijing Cancer Hospital between January 1, 2019 and June 30, 2020, after approved by the local ethics committee.

We included all patients (age ≥ 18 years) who received PICCs in the Venous Access Center and underwent postoperative CXR. We excluded patients who (1) had a baseline non-sinusal rhythm, (2) had an artificial pacemaker or implacable cardioverter-defibrillator (ICD), (3) did not have a postoperative CXR check, and (4) were younger than 18 years of age.

2. PICC management
2.1 Personnel qualifications: All patients were inserted uniformly by the nurses of the Venous Access Center, who was specialized in the intravenous treatment and had more than 5 years of working experience. All nurses and medical staff were trained in IC-ECG and ultrasound-guided procedures at the beginning of the study.
2.2 Catheter types: The catheters used were single lumen 4 French PICC catheters (B. Braun Melsungen AG, 34209 Melsungen, Germany), and the specifically designed set for IC-ECG and electromagnetic tracking device Certodyn® Universal Adapter (B. Braun Melsungen AG, 34209 Melsungen, Germany).
2.3 Placement sites and vein puncture: The left and right upper limbs were selected for placement according to the patient’s wishes and vascular characteristics. Usually, the right upper limb is preferred. The basilic vein is mainly selected for puncture, followed by the brachial vein and the cephalic vein.
2.4 Placement procedures: Before placement, the patient's veins were assessed by a nurse from the Venous Access Center using the LOGIQ Book ultrasound system. Ultrasound-guided modified seldinger technique (MST) was applied according to the universal process: After the successful puncture, the catheter was inserted. When the catheter was inserted to the length of 30cm, a sterile electrical lead was used to correctly connect the catheter guidewire and the IC-ECG lead. The catheter was then slowly inserted while observing the changes of the P-wave on ECG. When the tip of the catheter reached the atrium, the P-wave showed negative deflection. If there was no dynamic change in the P-wave, the ultrasound would determine whether the tip of the catheter was misplaced and connected to other vessels. After bidirectional P-waves occurred and the catheter was withdrawn to the highest level of positive P-wave amplitude, the tip of the catheter remained in this place. The catheter was washed with isotonic saline solution, and was sealed by the positive pressure technique. A typical ECG pattern is illustrated in Fig. 1

2.5 After the implantation, CXR results of all patients were obtained, and body positions were kept consistent. Catheter tip positions were independently recorded by 2 certified radiologists with 5 and 12 years of experience respectively. The ideal location of the catheter tip is defined as the lower third of the superior vena cava (SVC) or the cavoatrial junction (CAJ) [7].
2.6 Data collection: The following data were collected: patient age, gender, body mass index (BMI); target vein for PICC, left/right arm, catheter tip position, vessel diameter and depth, arm circumference, number of insertion, and the vein with misplaced PICC on B-scan ultrasonography during the operation.
3. Statistical analysis
Descriptive data were expressed as median and interquartile range (IQR, i.e., 25th-75th percentile). Risk assessment was divided into odds ratio (OR) with 95% confidence interval (95% CI). Univariate and multivariate logistic regression models were used to evaluate the risk factors related to PICC misplacements. All statistical analyses were performed using SPSS version 16.0 (SPSS Inc., Chicago, IL, USA), and "P-value < 0.05" was considered statistically significant.

Results

A total of 3,185 PICCs were initially enrolled, among which 255 cases were excluded mainly due to the presence of non-sinusal rhythm (n = 116). There were 73 cases without postoperative CXR and thus excluded, and no patients in this cohort developed clinical PICC-related complications. The complete screening procedure is posted on Fig. 2.

The analysis included 2,857 samples from 2,647 patients with complete records, in which 184 patients received two or more PICCs. Patient demographic characteristics are presented in Table 1. The average age of the patients was 55.5 years (95% CI: 47–65). Males accounted for 49.3%. The majority of PICCs (73.3%) were inserted in the right arm. The basilic vein was the most common site of placement (83.9%; n = 2,394), followed by the brachial vein (14.3%; n = 407) and the cephalic vein (1.8%; n = 51). There were 91% of the PICCs reached the desired position in the first attempt.

Table 1
Patient & Surgical Demographics

Demographics	Total
Age(years)	55.5(47–65)
Sex	
Male	1408(49.3%)
Female	1449(50.7%)
Body mass index (kg/m2)	23.8(21.2–26.0)
Insertion arm	
Left	763(26.7%)
Right	2094(73.3%)
Insertion vein	
Basilic	2398(83.9%)
Brachial	408(14.3%)
Cephalic	51(1.8%)
Vascular diameter(cm)	0.41(0.35–0.45)
Vascular depth(cm)	0.90(0.62–1.11)
Arm circumference(cm)	26.77(25.00-28.60)
No. of delivered attempts	
1	2599(91.0%)
>1	258(9.0%)
Misplacement during PICC insertion	210(7.4%)
Misplacement following PICC insertion	19(0.67%)
Abbreviation: BMI: Body mass index	

Misplacement

A total of 210 misplaced PICCs (7.4%) were identified by ultrasound and IC-ECG, and all of them were repositioned to the SVC by individualized treatment methods. However, there were still 19 PICCs (0.67%) misplaced on CXR, including 18 cases via the basilic vein, 1 case via the brachial vein, 15 cases via the left arm and 4 cases via the right arm. All of them were misplaced into the azygos vein (Fig. 3). The most common site of intraoperative misplacement was the internal jugular vein in 158 cases (158/210, 75.2%), followed by the axillary vein (27/210, 12.9%) and the cephalic vein (16/210, 7.6%). The vessels and veins with misplaced PICCs are shown in Table 2.

Table 2
Ectopic vessels and catheterized veins

Ectopic vessels	Left arm			Right arm		
	Basilic vein	Brachial vein	Cephalic vein	Basilic vein	Brachial vein	Cephalic vein
Azygos vein	15	0	0	3	1	0
Subclavian vein	4	0	0	4	1	0
Axillary vein	4	4	0	11	4	4
Jugular vein	20	7	0	121	9	1
Brachiocephalic vein	4	5	1	5	1	0

In the univariate analysis, intraoperative catheter misplacement was associated with arm circumference (OR: 0.952; 95% CI: 0.907–0.999; $p = 0.044$), and the number of insertion (OR: 5.958; 95% CI: 4.849–7.322; $p < 0.001$). The postoperative catheter misplacement was associated with left/right arm insertion (OR: 10.478; 95% CI: 3.467–31.670; $p < 0.001$), with a significantly higher rate of misplacement via the left arm than the right arm, and there was a correlation with patient age (OR: 1.034; 95% CI: 0.995–1.074; $p = 0.090$) (Table 3).

Table 3
Univariate Logistic Regression Analysis for Misplacement during and following PICC insertion

Predictors	**Misplacement during PICC insertion**		**Misplacement following PICC insertion**	
	OR(95% CI)	P value	OR(95% CI)	P value
Age	0.99(0.99–1.007)	0.547	1.034(0.995–1.074)	0.090
Sex (Male VS Female)	1.097(0.828–1.453)	0.518	1.418(0.569–3.537)	0.453
Height	1.000(0.983–1.01)	0.986	1.042(0.986–1.102)	0.146
Weight	0.992(0.980–1.003)	0.162	1.007(0.997–1.018)	0.157
BMI	0.968(0.932–1.006)	0.100	1.020(0.982–1.059)	0.313
Catheter side (Left VS Right)	0.946(0.686–1.305)	0.736	10.478(3.467–31.670)	<0.001
Cannulated vein		0.906		NA
Brachial	Reference	-	-	-
Basilic	0.963(0.648–1.433)	0.853	-	-
Cephalic	0.760(0.224–2.581)	0.660	-	-
Vascular diameter	0.592(0.100-3.519)	0.564	8.237(0.580-116.906)	0.119
Vascular depth	0.835(0.563–1.240)	0.371	0.896(0.262–3.062)	0.862
Arm circumference	0.952(0.907–0.999)	0.044	1.106(0.955–1.281)	0.177
No. of delivered attempts	5.958(4.849–7.322)	<0.001	0.976(0.587–1.624)	0.927
Abbreviation: OR: Odds ratio, BMI: Body mass index, NA: Not Applicable.				

In the multivariate analysis, intraoperative catheter misplacement was associated with the number of insertion (OR: 5.974; 95% CI: 4.857–7.347; $p < 0.001$). Postoperative catheter misplacement was associated with left/right arm insertion (OR: 9.959; 95% CI: 3.265–30.376; $p < 0.001$), and patients with left-arm insertion were prone to occur misplacement (Table 4).

Table 4
Multivariate logistic regression analysis for misplacement during and following PICC insertion

Predictors	Misplacement during PICC insertion		Predictors	Misplacement following PICC insertion	
	OR(95% CI)	P value		OR(95% CI)	P value
Arm circumference	1.011(0.948–1.078)	0.748	Age	1.034(0.995–1.075)	0.089
No. of delivered attempts	5.974(4.857–7.347)	<0.001	Catheter side (Left VS Right)	9.959(3.265–30.376)	<0.001
Abbreviation: OR: Odds ratio.					

All patients with misplaced PICCs (n = 19) had trouble getting blood return by aspiration and underwent secondary placement, and no misplacements were reviewed after the second placement. No patient experienced complications related to PICC misplacement.

Discussion

The result of this study showed that the incidence of PICC misplacement was 7.4% under the guidance of ultrasound and IC-ECG, while reduced to 0.67% on postoperative CXR after intraoperative adjustments and subsequent IC-ECG check. Cost analysis showed that postoperative CXR was a very expensive screening test when used to eliminate PICC-related mechanical complications. Notably, all postoperative catheter misplacements occurred in the azygos vein without any serious complications, and patients had trouble getting blood return by aspiration, which can be used to determine the further use of CXR, thus further clarifying the location of the tip of the catheter.

The cost of CXR varies depending on the geographic location. In this analysis, we used our hospital's quoted cost of $12.50 per orthopantomogram. The total number of CXR performed in this study was 2,857, so the total cost was $35,712 (1.5 years), or $23,808 per year. The cost of using CXR to diagnose one case of catheter misplacement, i.e. PICC repositioning, was $1,253.

This study demonstrated that the incidence of catheter misplacement was very low and the cost of routine postoperative CXR was very high. This finding suggests that postoperative CXR has a low ability to intervene and predict PICC misplacement. IC-ECG itself is better able to avoid various catheter tip misplacements. Previous guidelines recommend postoperative CXR to determine catheter tip position, and misplaced catheter tips are usually repositioned and examined by another imaging test to reassure optimal position[8]. This procedure may prolong the use of the catheter. In addition, possible and unnecessary radiation exposure from CXR should be considered as well[9].

We also determined that placement via the left arm increased the incidence of catheter misplacement, around 10 times than right-sided insertion. There are no previous studies of left or right-sided insertion for

PICC misplacement. A previous study found a significantly increased risk of central venous catheter tip misplacement by left-sided insertion[10]. Another study found that there was no significant difference in the incidence of tunneled hemodialysis catheter misplacement to the azygos vein by left- or right-sided insertion[11]. The exact reason is unclear. Anatomically, the left innominate vein is at a higher level and closer to the junction of the SVC compared to the right innominate vein. The guidewire inserted from the left side is always in contact with the lateral wall of the SVC before it is flipped into the correct position. This appears to be the mechanism of catheter misplacement into the azygos vein[12].

These findings suggest that routine postoperative CXR is not necessary for routine placement. However, it still should be considered in case of a high suspicion of catheter misplacement, such as after multiple attempts of insertion, or if the insertion site is not right-sided and blood return is not normal.

This study focused on perioperative PICC placement performed under ultrasound guidance. The results of this study may not be applicable to other clinical settings, as the use of ultrasound significantly reduces the dependency on practitioner’s experience in vascular cannulation. This study was performed at an institute in a university hospital in China, where ultrasound machines are widely used, and the operators have extensive experience with ultrasound-guided cannulation. The applicability of our findings to other clinical settings or to operators with different levels of experience must be considered on an individual basis.

In our study, the intraoperative misplacement rate and the incidence of vessels with misplaced catheters were similar to other studies[13]. Our postoperative misplacement rate was significantly decreased after intraoperative adjustments by IC-ECG, and all postoperative catheter misplacements occurred in the azygos vein with an incidence of 0.67%, marginally different from the previous studies (0.7%-3.8%)[10, 14, 15]. This indicates that IC-ECG method has little role in preventing catheter tip misplacement into the azygos vein. Even if the placement is successful, inappropriate patient movement or high intracranial pressure during severe nausea, vomiting, hiccups, and constipation may also cause misplacement [16]. In the present study, we monitored normal blood return with aspiration catheter after IC-ECG examination during the operation, but found misplacement of the catheter tip on postoperative CXR. Besides, abnormalities were found on a repeated catheter aspiration and IC-ECG localization. Therefore, whether the catheter tip is misplaced into the azygos vein due to the patient's body position change after the placement still needs further investigation.

Recently, there has been a significant focus on the "Choosing Wisely" movement in the North American health care system, with the aim of reducing low-value and wasteful tests or procedures[17, 18]. These unnecessary tests and interventions fail to bring meaningful benefits to patients and can be potentially harmful, requiring additional effort to investigate false positives, which is a significant waste of resources for both patients and health professionals. More than 50 medical societies are involved in this movement and have compiled lists of the most commonly overused tests or procedures in various relevant clinical areas[17]. In the present study, our findings suggested that routine CXR after the use of ultrasound and IC-

ECG guided PICCs is not a wise choice and should be included in the list of unnecessary test and procedures.

However, it is difficult to make changes in clinical practice[19, 20], and there is a need of cultural awareness, physician perception, and redesign of patient care processes and related guidelines[21]. This can be facilitated by the combination of ultrasound-guided PICC implantation, subsequent ECG localization and blood return test by catheter aspiration.

LIMITATIONS

A major limitation of this study is the unavoidable information bias due to the retrospective design. To ensure that information bias was minimized, we evaluated each patient's electronic CXR film and radiologist's report to verify any mechanical PICC-related complications. We also conducted data verification by a second evaluator. The other limitation is the lack of data on the duration of each PICC placement. Moreover, the cost analysis for this study was based on cost estimates for a single CXR at our institute, which may vary at other institutions.

Conclusion

This study is the largest to date, involving a sample size of 2,857 PICCs and providing a scientific basis for questioning the current practice (routine CXR after PICC placement) as prescribed by current guidelines [9]. Our results show that PICC misplacement after ultrasound guidance is rare and postoperative CXR has low predictability for identifying interventions for PICC-related mechanical complications. Besides, postoperative CXR is high-cost. We conclude that once the ECG-guided system is identified to be highly accurate, routine postoperative CXR is unnecessary and also uneconomical in our setting. The applicability of our results in other clinical settings must be considered on an individual basis.

Abbreviations

CXR: chest X-ray; PICC: peripherally inserted central venous catheter; IC-ECG: intracavitary electrocardiography; VTE: venous thrombotic event; ICD: implacable cardioverter-defibrillator; MST: modified seldinger technique; SVC: superior vena cava; CAJ: cavoatrial junction; BMI: body mass index; OR: odds ratio; CI: confidence interval.

Declarations

Ethics approval and consent to participate

The study was in line with the Helsinki Declaration and approved by the Peking University Cancer Hospital Ethics Committee. Written informed consent was obtained from the patients for their

 this study.

Consent for publication

All authors provided consent for publication.

Availability of data and materials

The data sets used and/or analyzed during the current study are available from Guo-dong Wang on reasonable request. （Email: wgd0634@163.com）

Competing interests

The authors declare that they have no competing interests.

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Author contributions

G.W.: concept, design, analysis, interpretation, critical writing, revision, and final approval. Y.S.: design, analysis, interpretation, revision, and final approval. J.D. and X.W.: design, interpretation, critical revision, and final approval. X.W. and Y.Z.: design, interpretation, and final approval.

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Figures

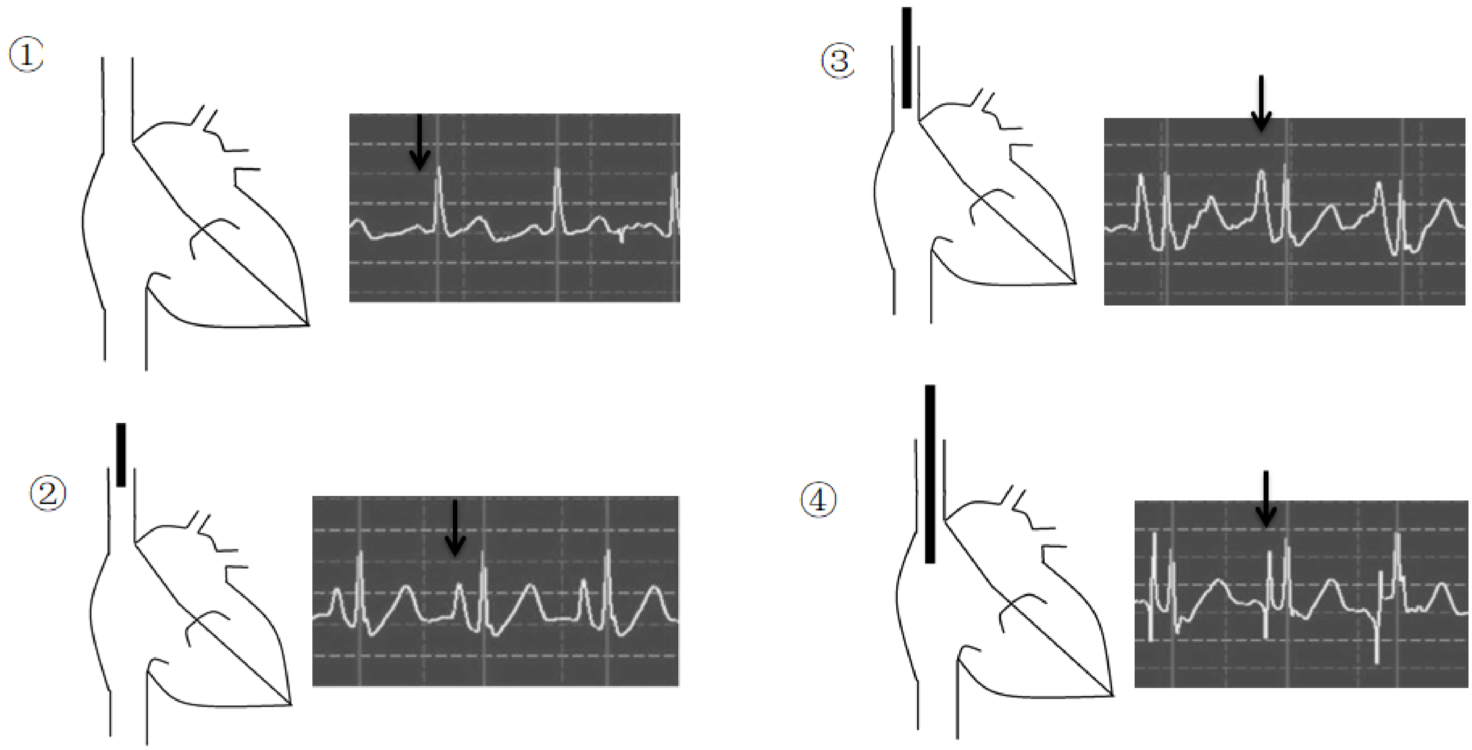

Figure 1

①Normal P-wave. ②The catheter is approaching the atrium and the P-wave is getting bigger. ③ Optimal position: the tip is in the CAJ and the P-wave is maximal. ④The tip is entering the atrium and a negative deflection appears.

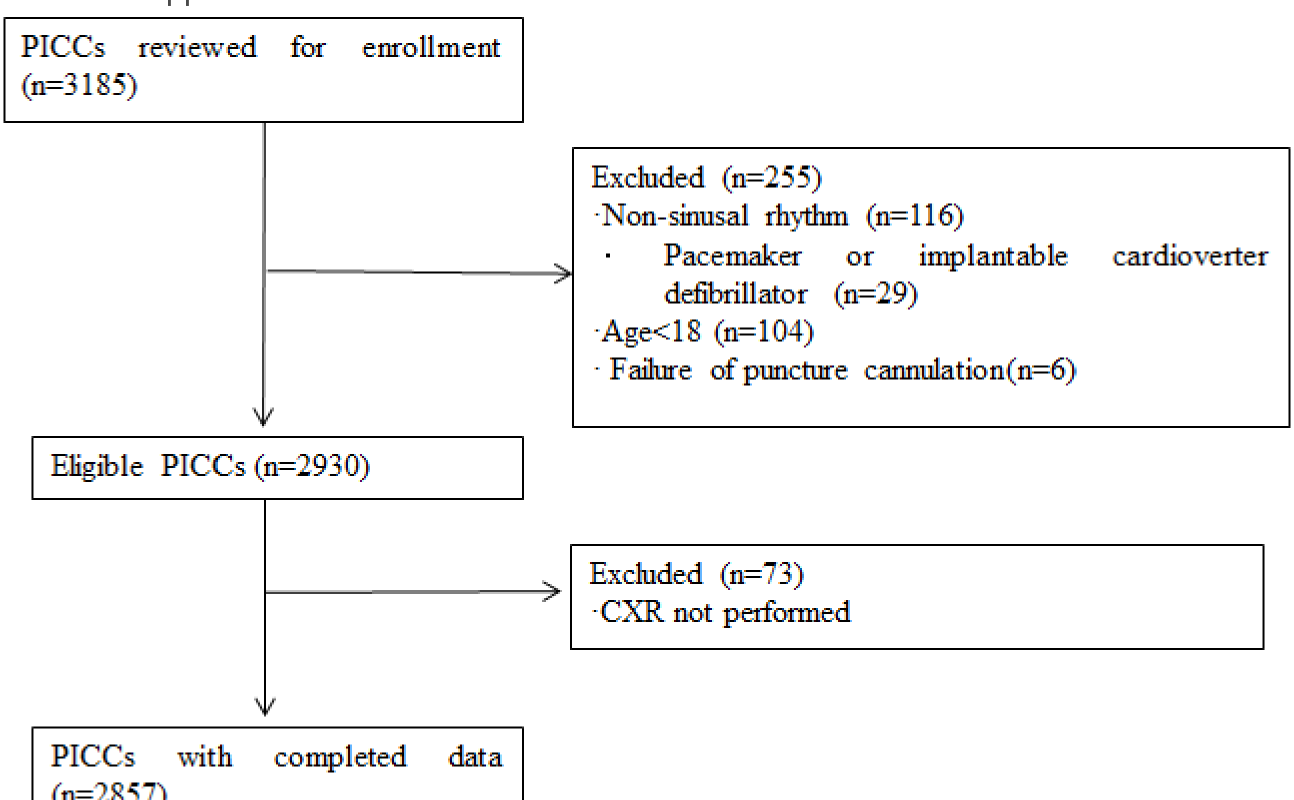

Figure 2

Flow diagram illustrating generation of final study cohort Abbreviations: PICC, peripherally inserted central catheter; CXR, chest X-ray.

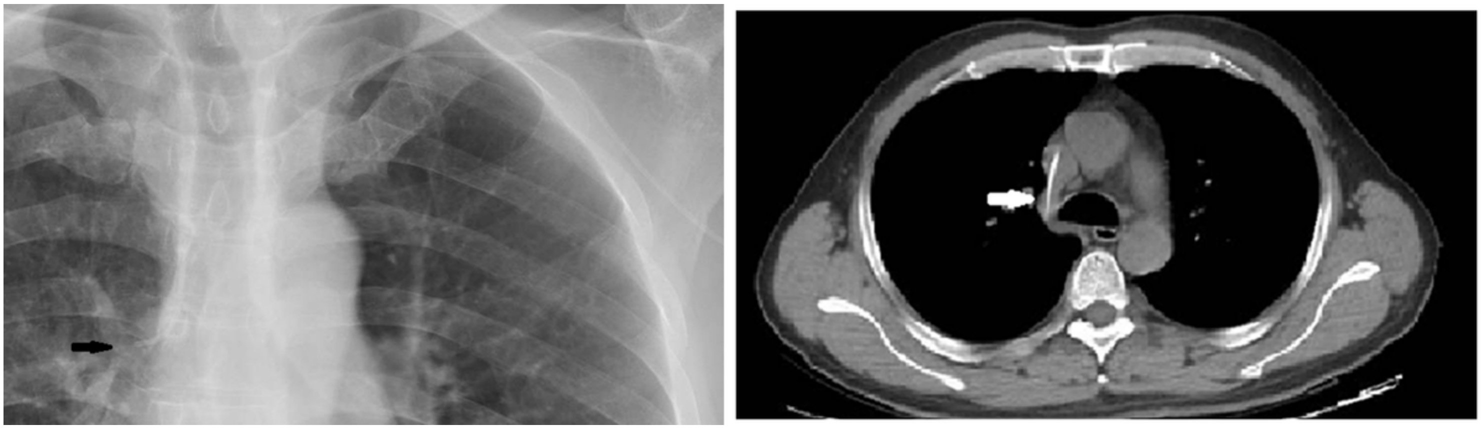

Figure 3

A Catheter malposition into the azygos vein. AP(anterio-posterior) view. B Catheter malposition into the azygos vein. Computed tomography cross-sectional image of the thorax.