Application of intracavitary ECG for positioning the totally implantable venous access port in the upper arm of cancer patients

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Received March 30, 2022; Accepted May 20, 2022

DOI: 10.3892/etm.2022.11404

Abstract. Accurate positioning of the catheter tip is one of the most critical procedures in central venous catheter insertion. The traditional surface measurement method frequently has a large deviation and increases the X-ray exposure of doctors and patients. In the present retrospective study, cancer patients who received a totally implantable venous access port (TIVAP) in the upper arm using intracavitary electrocardiogram (ECG) guidance were compared with those where the traditional surface measurement method was used in terms of the rate of correct placement of the catheter tip, the rate of achieving the best position, the operation time and the complications. The results indicated that the correct placement rate and the best position rate of the catheter tip at the first attempt were higher in the ECG-guided group than in the traditional surface measurement method group (95.65 vs. 82.91% and 90.58 vs. 68.38%, respectively). The mean operation time was shorter in the ECG-guided group than in the surface measurement group (46.28 vs. 63.26 min). The incidence of complications in the ECG-guided group was 6.52%, while that in the surface measurement group was 10.26%. This indicated that the intracavitary ECG-guided tip positioning technique may improve the accuracy of tip catheter placement and shorten the operation time, thus reducing ionizing radiation caused by repeated positioning. Therefore, the intracavitary ECG-guided tip positioning technique is able to effectively place the tip of the TIVAD in the upper arm, holding great promise as a clinical application.

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Key words: intracavity electrocardiogram localization, upper arm implantable infusion port, cancer patients

Introduction

Totally implantable venous access port (TIVAP) is a closed intravenous infusion device that may be implanted under the skin and retained in the body for a long duration (1,2). It mainly comprises an injection seat for puncture and an intravenous catheter system and may be used for infusion, rehydration, nutritional support and blood transfusion of various chemotherapy drugs (3,4). Compared with peripherally placed central venous catheter (PICC) and central venous catheter, TIVAP has obvious advantages in terms of safety, infection rate and patient satisfaction (5,6). It is widely used in clinical applications, is superior to other long-term central venous catheters and is the best choice for cancer patients (7-9). At present, TIVAP is mainly implanted through the subclavian vein, internal jugular vein and upper arm vein. Compared with the subclavian vein and internal jugular vein, TIVAP implanted in the upper arm has the advantages of a higher puncture success rate and a lower risk of haemopneumothorax (10). Arm ports are more cosmetically appealing (11) and are more popular with female patients.

TIVAP in the upper arm is an operation performed by nurses and completed with the cooperation of doctors, which has been gradually popularized and applied in patients with malignant tumours in recent years. Accurate positioning of the catheter tip is one of the most critical technical steps in central venous catheter insertion. Traditionally, the reserved length of the catheter is measured by the surface measurement method and the length of the catheter is adjusted according to the placement of the catheter tip under digital subtraction angiography (DSA) guidance (12). This method frequently has a large deviation and increases the X-ray exposure of clinicians and patients.

In recent years, the intracavitary ECG-guided tip positioning technique has been widely used in PICC tip placement, and research has confirmed the stability and accuracy of this technology (13,14). However, only a small number of studies have reported on the application of intracavitary ECG-guided tip positioning techniques of TIVAP in the upper arm. In the present study, an intracavitary ECG positioning technique guided by a trocar needle was used to insert the tip of the catheter of the TIVAP in the upper arm of patients with malignant tumours. It was determined that this technique is a safe and effective method for catheter tip placement and has high prospects for clinical application.

Materials and methods

Patients and study design. The present study was a retrospective study according to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines (15). This study was approved by the Ethics Committee of The Affiliated Suzhou Hospital of Nanjing Medical University (Suzhou, China; no. KL171072). Clinical data were acquired from medical records (mainly surgical and nursing records). The inclusion criteria were as follows: i) Cancer patients who received a TIVAP in the upper arm in our department; and ii) ECG displaying a sinus rhythm with a normal P wave. Furthermore, the following exclusion criteria were applied: i) Patients with severe primary diseases, such as those of the heart, liver, kidney and haematopoietic systems; ii) previous upper limb oedemaedema; iii) dysfunction of blood coagulation; and iv) patients with alcoholism and drug addictions. Finally, a total of 255 adult inpatients who required TIVIP in the upper arm between March 2017 and July 2020 at the Affiliated Suzhou Hospital of Nanjing Medical University (Suzhou, China) were included. There were no significant differences between the two groups in terms of age, sex, body height, body weight, smoking or venipuncture site (Table I). In the present retrospective study, all cancer patients who received a TIVAP in the upper arm at our department using ECG guidance were compared with those in whom the traditional surface measurement method was applied.

Procedure. All patients were implanted an Infusion Port, Model 5 Fr (B. Braun). The procedure for intracavitary ECG-guided tip positioning used in the first cohort was as follows (16,17): A three-electrode ECG monitoring mode was used to connect the ECG monitor (Philips Medical Systems B.V.) and the ECG monitor was adjusted to lead II to record the basic ECG on the patient's body surface. After skin disinfection and local anaesthesia, puncture was performed through the basilic vein or brachial vein under the guidance of ultrasound (Volcano). Subsequently, the sheath was inserted using the Seldinger technique. When the catheter was inserted 5 cm, the delivery of the catheter was stopped and the intracavitary ECG connection was made through a trocar needle. With the catheter tip entering the superior vena cava, the P wave of the ECG exhibited characteristic changes (Fig. 1). When the P wave fell back after reaching the peak or a bidirectional P wave appeared, the catheter was judged to have entered the right atrium (18,19). At this time, when the catheter was stopped and retreated to achieve the horizontal position of the highest peak of the positive P wave (exited for 20 mm), the catheter was fixed and the catheter scale was recorded. The catheter position was confirmed by X-ray (Fig. 2A and B). Finally, a doctor set up a subcutaneous tunnel under the puncture point, cut the skin ~2 cm horizontally, made a pouch, connected the catheter with the injection seat and wrapped it with a sterile dressing after suture (Fig. 2C).

In the second cohort, the traditional surface measurement method was used for catheter tip positioning. First, the distance was measured from the puncture point to the right sternoclavicular joint and then down to the third rib. The insertion technique was similar to the above. Subsequently, the catheter was inserted with the predicted length. The length of the catheter was adjusted according to the position of the catheter tip under the visual guidance of DSA (Siemens AG). The next steps were the same as those for intracavitary ECG-guided tip positioning.

Outcomes. The number of cases in whom the correct position of the catheter tip and the best position were achieved on first attempt, as well as the operation time, were compared between the two groups. When the catheter tip was located in the superior vena cava (SVC) and caval-atrial junction, it was judged as the correct position of the catheter tip and the catheter tip located in the lower third of the SVC was judged as the best position. Early complications within 14 days after placement, including phlebitis, venous thrombosis and arrhythmia, were compared between the two groups.

Statistical analysis. Statistical analysis was performed using the SPSS 20 software package (IBM Corporation). Where appropriate, Student's t-test and the χ^2 test were used to examine the significance of the results. $P<0.05$ was considered to indicate a statistically significant difference.

Results

Success of catheter positioning and operation time. The correct positioning rate and the rate of achieving the best position of the catheter tip at the first attempt were higher in the ECG-guided group than in the traditional surface measurement method group (Table II). The mean operation time was significantly shorter in the ECG-guided group than in the surface measurement group (46.28 vs. 63.26 min; P=0.0226; Table II).

Complications. Complications were phlebitis, venous thrombosis and arrhythmia. The incidence of complications in the ECG-guided group was 6.52% (9/138), while that in the surface measurement group was 10.26% (12/117) (Table III).

Discussion

Compared with chest TIVAP, the arm implementation site provides an improvement in patient satisfaction and quality-of-life categories during chemotherapy (20). The position of the catheter tip is important for central venous catheters, particularly for long-term devices (21,22). Accurate positioning of the catheter tip is one of the most critical technical steps in central venous catheter insertion (23). The traditional measurement method is the most common and convenient one, while intracavitary ECG-guided tip positioning has high

Table I. Clinical characteristics of patients.

Item	Overall (n=255)	Surface measurement group (n=117)	ECG-guided group (n=138)	P-value
Age, years	54.91±14.29	53.42±13.68	56.19±16.44	NS
Males/females	127/128	56/61	71/67	NS
Body height, cm	165.16±15.18	164.72±9.68	165.54±13.26	NS
Body weight, kg	60.58±10.43	59.77±11.37	61.27±9.87	NS
Smoker	73	35	38	NS
Venipuncture site				
Basilic vein left	22	10	12	NS
Basilic vein right	143	78	65	NS
Brachial vein left	24	10	14	NS
Brachial vein right	66	32	34	NS

Values are expressed as n or the mean ± standard deviation. NS, not significant.

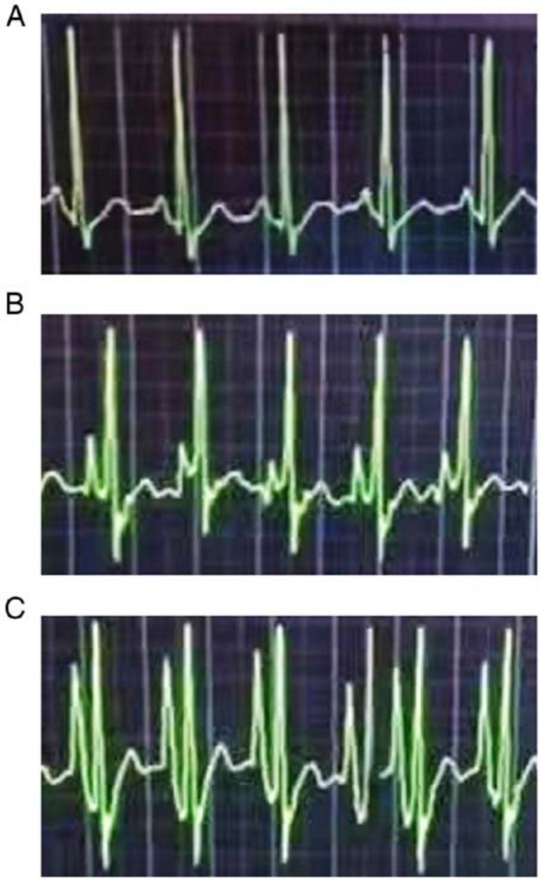

Figure 1. Characteristic changes of intracavitary ECG during catheter insertion. (A) Sinus P wave in lead II. (B) A biphasic P-wave in lead II occurred when the catheter was judged to have entered the right atrium. (C) When the catheter was retreated to the location associated with the horizontal position of the highest peak of the positive P wave, the catheter tip was in its best position.

specificity and sensitivity (24). Recent research on PICC ports recommended using the intracavitary ECG technique to locate the catheter tip (25). The principle of intracavitary ECG localization technology is to guide the patient's intracavitary ECG using the conductivity of blood, normal saline or a guide wire. In the present study, the accuracy and the best positioning rate of the catheter tip were compared between the ECG-guided positioning technique and the traditional measurement method. The results suggested that intracavitary ECG guidance is able to improve the accuracy and the best positioning rate of the catheter tip compared with the traditional measurement method, which proved that the intracavitary ECG-guided tip positioning technique is feasible and effective in placing the upper arm implantable infusion port in patients with malignant tumours.

Improper catheter placement not only prolongs the operation time but also increases the radiation exposure of patients and medical staff by repeated DSA fluoroscopy (26). The present study indicated that the intracavitary ECG-guided tip positioning technique is able to improve the accuracy of tip catheter placement and save operation time, thus reducing exposure to ionizing radiation due to repeated positioning. Considering the accuracy of intracardiac ECG localization at the tip of the central venous catheter and the influence of X-ray irradiation on patients, an increasing number of researchers suggested that X-ray examination should be cancelled after intracavitary ECG-guided tip positioning (26,27). However, this technology requires medical staff to have a high ability to analyse and interpret ECG. In the clinic, it may be suggested that surgeons with certain operating experience cancel the X-ray examinations after the operation.

Compared with the chest wall port, TIVIP in the upper arm is able to reduce complications such as pneumothorax, haemothorax and pinch-off syndrome. The latest research indicates that the PICC port is a safe vascular device and may be an alternative option to traditional arm ports and chest ports (25). Compared with the PICC port, the arm ports may have a slightly higher incidence of complications. However, the arm ports also have the advantages of relatively simple operation and less restriction on arm movement. The only constant issue is that they all require accurate positioning of the catheter tip. If the central venous catheter is too shallow, the incidence of phlebitis and venous thrombosis increases (28). If the catheter

Table II. Comparison of correct placement and best position of catheter tip and operation time.

Item	Overall (n=255)	Surface measurement group (n=117)	ECG-guided group (n=138)	P-value
Correct placement of catheter tip	229 (89.80)	97 (82.91)	132 (95.65)	0.0018
Best position	205 (80.39)	80 (68.38)	125 (90.58)	<0.0001
Operation time, min	54.07±9.77	63.26±8.76	46.28±9.76	0.0226

Values are expressed as n (%) or the mean ± standard deviation.

Table III. Details regarding complications.

Complication	Overall (n=255)	Surface measurement group (n=117)	ECG-guided group (n=138)	P-value
Phlebitis	8 (3.14)	5 (4.27)	3 (2.17)	NS
Thrombosis	6 (2.35)	4 (3.42)	2 (1.45)	NS
Arrhythmia	7 (2.76)	3 (2.56)	4 (2.90)	NS

Values are expressed as n (%). NS, not significant.

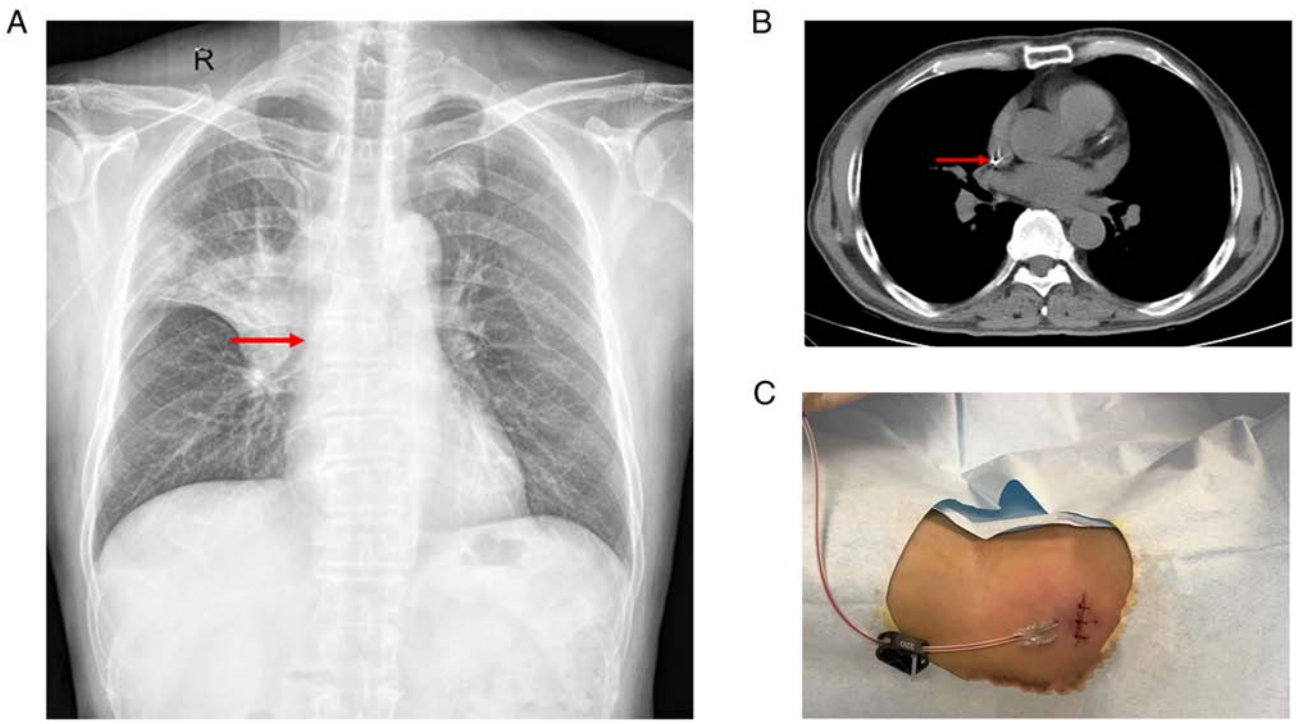

Figure 2. (A) Representative post-procedure chest X-ray, (B) corresponding chest CT image and (C) photograph of insertion site. The red arrow in A and B indicates the catheter tip.

is implanted too deeply, the head end may enter the right atrium, which may lead to complications such as arrhythmia or myocardial injury (29). The intracavitary ECG-guided tip positioning technique has the function of real-time positioning. The optimal position of the catheter may be found in time and adjusted during the operation, without repeated adjustment after the operation, which may reduce the occurrence of complications (30).

Adjusting the position of the catheter tip causes friction between the catheter and the blood vessel, which leads to intimal damage and subsequently to phlebitis and venous thrombosis. The present study suggested that the intracavitary

ECG-guided tip positioning technique may reduce the occurrence of complications caused by catheter placement. Further studies and prospective multicentre clinical trial data should be collected to confirm the results.

Based on the above results, it may be recommended to use the intracavitary ECG technique to locate the catheter tip as an alternative to the traditional surface measurement method. This is in line with the recommendations of other researchers (25,31). However, there are certain limitations to this study. First, as with any retrospective study, there was poor control over the factors influencing outcomes, covariates and potential confounders. Furthermore, the present study was a single-centre study. The sample size of the study was small and larger-sample studies should be performed to validate the results. In addition, late complications should be assessed in a multicentre, prospective study.

In conclusion, the intracavitary ECG-guided tip positioning technique may accurately locate the tip of the catheter of the upper arm implantable infusion port and reduce the operation time, which has great clinical significance. The related operation steps and procedures provided in the present study have been implemented in clinical practice and the results are remarkable. However, the sample size of the present study was small and methods require to be constantly revised and improved in future clinical practice.

Acknowledgements

Not applicable.

Funding

This study was funded by the Nursing Society of Suzhou (grant no. 2019C06).

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

JZ was the main leader and director of the project. JZ and HL were responsible for the conception and design of the study. LS, HC and HL collected the data, analysed the datasets and provided academic support. LS and HC analysed and interpreted the datasets and wrote the manuscript. YY assisted in the experiments and provided data analysis. HL critically revised the manuscript. LS and HC confirm the authenticity of all the raw data. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The study was approved by the Ethics Committee of The Affiliated Suzhou Hospital of Nanjing Medical University (Suzhou, China). Consent to participate was provided by each of the patients. All procedures of this study were performed in accordance with the Declaration of Helsinki.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests regarding this work.

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