Accurate Central Venous Port-A Catheter Placement: Intravenous Electrocardiography and Surface Landmark Techniques Compared by Using Transesophageal Echocardiography

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Using transesophageal echocardiography (TEE) to locate the tip of central venous catheters inserted via the right subclavian vein, we compared IV electrocardiography (IV-ECG)-guided catheter tip placement with the conventional surface landmark technique. Sixty patients were randomly assigned into two groups. In Group E, the IV-ECG signal was conducted along an $NaHCO_3$-filled catheter to facilitate catheter placement. In Group S, surface landmarks on the chest wall were used to determine the appropriate catheter length. The goal was to visualize the catheter tip with TEE at the superior edge of the crista terminalis, which is the junction of the superior vena cava (SVC) and right atrium (RA). The catheter tip position was considered to be satisfactory, as the tip was within 1.0 cm of the upper crista terminalis edge. All 30 Group E patients had satisfactory catheter tip placement when the ECG P wave was at its maximum. In contrast, 16 of the 30 patients in Group S had satisfactory tip positions ($P < 0.001$). All catheters were repositioned under TEE guidance to adjust the tip to the SVC-RA junction. After the catheter tips were confirmed to be located at the SVC-RA junction, the catheter tips were still visualized in the mid portion of RA in 12 of 60 patients on supine chest radiographs. We concluded that IV-ECG guidance to position a catheter resulted in satisfactory catheter tip placement that is in accordance with TEE views. Catheter placement at the SVC-RA junction with the surface landmark technique was unreliable.

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Cancer patients often require placement of permanent central venous catheters for the administration of IV chemotherapy, antibiotics, and total parenteral nutrition. To decrease the incidence of catheter dislodgement, vessel wall erosion, thromboembolism, and device dysfunction, accurate positioning of the catheter tip near or at the junction of the superior vena cava (SVC) and right atrium (RA) is necessary (1–6).

Various techniques have been developed to ensure correct placement of long-term central venous catheters. Although roentgenography or fluoroscopy is often used, an alternative technique using IV electrocardiographic (IV-ECG) guidance has been developed to reduce radiation exposure and cost (7–9). This IV-ECG technique suggests proper catheter positioning when the amplitude of the ECG P wave is at its maximum from the bipolar arm lead (10), and it is dependent on capturing the impulse from the spindle-shaped structure of the sinoatrial (SA) node located in the RA sulcus terminalis, lateral to the junction of the SVC and RA. No reports have confirmed the exact position of the catheter tip relative to the SVC-RA junction when the IV-ECG shows the largest P wave. Transesophageal echocardiography (TEE) has been shown to accurately monitor the placement of catheter tip at the SVC-RA junction (11), and it provides a more sensitive assessment than chest radiography (12,13). Accordingly, to correctly position the central venous catheter at the SVC-RA junction, this study aimed to establish the accuracy of the IV-ECG technique by TEE and to compare it with the surface landmark technique.

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Methods

Between February 1999 and October 2002, 60 adult patients who had malignant diseases and were scheduled

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for the placement of an indwelling central venous access (venous port access catheter) at the time of major surgical procedures were included in this study. The Kaohsiung Medical University ethics committee approved this prospective study, and written, informed consent was obtained from patients. Patients with intermittent dysrhythmia, atrial fibrillation, esophageal varices, or neoplastic changes were excluded from this study.

All the patients were premedicated with atropine 0.01 mg/kg and metoclopramide 10 mg. After the induction of general anesthesia, endotracheal intubation, and mechanical controlled ventilation, a multiplane TEE probe was inserted to evaluate patient cardiac function and hemodynamic changes during major surgical procedures. Venous Port-A-Cath implantation took place once the major surgical procedures had been completed. At this point, patients were randomly assigned to either Group E, which used IV-ECG to position the catheter, or to Group S, which used surface landmarks on the chest wall to determine the appropriate length of catheter insertion. The right subclavian vein was cannulated via the infraclavicular area of the anterior chest wall, just lateral to the midpoint of the clavicle. After venous access was achieved, a radiopaque silicone catheter (single lumen, Delrin®; HDC Corp.) was introduced into the vessel.

The procedure used for the IV-ECG catheter tip guidance in Group E was standardized. After the port was connected to the catheter, the catheter and port system was flushed with 0.8 mEq/mL $NaHCO_3$, and a sterile electrode lead was attached directly to the noncoring needle that was inserted into the septum of the port and connected to the Certofix switch box (Certodyn®; B. Braun Melsungen AG), so that it changed a normal two-limb-lead ECG to an IV-ECG. The IV-ECG signals were shown on two separate monitors (Siemens SC 9000XL; Danvers) at the same time over an Intranet connection. Another anesthesiologist, who was unaware of the surgical procedure, evaluated the IV-ECG signals from another room and determined when the proper catheter position had been achieved. As the catheter tip was advanced toward the SA node, the P wave increased in amplitude until it was as large or larger than that of the QRS complex (P atriale). The P wave then became biphasic as the catheter tip passed the SA node. Once the biphasic P wave was observed, the catheter was withdrawn until the largest P wave or P atriale was once again obtained; meanwhile, the length of insertion was recorded as the initial catheter length. At the same time, a cardiologist manipulated the TEE probe to obtain a longitudinal view of the atria and cavae to view the SVC-RA junction (Fig. 1A). The catheter was recognized as several parallel, bright echodense lines surrounding the darker fluid-filled lumen. The tip was identified by directly visualizing the end of the venous catheter and many hyperechogenic microbubbles quickly flowing out of the distal catheter after a rapid flush of saline (Fig. 1B).

Using the TEE, the initial position of the catheter tip was defined to be satisfactory if the tip was within 1.0 cm of the upper edge of the crista terminalis (CT). After the initial catheter length was recorded, the location of the catheter tip was readjusted to the upper edge of the CT under TEE monitoring, and this was called the TEE-corrected length. Tip correction distance was then measured as the difference of TEE-corrected length and initial catheter length. Finally, a supine portable anteroposterior chest radiograph was then obtained to exclude catheter looping, unintentional pneumothorax, and hemothorax. In addition, the relative position of the catheter tip and the SVC-RA junction from the radiograph was evaluated.

The chest wall surface landmark technique used to determine the catheter length from the skin entrance to the RA (Group S) was also standardized. The distance between the skin puncture site and the mark point of 5 cm below the manubriosternal junction was obtained (14) and recorded as the initial catheter length. The silicone catheter was advanced into the vessel according to the initial catheter length. TEE was then used to define satisfactory placement, adjust the catheter tip, and measure the tip correction distance in the same manner described for Group E. A supine portable anteroposterior chest radiograph was then obtained for the same reasons as for Group E.

A radiologist viewed all films, and the SVC-RA junction was defined as the intersection of the curvilinear lines representing the mediastinum and the right heart border. The radiologist determined the location of the junction and measured the distance from that point to the catheter tip. The proper radiographic position of the catheter tip was defined as within 1 cm inferior to the identified position of the SVC-RA junction in the supine chest radiograph (15).

Statistical analysis was performed with Student's *t*-test and χ^2 tests. *P* values of <0.05 were considered statistically significant.

Results

Both groups were matched with respect to age, body weight, sex, and type of major abdominal malignancy. In all patients, the right subclavian vein was used, and catheter placements were uneventful (Table 1).

There was no difference between groups in total catheter tip placement time, initial catheter length, and TEE-corrected catheter length (Table 2). Regarding the tip correction distance, Group E obtained a significant difference in the subcategories of "≦ 0.5 cm" and "1.1–2.0 cm" items compared with Group S. As for satisfactory placement, all Group E patients had satisfactory catheter tip placement with the IV-ECG technique. In comparison, 16 of the 30 patients in Group S obtained a satisfactory catheter position ($P < 0.001$), with 14 of the 30 catheters in an unsatisfactory position ($P < 0.001$). In

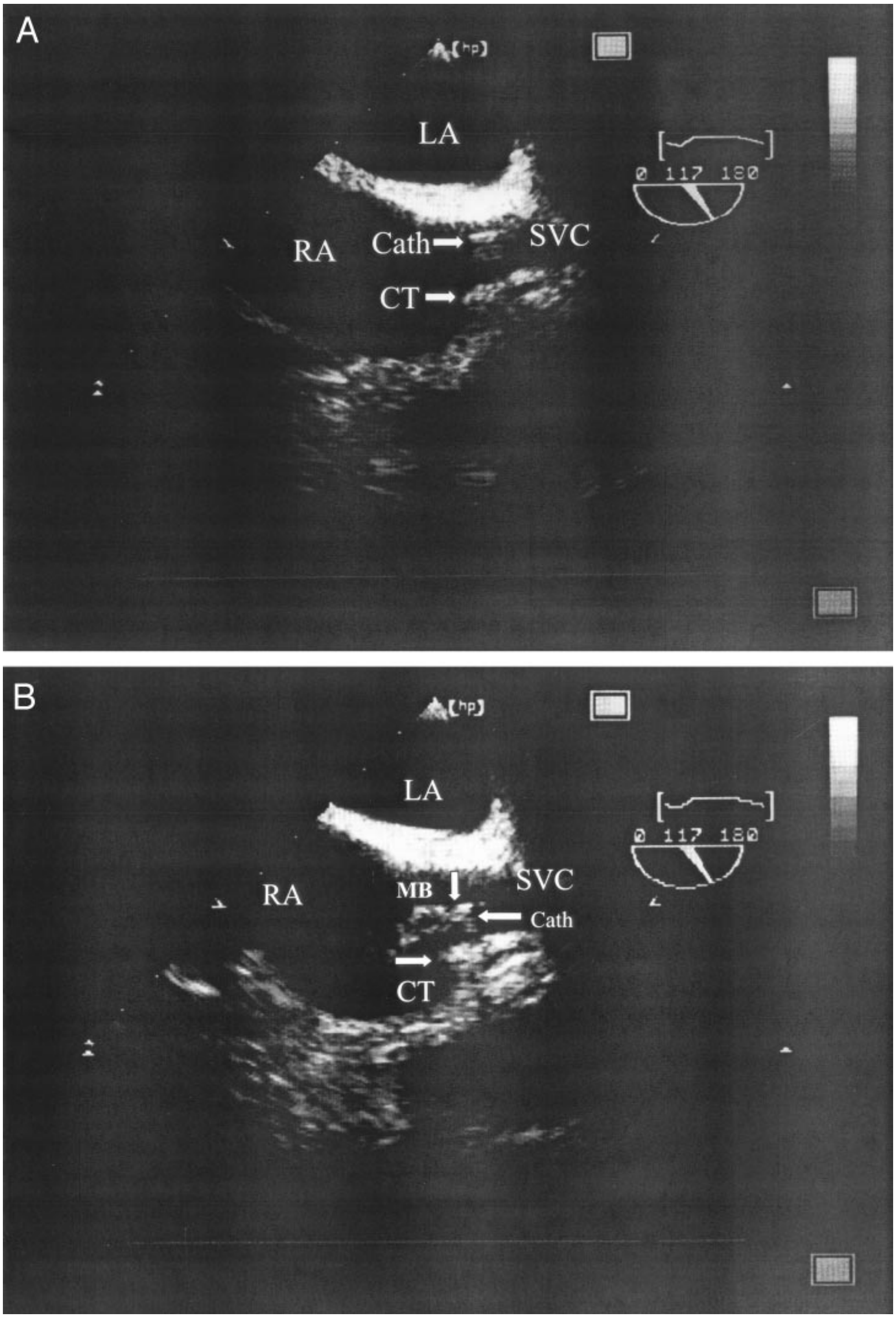

Figure 1. A, A central venous catheter advanced to the SVC-RA junction seen in a longitudinal plane of the transesophageal echocardiographic view. B, Multiple hyperechogenic microbubbles flowing quickly out of the distal end of the catheter from a rapid flush of saline, confirming the location of the catheter tip. LA = left atrium; SVC = superior vena cava; RA = right atrium; Cath = catheter; CT = crista terminalis; MB = microbubbles.

three patients, the catheter tips were 2 cm beyond the upper portion of the CT. In two of these three patients, the catheter tips were located in the RA cavity.

When the radiologist reviewed the supine chest radiographs, 25 of the 30 catheters in Group E and 23 of the 30 catheters in Group S ($P = 0.52$) were in the radiographically defined proper position. The remainder of the catheters appeared in the mid portion of the atrial cavity (5 in Group E and 7 in Group S).

Discussion

There is controversy about the exact position of the catheter tip when IV-ECG shows the largest P wave. According to Corsten et al. (10), as the wire-conducted intravascular ECG signal develops the intraatrial P wave (P atriale), it should be at the level of the SVC-RA junction. After withdrawal of the catheter 3 cm, the tip is then located in the SVC or the SVC-RA junction on the chest radiograph. According to Madan

Table 1. Demographic Data and Characteristics of Patients Undergoing Long-Term Central Venous Catheterization via the Right Subclavian Vein

Variable	Group E	Group S	*P* value
No. patients	30	30	
Age (yr)	54 ± 14	55 ± 13	0.517
Sex (M/F)	18/12	14/16	0.301
Weight (kg)	59 ± 8	62 ± 10	0.189
Major diseases			
Upper abdominal malignancy	21 (70%)	17 (56.7%)	0.284
Lower abdominal malignancy	9 (30%)	13 (43.3%)	

Group E: conducted IV Electrocardiograph signals were used to position the catheter tip; Group S: catheter length was derived from surface landmarks on the chest wall.
Values are mean ± SD.

Table 2. Catheter Positions in Both Groups as Determined by Transesophageal Echocardiography (TEE) and X-ray radiograph

Variable	Group E	Group S	*P* value
Initial catheter length (cm)	17.0 ± 0.9	17.3 ± 1.3	0.24
TEE-corrected length (cm)	16.8 ± 0.9	16.9 ± 1.3	0.58
Total catheter-placing time[a] (min)	11.2 ± 2.5	10.7 ± 2.1	0.331
Correction distance of tip (cm)			
≤0.5	23	8	<0.001[a]
0.6–1.0	7	8	
1.1–2.0	0	11	<0.001[a]
≥2.1	0	3	
Catheter placement			
Satisfactory	30 (100%)	16 (53.3%)	<0.001[b]
Unsatisfactory	0 (0%)	14 (46.7%)	
Radiographic illustration of TEE-corrected tip			
Proper	25 (81.3%)	23 (76.7%)	0.52
Improper	5 (16.7%)	7 (23.3%)	

Group E: conducted IV Electrocardiograph G signals were used to position the catheter tip; Group S: catheter length was derived from surface landmarks on the chest wall.
Values are mean ± SD.
[a] There was a significant difference between groups on the subcategories of "≥0.5 cm" and "1.1–2.0 cm." *P* value by χ^2 and Fisher's exact test.
[b] Catheter tip location was considered to be satisfactory if the tip was within 1.0 cm of the upper edge of the crista terminalis.*P* value by Fisher's exact test.

et al. (9), as the tip passed the SA node, the tall peak P wave changed to a biphasic pattern. After withdrawal of the catheter by 3 cm, the tip was located in the lower half of the SVC. According to McGee et al. (16), when the saline-filled central venous catheter was advanced toward the RA, as the point of maximal P-wave amplitude was reached, its position was usually within the proximal RA. Watters and Grant (7) reported that the SVC-RA junction had been reached when the P-wave amplitude was as large as or larger than the QRS complex pattern. The findings of this study suggest that an $NaHCO_3$-flushed catheter conducting the IV-ECG signal shows the largest P wave when the catheter tip is positioned within 1.0 cm of the upper edge of the CT, as confirmed by TEE. On the basis of the findings of this study, correct catheter placement at the level of the SVC-RA junction has been achieved when the P-wave amplitude shows the largest P wave without a biphasic pattern.

Surface landmarks on the chest wall have been used to estimate the expected catheter length for central venous catheterization, and a subsequent chest radiograph is needed to move the catheter to its proper position. Upright or semi-Fowler chest films are difficult and time consuming in anesthetized patients in operating rooms, explaining why portable chest radiographs are usually performed in operating rooms immediately after long-term central venous catheter placement. In this study, 12 of 60 patients in whom the catheter tip was shown to be correctly placed on TEE were found to have the tip in their atrial cavity on a supine chest radiograph. Andropoulos et al. (12) also demonstrated that 21 of 141 patients in whom TEE showed catheters in good positions within the SVC had apparent positions in the RA on radiographs. In most of them, the catheters were positioned just below the radiographic SVC-RA junction. Aslamy et al. (17) used magnetic resonance imaging to evaluate the radiographic landmarks of central venous anatomy with the SVC-RA junction and reported that the right upper cardiac silhouette was formed by the left atrium in 38% of patients and in these cases was higher than the junction of the RA with the SVC. The atriocaval junction cannot therefore be reliably identified from portable chest radiographs, and it is difficult to accurately assess catheter tip position for long-term central venous devices during operations. It seems that the SVC-RA junction can be more precisely determined with echocardiography than by a portable supine chest radiograph.

The position of an implanted central venous catheter may change with the patient's daily activities and with sudden postural changes. With insertion of the central venous catheter via the basilic or axillary veins, the catheter tip may advance toward the heart with movement of the arm from 90° abduction to a position across the chest (18,19). However, with the catheter inserted via the SVC or internal jugular vein, peripheral catheter migration is a common event, and the catheter tip should be initially positioned approximately 3–4 cm more centrally than the desired final position (20). Nazarian et al. (21) also reported that catheter tip position may change from the mid RA initially to the low SVC with changes from supine to upright patient positions and that tip migration was more frequent for catheters in the subclavian veins, in females, and in obese patients (3). Accordingly, the catheter tip should be positioned at the SVC-RA junction or slightly into the RA cavity to account for these postural changes. This final catheter tip position for long-term central venous access devices differs from those used for short-term central venous catheters (22). Long-term catheters tend to be more flexible and have a blunter catheter tip to facilitate this.

Summary

In this study, the position of the catheter tip shown on TEE was within 1.0 cm of the upper edge of the CT when the ECG derived through an $NaHCO_3$-flushed catheter showed the largest P wave; the IV-ECG method accomplished the goal 100% (30 of 30) of the time, whereas the use of surface landmarks to determine catheter length did so only approximately 53% (16 of 30) of the time. The IV-ECG approach can be as effective as the TEE and less expensive. Once the catheter tip was corrected by TEE, the catheter tip appeared in the RA approximately 20% of the time in postplacement chest radiographs. The portable anteroposterior chest radiograph could not reliably identify the location of catheter tips at the SVC-RA junction. Accordingly, a technique using an $NaHCO_3$-flushed catheter to conduct IV-ECG signals shows great promise because it can reliably indicate that the SVC-RA junction has been reached when the largest P-wave amplitude without a biphasic pattern is seen.

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