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Transoesophageal echocardiographic evaluation of central venous catheter positioning using Peres' formula or a radiological landmark-based approach: a prospective randomized single-centre study†

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Abstract

Background. The lower superior vena cava (SVC), near its junction with the right atrium (RA), is considered the ideal location for the central venous catheter tip to ensure proper function and prevent injuries. We determined catheter insertion depth with a new formula using the sternoclavicular joint and the carina as radiological landmarks, with a 1.5 cm safety margin. The accuracy of tip positioning with the radiological landmark-based technique (R) and Peres' formula (P) was compared using transoesophageal echocardiography.

Methods. Real-time ultrasound-guided central venous catheter insertion was done through the right internal jugular or subclavian vein. Patients were randomly assigned to either the P group (n=93) or the R group (n=95). Optimal catheter tip position was considered to be within 2 cm above and 1 cm below the RA–SVC junction. Catheter tip position, abutment, angle to the vascular wall, and flow stream were evaluated on a bicaval view.

Results. The distance from the skin insertion point to the RA–SVC junction and determined depth of catheter insertion were more strongly correlated in the R group [17.4 (1.2) and 16.7 (1.5) cm; r=0.821, P<0.001] than in the P group [17.3 (1.2) and 16.4 (1.1) cm; r=0.517, P<0.001], with z=3.96 (P<0.001). More tips were correctly positioned in the R group than in the P group (74 *vs* 93%, P=0.001). Abutment, tip angle to the lateral wall >40°, and disrupted flow stream were comparable.

Conclusions. Catheter tip position was more accurate with a radiological landmark-based technique than with Peres' formula.

Clinical trial registration. Clinical Trial Registry of Korea: https://cris.nih.go.kr/cris/index.jsp KCT0001937.

Key words: central venous catheters; echocardiography; transoesophageal; vena cava, superior

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Editor's key points

- Malpositioned central venous catheters can cause catastrophic complications, but reliable procedures for positioning the catheter tip during insertion are not established.
- Accuracy of catheter tip placement was compared using Peres' formula or a radiological landmark-based technique.
- Catheter tip positioning was more accurate using the radiological landmark-based technique.

Central venous catheterization is a standard clinical practice for infusion of fluids, blood products, or vasoactive drugs to the central circulation and to monitor central venous pressure during perioperative periods. However, this procedure can lead to significant complications, including cardiac arrhythmia, vascular injury, hydrothorax, haemothorax, hydromediastinum, and cardiac tamponade.[1–3] Such complications can occur when the catheter tip is inserted within the heart chamber or when it abuts the vascular wall at a steep angle.[4]

Although optimal positioning of the catheter tip is controversial according to short-term or long-term use and catheter performance, the US Food and Drug Administration has stated that the catheter tip should not be located in or allowed to migrate into the heart.[5] If the running direction of the catheter is not parallel to the long axis of the superior vena cava (SVC), the vascular wall can be eroded by touching the tip of the catheter. In addition, venous thrombosis and misplacement of the catheter in the left brachiocephalic vein or small collateral vessels, such as the azygous vein, are possible in the upper and middle SVC.[6 7] To prevent these risks and to ensure proper haemodynamic monitoring, the catheter tip should be in the lower SVC, near the junction of the right atrium and the SVC (RA–SVC junction).[4 5] The lower SVC, near the RA–SVC junction, might be the optimal position of the catheter tip for monitoring and administration of vasoactive drugs during perioperative periods and for preventing malfunction, migration, and thrombosis. Moreover, if the catheter tip is positioned in the lower SVC, near the RA–SVC junction, the catheter tip should float freely inside the vessel lumen without abutment, and the devastating complication of cardiac tamponade might be avoided, even though the catheter tip is positioned below the level of pericardial reflection on the SVC, and even in the upper RA.

Several methods have been used to verify the position of the catheter tip. In most instances of short-term perioperative use, the position is confirmed by a post-procedural chest radiograph, not by real-time imaging. Post-procedural radiographic imaging is time consuming, involves radiation exposure, and creates the possibility of infection from repositioning.[8] Intracardiac ECG while observing the P wave can resolve differences in interpretation according to the waveform of the P wave, but is difficult in patients with a pacemaker or atrial fibrillation.[9] Transthoracic echocardiography is limited by the transmission of ultrasound beams to the SVC and the skill of the practitioner, and can be difficult to use in obese patients or those with pneumothorax.[10] Transoesophageal echocardiography (TOE), which provides information on the structure and function of the heart, can verify the RA–SVC junction and actively illustrates the angle of the catheter tip to the vascular wall.[11]

To avoid intracardiac catheter placement, the Peres formula relating body height to catheter insertion depth has been widely used. It is simple to use and easy to remember in traditional landmark-based central venous catheterization.[12] However, this method does not take into consideration individualized needle insertion points and different images for real-time ultrasound guidance. The suggestion that catheters in the subclavian vein generally need to be inserted 2 cm less than those from the internal jugular vein (IJV) is dismissed by most clinicians today. This change could be a result of the ultrasound moving the vein puncture laterally to the axillary rather than the subclavian vein. The tracheal carina is an attractive radiological landmark for catheter tip positioning.[13] The right brachiocephalic vein is formed by the union of the right subclavian veins and the IJV behind the right sternoclavicular joint, and descends vertically.[14] The sternoclavicular joint can be identified on chest radiograph and is superficially palpable at the medial end of the clavicle. Taking into account the relationship between these anatomical structures, we planned to position the catheter tip in the lower SVC, close to the RA–SVC junction, with a new formula for estimating catheter insertion depth using the skin insertion point with real-time ultrasound guidance. The right sternoclavicular joint and the carina were used as the radiological landmarks, and a distance of 1.5 cm was added as a safety margin. This study evaluated the location of the central catheter tip between our radiological landmark-based technique and the existing Peres formula using TOE.

Methods

The institutional review board of Kangdong Sacred Heart Hospital approved the study (institutional review board no. 2016-02-004-001), and written informed consent was obtained from either patients or relatives. This prospective, randomized study was conducted from February to July 2016, and was registered with the Clinical Trial Registry of Korea (KCT0001937).

We recruited 198 subjects 20–80 yr of age, for whom central venous catheterization and TOE examination were planned to monitor or evaluate cardiac function, structure, and haemodynamic changes in major surgery. Exclusion criteria were a change in the mediastinal structure from previous thoracic surgery or lung neoplasm, any potential risk from TOE examination, including oesophageal varices, fistula, or stenosis, or refusal to enrol.

Central venous catheterization was done by real-time ultrasound guidance with a portable ultrasound machine (MicroMaxx; SonoSite Inc., Bothell, WA, USA) equipped with a linear array transducer (HFL38/13–6 MHz; SonoSite Inc.). The site for catheterization selected for patients undergoing neurovascular or neck surgery was the right subclavian vein. The site for other subjects was in the right IJV, taking into consideration the judgement of the practitioners and patient comfort.

Subject characteristics, including sex, age, height, and weight, were recorded. Subjects were randomized by computer-generated randomization (www.graphpad.com/quickcalcs, 1:1 in block sizes of six) to either the Peres formula group (P group) or the radiological landmark group (R group). In the P group, catheter insertion depth was derived from the Peres formula as height/10 cm for the right IJV and (height/10)−2 cm for the right subclavian vein. In the R group, the vertical length from the midpoint of the right sternoclavicular joint to the carina was measured from the routine preoperative chest radiograph using an internal measuring tool available on the Picture Archiving