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Original Article

Feasibility of the Use of Transesophageal Echocardiography as a Surface Probe for Puncturing and Catheterization of the Internal Jugular Vein: A Randomized Controlled Pilot Study

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Objective: To compare the transesophageal echocardiography (TEE) probe as a surface probe with the vascular probe for guiding internal jugular vein (IJV) catheterization.
Design: Prospective, randomized, controlled pilot study.
Setting: University hospital.
Participants: One hundred cardiac surgery patients, including 50 adult and 50 pediatric patients.
Interventions: Patients in the TEE probe group received right IJV catheterization using the TEE probe, while the vascular probe group used the vascular probe for catheterization.
Measurements and Main Results: The puncture time, first-attempt success rate, quality of the imaging with needle tip positioning, wire positioning, and catheter positioning were recorded. The incidence of complication or any adverse event also was observed. *Adult patients*: In the vascular probe group, the success rate for first attempt IJV catheterization was 24/25 (96%), while in the TEE probe group, the success rate for first attempt IJV catheterization was 25/25 (100%). There was no statistical difference in the puncture time, image quality, needle tip positioning, wire positioning, and catheter positioning between groups ($p > 0.05$). *Pediatric patients*: The success rate for first-attempt IJV catheterization was 100% in both groups, and there were no statistical differences in the puncture time, image quality, and positioning between the 2 groups ($p > 0.05$). No complications or adverse events were observed in either group.
Conclusion: The TEE probe, used as a surface probe, can be used to guide IJV puncturing and catheterization in cardiac surgery patients with favorable feasibility and safety.

Key Words: transesophageal echocardiography; ultrasound; internal jugular vein; cardiac surgery

Central venous catheterization (CVC) is widely used in the perioperative management of cardiac surgery patients to assess heart function, pulmonary artery pressure, and the need for perioperative fluid therapy or rapid transfusion.[1] Due to the internal jugular vein (IJV) puncture point location near the carotid artery and other important anatomic relationships, traditional methods of CVC, which locate the IJV mainly relying on anatomic landmarks, may cause severe complications.[2,3] As studies report, the overall incidence of complications including pneumothorax, hematoma, hemothorax, neurologic damage, and infection is estimated to be 5.4% to 11%.[4,5] Additionally, studies showed that the failure rate of catheterization for inexperienced physicians was up to 13.8%, while the success rate of catheterization on first attempt was between 50% and 80%.[6]

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Compared to the traditional methods of using anatomic landmarks as a guide, ultrasound-guided central venous puncture improves patient outcomes by improving success rates and reducing complications,[3] especially indifficult patients, such as obese, newborn, or pediatric patients.[7,8] The success rate of ultrasound-guided catheter insertion was 100%, while the rate of arterial puncture was 1.1%, as revealed by a previous study. Additionally, the rate of success and arterial puncture using the anatomic landmark method was 94.4% and 10.6%, respectively.[2]

Transesophageal echocardiography (TEE) monitoring applies the same principle of B-mode ultrasound as body surface ultrasonography does, but the scanning probe is designed specifically to observe heart function through the esophagus. TEE commonly is used for evaluating heart function or other cardiac abnormalities in patients before major surgeries for outcomes, cardiac function during surgery, and early detection of myocardial ischemia or cardiac complications.[9,10] Almost every cardiac operating room is equipped with an ultrasonic machine with TEE probe; however, not every ultrasonic machine may have the vascular probe. Andropoulos et al suggested that esophageal placement of the TEE probe may be advantageous to use to guide central venous catheter placement in congenital heart surgery.[11] Additionally, Stevenson et al used the TEE probe as a surface probe for detecting the position of the IJV.[12] Inspired by this idea, the authors designed this experiment to investigate whether the TEE probe can provide the same information as the vascular probe. Therefore, the aim of this prospective randomized controlled pilot study was to explore the feasibility and efficacy for use of the TEE probe as a surface probe in guiding the puncturing and catheterization of the IJV in patients undergoing cardiac surgery.

Methods

This prospective, randomized, pilot study was approved by the Ethics Committee of West China Hospital, Sichuan University. All the participants were informed about the study and a written informed consent was obtained from each participant. The trial protocol was registered in the Chinese Clinical Trial Registry (ChiCTR-INR-16009856, http://www.chictr.org.cn). Fifty adults were recruited, aged 18 to 70 years of age and 50 young children aged 1 to 6 years of age, who were scheduled for elective cardiac surgery and IJV puncturing and catheterization. The exclusion criteria for this study included local infections, neck surgery history, and/or mass lesions in the neck. Randomization was performed with a computer-generated random numbers table. The eligible patients received a unique random code, assigning them into either the vascular probe group or the TEE probe group.

Upon entering the anesthesia preparation room, the adult patients received 500 mL of Ringer's lactate solution and underwent left radial arterial catheterization under local anesthesia. Then, patients were transferred to the operating room to receive mask ventilation and monitoring of the electrocardiogram, pulse oxygen saturation, and invasive blood pressure. The standard protocol for anesthesia induction and endotracheal intubation was provided for both groups. The pediatric patients received mask ventilation with sevoflurane and monitoring of the electrocardiogram, pulse oxygen saturation and noninvasive blood pressure after entering the operating room. Anesthesia induction and endotracheal intubation in the 2 groups were performed following the same regimen. Left radial artery catheterization and invasive blood pressure monitoring were performed after endotracheal intubation in pediatric patients.

Both adult and pediatric patients underwent right IJV puncturing and catheterization. Before routine sterilization and draping, patients were placed in the Trendelenburg position. The anesthesiologist dressed in sterile garb and covered the probe with a sterile endoscope sleeve. An assistant carefully fed the probe into the sheath and the sheath was extended along the length of the probe wire. A 20 × 30-cm sterile plastic clip was used to cover the probe surface to secure the sheath around the transducer. The TEE probe was set to a depth of 40-mm, 7-MHz frequency (X7-2t, Philips, Bothell, WA, USA), and the sound beam angle was adjusted to 90°, while the depth for the vascular probe was 25-mm, 5-MHz frequency (L9-3, Philips). The probe was held with the left hand and placed at the apex of the triangle, delimited by the 2 heads of the sternocleidomastoid muscle and the clavicle, to detect the position of the IJV. The TEE probe was angled toward the lateral axis of the patient. Therefore, in that position, the artery appears lateral to the vein (Fig 1B). The authors identify the artery and vein with the shape, the artery pulse, and color Doppler. After the operating anesthesiologist placed the IJV in the middle of the screen, the right hand was used to insert the needle 1 cm above the probe (Fig 2A, B). After the needle advanced into the IJV and a flashback of dark venous blood was identified, a guiding wire was placed through the end of the puncture needle. The out-of-plane approach was used to guide cannulation and both the out-of-plane and in-plane (IP) approaches were used to identify catheterization. Since using the TEE probe to scan the long axis of the IJV, the image was shown as a sector and the vessel was presented as an arc; the authors did not use the IP approach to guide the puncture.

In the present study, all cannulations were performed by one anesthesiologist. Another anesthesiologist of equal expertise observed the whole procedure and scored the image quality based on the scoring guide. When the operating anesthesiologist performed the procedure, an assistant helped to cover the probe with the sterile sheath and collected the images as well as recorded the puncture time and image quality scores. Both anesthesiologists are skilled in either landmark-guided or ultrasound-guided CVC cannulation. During the whole procedure, the puncture time, the success rate of the first attempt, image quality, needle tip positioning, wire positioning, and catheter positioning were recorded. All evaluation indices were defined as follows:

Puncture time: the time from the beginning of locating IJV to the successful puncture.

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