Ultrasound-guided Internal Jugular Venous Cannulation in Infants

A Prospective Comparison with the Traditional Palpation Method

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Background: Percutaneous cannulation of the internal jugular vein in infants is technically more difficult and carries a higher risk of carotid artery puncture than in older children and adults. In this prospective study, the authors tested their hypothesis that using an ultrasound scanner would increase the success of internal jugular cannulation and decrease the incidence of carotid artery puncture in infants.

Methods: After approval from the institutional review board and receipt of written informed parental consent, 95 infants scheduled for cardiac surgery were randomized prospectively into two groups. In the landmarks group, the patients' internal jugular veins were cannulated using the traditional method of palpation of carotid pulsation and identification of other anatomic landmarks. In the ultrasound group, cannulation was guided using an ultrasound scanner image. The cannulation time, number of attempts, success rate, and incidence of complications were compared for the two groups.

Results: There were no significant differences between the two groups with regard to weight, age, and American Society of Anesthesiologists physical status classification. The success rate was 100% in the ultrasound group, with no carotid artery punctures, and 77% in the landmarks group, with a 25% incidence of carotid artery punctures. Both differences were significant \( P > 0.0004 \). The cannulation time was less, the number of attempts was fewer, and the failure rate was significantly lower in the ultrasound group than in the landmark group.

Conclusion: Ultrasonographic localization of the internal jugular vein was superior to the landmarks technique in terms of overall success, speed, and decreased incidence of carotid artery puncture. (Key words: Cannulation success; infant cardiac anesthesia; internal jugular vein position; scanner image.)

CENTRAL venous cannulation is performed routinely to monitor central venous pressure and infusion of vasoactive drugs in infants undergoing open heart surgery. In our institution, internal jugular vein (IJV) cannulation is preferred to cannulation of the subclavian vein because of the higher incidence of pneumothorax and subclavian artery puncture associated with the latter. Internal jugular vein cannulation guided by palpation of anatomic landmarks is often difficult in infants and young children. The incidence of carotid artery (CA) puncture is higher in children younger than 5 yr than in older children during this procedure. The use of ultrasonography has been shown to increase the success rate and decrease the incidence of complications associated with IJV cannulation in adults. Our purpose was to randomly compare the use of the ultrasound scanner with the traditional method of palpation in cannulation of the IJVs of infants.

Materials and Methods

This protocol was approved by our institutional review board, and parental consent was obtained for each pa-
tient. Ninety-five infants scheduled for cardiovascular surgery were studied in a prospective, randomized manner. All the patients were younger than 12 months and weighed less than 10 kg. The study was conducted during a 3-yr period. After routine monitors were placed, general tracheal anesthesia was induced, peripheral intravascular lines were inserted, and central venous cannulation was attempted. All procedures were performed by Board-eligible pediatric anesthesia fellows who completed residency training in anesthesia. They were supervised by an attending specialist in cardiac anesthesia. Patients were randomized to one of two approaches to IJV cannulation (i.e., landmarks or ultrasound) according to a computer-generated randomization table. All patients were placed in a 15° Trendelenburg position with the head in the midline. In all patients, the high approach to IJV cannulation was chosen to minimize the chance of pleural injury. Each fellow participating in this study was trained in the landmarks and the ultrasonographic techniques using five patients not included in the protocol (for a total of 10 cases).

**Landmarks Technique**

The traditional approach entailed identifying the external landmarks (sternocleidomastoid muscle, clavicle, sternal notch, and cricoid ring) and palpating the CA pulse. At the level of the cricoid ring and at the apex of the triangle formed by the division of the sternocleidomastoid muscle and the base of the clavicle, a 21-gauge, 4-cm-long needle was inserted at a 30° angle lateral to the CA and directed toward the ipsilateral nipple. This point lies approximately lateral to the intersection of the CA with a line between the mastoid process and the suprasternal notch (fig. 1). The anesthesiologists used their left index and middle fingers to retract the pulsating CA. They identified the IJV puncture by the easy aspiration of dark venous blood from the vein through the needle. Using a standard Seldinger technique, a guide wire (0.018 inches in diameter, 40 cm long) was passed through the needle, followed by tissue dilation with a 5-French 8-cm-long dilator and advancement of a heparin-coated polyurethane 4-French (18-gauge), 8-cm (3 1/8 inch) double-lumen catheter (Cook Central Venous Catheter; Cook Critical Care, Bloomington, IN). Successful placement was confirmed by the easy aspiration of dark blood from the lumens of the catheter and by observation of the transduced atrial waveform on the monitor. The position of the central line was absolutely confirmed by chest radiography performed at the conclusion of surgery.

**Ultrasound Technique**

The Site Rite scanner (Dymax Corp., Pittsburgh, PA) was used in infants who were randomized for cannulation using ultrasound. This computerized unit is a portable, real-time, high-resolution imaging system specifically designed to view the IJV and the CA. The probe uses a frequency of 9 MHz and a sector angle of 25°, with the focal length positioned 1.5 cm from the cap. The image is displayed on a 7.62-cm diagonal display monitor. To maintain a sterile field, the 9-MHz transducer was covered by an elongated sterile sheath containing Aquasonic 100 (ultrasound transmission gel; Parker Laboratories, Inc, Fairfield, NJ). This latex-free cover measures 14 × 61 cm and comes in a sterile kit with a gel packet and two elastic bands (General Purpose CIV-Flex Sterile...
Fig. 2. The Site Rite ultrasound probe was used during internal jugular vein cannulation. The probe was held perpendicular to the right side of infant's neck.

Ultrasound Transducer Cover Kit; CIVCO Medical Instruments, Kalona, IA).

After antiseptic preparation and draping of the right side of the infant's neck, the sterile sheath for the ultrasound probe was opened and a generous amount of Ultra/Phonic gel was placed inside the sheath and on the neck. The probe was placed on the right side of the neck, perpendicular to the vessels just lateral to the trachea and superior to the clavicle by the operator's left hand (fig. 2). After the pulsating vessels were identified, the central mark of the probe was placed over the center of the jugular vein. The CA and the IJV were identified by their relative positions, compressibility of the vein, and enlargement of the vein by liver compression or the Valsalva maneuver (fig. 3). The needle could be seen to dimple the vein and indent the overlying skin when the needle point was positioned correctly. Excessive pressure on the skin by the transducer can compress the vein but not the artery. The needle was advanced into the vein as directed by the ultrasonogram. As soon as blood was aspirated through the needle, the probe was placed on the sterile field and the needle was stabilized with the operator's left hand. Cannulation was performed using the Seldinger technique. A 21-gauge, 4-cm-long needle and a heparin-coated polyurethane, 4-French (18 gauge), 8 cm, double-lumen catheter (Cook Central Venous Catheter) were used in all the study cases. The intravenous fluids administered to all infants in the study were similar.

The time to palpate the sternal notch, clavicle, mastoid bone, cricoid cartilage, and CA was less than 15 s in each case in the landmarks group. The time taken to obtain an image of the IJV on the screen was also less than 15 s in the ultrasound group. Cannulation time was defined as the time from the initial needle stick to the easy aspiration of blood from the jugular vein through the distal port of the catheter. The number of attempts and the duration of each attempt were recorded. An attempt was defined as the time from needle entry into the skin to its removal. If the IJV could not be located after seven attempts, if CA puncture with hematoma formation was encountered, or if 45 min elapsed, then an alternative approach was sought and the technique was considered a failure. In the landmark group, the ultrasound scanner was used to visualize the vessels on the same side and cannulation was attempted by following the images. If the vessels were not well-visualized, the external jugular veins were cannulated for intraoperative use, and right atrial lines were placed by the surgeon before chest closure in these infants. If CA puncture occurred but hematoma formation was averted by applying pressure, a further attempt was made on the same side by the attending anesthesiologist. If attempts using ultrasound were unsuccessful, then the anesthesiology fellow would try the landmark technique on the same side. The complications encountered during each attempt were recorded. The usual complications that can occur during

Fig. 3. The carotid artery and the internal jugular vein are shown on an ultrasonogram.
Table 1. Demographic Data, Cannulation Time, Attempts, Success Rate, and Complications in Two Groups of Infants Using Two Techniques: Landmarks versus Ultrasound

<table>
<thead>
<tr>
<th>Group</th>
<th>Landmarks (median) (n = 52)</th>
<th>Ultrasound (median) (n = 43)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mo)</td>
<td>5.9 ± 4.4 (6.0)</td>
<td>6.4 ± 3.8 (6.0)</td>
<td>—</td>
</tr>
<tr>
<td>Q1–Q3</td>
<td>3.75–11.00</td>
<td>5.00–10.00</td>
<td>—</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>5.8 ± 2.0 (5.3)</td>
<td>6.0 ± 2.3 (6.0)</td>
<td>—</td>
</tr>
<tr>
<td>Q1–Q3</td>
<td>3.8–7.25</td>
<td>4.2–7.0</td>
<td></td>
</tr>
<tr>
<td>Cannulation time (min) (median)</td>
<td>14.0 ± 15.1 (10.0)</td>
<td>4.2 ± 2.8 (3.3)</td>
<td>P &lt; 0.0001 (Mann-Whitney)</td>
</tr>
<tr>
<td>Q1–Q3</td>
<td>4.0–17.5</td>
<td>2.0–5.0</td>
<td></td>
</tr>
<tr>
<td>Number of attempts (median)</td>
<td>3.3 ± 2.8 (2.0)</td>
<td>1.3 ± 0.6 (1.0)</td>
<td>P &lt; 0.0001 (Mann-Whitney)</td>
</tr>
<tr>
<td>Q1–Q3</td>
<td>1.0–4.5</td>
<td>1.0–2.0</td>
<td></td>
</tr>
<tr>
<td>Success rate</td>
<td>76.9%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>CA puncture</td>
<td>13 (25%)</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Q1 = 25th percentile; Q3 = 75th percentile.
Values are mean ± SD, and median Q1–Q3 25th–75th percentile.

IJV cannulation (CA puncture with or without hematoma; venous hematoma; hemodynamically significant arrhythmias; pneumothorax; and catheter-related complications, such as kinking, knotting, breaking, and threading difficulties) were specifically recorded. When the IJV was cannulated within 45 min without significant complications, the procedure was considered a success. The anesthesiologist’s inability to perform cannulation of the IJV within 45 min or after seven attempts rendered the technique a failure. If a serious complication occurred (CA puncture with hematoma, pneumothorax during IJV cannulation, or both), the cannulation was abandoned, regardless of its duration, and this was considered a failed technique. If CA puncture alone occurred without hematoma formation, further attempts to perform cannulation of the IJV were made.

Statistical Analysis

The two groups were compared for age and weight using the Student t test, and the time taken for cannulation and the number of attempts were compared using the Mann-Whitney U test. The success rate and the number of patients having complications (including CA puncture) were compared using the Fisher exact test. Statistical significance was defined as P < 0.05. The data were expressed as the mean ± SD and as the median (25th–75th percentile) for the number of attempts and the cannulation time.

Results

There were 43 infants in the ultrasound group and 52 in the landmarks group (table 1). The two groups were similar with respect to age, weight, and American Society of Anesthesiologists physical status. Cannulation of the IJV was successful in all 43 (100%) infants in the ultrasound group and in 40 of 52 (77%) infants in the landmarks group. When the ultrasound scanner was used, cannulation was subsequently successful in 3 of 12 infants with unsuccessful cannulation in the landmarks group. In four of the remaining infants, the external jugular vein was cannulated. Right atrial lines were placed by the surgeon before chest closure in these infants and in the remaining five infants who underwent unsuccessful IJV cannulation. The time (median) necessary for cannulation of the IJV within 45 min or after seven attempts rendered the technique a failure. If a serious complication occurred (CA puncture with hematoma, pneumothorax during IJV cannulation, or both), the cannulation was abandoned, regardless of its duration, and this was considered a failed technique. If CA puncture alone occurred without hematoma formation, further attempts to perform cannulation of the IJV were made.

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Six of these 13 infants also had other complications. These included internal jugular venous hematomas in four infants, catheter kinking (not guide wire) and threading problems (which could be a result of the hematoma) leading to unsuccessful cannulation in two infants, and pneumothorax and hemothorax in one patient who also had a large venous hematoma. The pri-
mary difficulty encountered in the ultrasound group was guide wire kinking during insertion, especially if the curved end was used. This occurred in six infants who weighed less than 5 kg when the curved end was inserted initially. This was easily overcome by using the straight end. There were no catheter kinking problems in the ultrasound group. No significant atrial or ventricular arrhythmias requiring treatment occurred in either of these groups during cannulation.

Discussion

The internal jugular vein frequently is used to monitor central venous pressure and to infuse vasoactive drugs in children undergoing cardiac surgery.6 Despite the reported complications,7-6,15 the IJV is a reliable and useful site for obtaining central venous access in children. English et al.16 reported a 91% success rate of cannulation in 85 infants and children, compared with a 96% success rate in 415 adult patients undergoing the same procedure. The incidence of CA puncture in children has been reported to be as low as 8.5% and as high as 23%.6,15 English et al. used a catheter-through-needle technique similar to that of Prince et al.,15 and they did not use the Seldinger technique, which we used in the current study and in other recent studies. Hayashi et al. reported an 11.3% incidence of CA punctures in their study of 106 children, 40 of whom were infants. The overall success rate was 97.2%; however, in infants younger than 3 months, the success rate was only 81.3%. In a previous study, we reported a success rate of 80% and a CA puncture incidence of 13.6% during IJV cannulation in infants younger than 6 months.17 In the current study, we had a 100% success rate in the infants in the ultrasound group and a 77% success rate in the landmark group. The CA was punctured in 13 patients in the landmarks group (25%); other complications that occurred in these 13 patients included jugular vein hematoma (n = 4), catheter kinking with inability to thread (n = 2), and pneumothorax and hemothorax in one patient with jugular vein hematoma.

The proximity of the CA to the IJV and the small caliber of the vessels make CA puncture more likely during IJV cannulation in infants than in older children. Côté et al.6 showed that IJV cannulation of children using the high approach is associated with a greater incidence of CA puncture than is the low approach. We used the high approach in all patients to avoid pleural injury, and we had a significantly greater incidence (25%) of CA puncture using the landmarks method than was reported in other studies. The incidence in the landmarks group was also greater than that reported in our previous study of infants, in which the cannulations were performed by staff anesthesiologists and trainees.17 Our preference for the high approach was based on a desire to avoid the incidence of pneumothorax associated with the low approach and on the inability to compress an expanding arterial hematoma. The higher incidence of carotid puncture in the landmarks group could be explained by the fact that all the patients in our study were infants and weighed less than 10 kg. Of the 13 infants in the landmarks group in whom the CA was punctured, 7 were younger than 3 months. All cannulations were performed by fellows under the supervision of an attending anesthesiologist using the high approach and a 21-gauge needle without using a seeker-needle first. In our experience, a seeker-needle is not an advantage in very small infants (those younger than 3 months) because it may lead to the formation of a small hematoma and create cannulation difficulties.

Anatomic variations have been reported in the relative positions of IJV and the CA in children18 similar to those seen in adults.19,20 Landmark-guided techniques may fail because superficial structures do not match the underlying IJV position. A study of more than 1,000 Polaroid photographs of the IJV ultrasonograms of adult patients by Troiano et al.20 showed a high incidence (54%) of posteriorly placed CA, which predispose those patients to CA punctures if the catheter needle traverses the IJV. Alderson et al.18 reported an 18% incidence of anomalous venous anatomy and a 10% incidence of posteriorly positioned CA in a pediatric group. In 4% of normally positioned IJVs, the diameter was unusually small (defined as < 3 mm for neonates and infants and < 5 mm for older children). They reported a decrease in the complication rate from 60% to 20% when an ultrasound scanner was used to guide cannulation. In adult studies using ultrasonography, CA palpation and extreme rotation of the head both produced anatomic changes that increased the difficulty of IJV cannulation.21

When we used the ultrasonographic device, we made observations about the vascular anatomy that may be relevant to the difficulties encountered during IJV cannulations with the landmarks method in children. Rotation of the neck more than 45° from the midline to the left brought the right IJV more anterior to the adjacent CA. The midline position of the head has been reported to be the ideal position for cannulation in adults, because the two vessels do not overlap in this position.22
authors of a recent study in children reached a similar conclusion. Real-time imaging showed significant compression of the IJV because of the pressure from the cannulation needle before entry into its lumen. Aspiration of venous blood is often possible only when the needle is being withdrawn and not while it is advanced. Excessive finger compression while the CA is palpated also may collapse the IJV, thereby further decreasing the success rate of cannulation.

Although there were no CA punctures in any of the 43 infants in our ultrasound group during the study, less-experienced anesthesiologists (who were not formally trained in using this device) later reported occasional incidents of subclavian puncture and carotid puncture when they used this device in infants and older children. During the current study, we had difficulty with guidewire threading in the ultrasound group (but not in the landmarks group), which could be overcome by using the straight end. As our own experience with the use of ultrasonographic device increased, we found that this difficulty was not unique to this device. These difficulties using the curved end of the guidewire occurred mainly in neonates and infants younger than 3 months, regardless of the technique used. The major reason for this failure was that the radius of the curvature of the wire's J-tip is the same as or larger than the diameter of the neonate's IJV. In an older child who underwent previous IJV cannulation by the traditional landmarks method, the vein looked smaller, perhaps because of partial occlusion. Cannulation was possible only after a smaller guidewire and a smaller catheter were used.

Our study shows that it is possible to avoid carotid puncture if real-time, two-dimensional imaging is used continuously and if the needle is advanced carefully and only after its effect on the two vessels is identified. The image must be followed almost continuously on the screen. The technique, which requires that one anesthesiologist holds the sheathed probe on the infant's neck with one hand and advances the cannulation needle with the other hand while visualizing the image on the screen, requires skilled hand-eye coordination. Mastering the technique requires training and experience. Each anesthesia fellow participating in this study was trained in using the landmarks technique and ultrasound technique in five patients not included in the study (for a total of 10 cases per fellow). The question of how helpful the scanner would be in all situations in which the landmarks method failed was not considered, because the anesthesiologist and the surgeon involved in some of these cases preferred to place right atrial lines after surgical repair. However, cannulation was successful when ultrasonography was used in three patients in whom the landmarks technique failed.

The cost of acquiring the Site Rite scanner (approximately $9,000) is an important issue that most departments must address. Subsequent costs include only the probe sheath and the Aquasonic gel, which comes packaged in a kit ($4.50). It may be justified on the basis of the decrease in the number of attempts, shorter time to cannulation, and the reduction of serious complications in infants. The cost of canceling surgery in a child who has a large hematoma from a CA puncture with subsequent dilation is another consideration. Before we used the ultrasound scanner in our institution, we encountered three such cancellations during a 2-yr period. Dilation of the CA could have been avoided in these cases if the needle had been connected to a transducer to enable the anesthesiologist to see the wave form and verify its position. Transducing the needle when it is in a vessel lumen is simple, but the physician must have a high degree of suspicion to resort to it.

In conclusion, two-dimensional, ultrasound-guided cannulation of the IJV in infants is a precise, safe, and easy alternative to the landmark method. The effect of anatomic variations of the IJV and the CA in the infant neck is minimized by ultrasonographic visualization.

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References

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