Ultrasound-Assisted Cannulation of the Internal Jugular Vein
A Prospective Comparison to the External Landmark-Guided Technique

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Background. Central venous access is an essential part of patient management in many clinical settings and is usually achieved with a blinded, external landmark-guided technique. The purpose of this study is to evaluate whether an ultrasound technique can improve on the traditional method.

Methods and Results. We prospectively evaluated an ultrasound-guided method in 302 patients undergoing internal jugular venous cannulation and compared the results with 302 patients in whom an external landmark-guided technique was used. Ultrasound was used exclusively in an additional 626 patients. Cannulation of the internal jugular vein was achieved in all patients (100%) using ultrasound and in 266 patients (88.1%) using the landmark-guided technique (p<0.001). The vein was entered on the first attempt in 78% of patients using ultrasound and in 38% using the landmark technique (p<0.001). Average access time (skin to vein) was 9.8 seconds (2–68 seconds) by the ultrasound approach and 44.5 seconds (2–1,000 seconds) by the landmark approach (p<0.001). Using ultrasound, puncture of the carotid artery occurred in 1.7% of patients, brachial plexus irritation in 0.4%, and hematoma in 0.2%. In the external landmark group, puncture of the carotid artery occurred in 8.3% of patients (p<0.001), brachial plexus irritation in 1.7% (p<0.001), and hematoma in 3.3% (p<0.001).

Conclusions. Ultrasound-guided cannulation of the internal jugular vein significantly improves success rate, decreases access time, and reduces complication rate. These results suggest that this technique may be preferred in complicated cases or when access problems are anticipated. (Circulation 1993;87:1557–1562)

KEY WORDS • ultrasound • venous access • catheterization

Central venous access has become a mandatory part of clinical management in a variety of clinical circumstances. A method for percutaneous cannulation of the internal jugular vein using external landmarks was first described in 1966. This approach compares favorably in terms of success and complication rates to cannulation of the subclavian vein. Nevertheless, one can expect a complication rate of 5–10% using this technique, depending on the experience of the operator. Complications include puncture of the carotid artery, neck or mediastinal hematoma, brachial plexus injury or irritation, pneumothorax, and injury to the stellate ganglion, phrenic, or recurrent laryngeal nerve. The landmark-guided technique usually affords rapid and easy entry. In an occasional case, however, there are technical difficulties probably because external landmarks do not correlate exactly to the location of the vessel. Inability to cannulate the internal jugular vein may occur in up to 19.4% of cases. The use of Doppler and ultrasound to assist cannulation of the internal jugular vein was reported as early as 1984+9 Although the ultrasound method has compared favorably with the landmark technique in all studies, its widespread use has been hampered by the impracticality and expense of full-sized echo devices and by the presence of larger prospective study data. We have developed a simple ultrasound-guided method using portable equipment for rapid cannulation of the internal jugular vein.

We prospectively evaluated this ultrasound-guided approach to cannulate the internal jugular vein in 302 patients and compared it with 302 patients in whom the internal jugular vein was cannulated using the external landmark technique. In an additional 626 patients, ultrasound-guided access was used exclusively.

Methods

Patients undergoing internal jugular venous cannulation as part of a cardiac catheterization or placement of a central venous line (n=1,230) were studied prospectively. In 928 patients, the internal jugular vein was cannulated with ultrasound guidance and in 302 patients, the external landmark-guided technique was used. The average patient age in the ultrasound group was 51±10 years (723 men, 205 women) and 51±10 years (247 men, 55 women) in the external landmark.

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group. Since both ultrasound-assisted and landmark techniques have been well described and used, no informed consent was obtained other than for routine internal jugular vein cannulation.

All cannulations were performed by operators with extensive experience in landmark-guided internal jugular vein access and included attending cardiologists and cardiology fellows. To allow for a fair comparison of the two techniques, particularly in view of the preference of most operators to use the ultrasound-guided technique, a sequential protocol was used in this study. Since we have a similar number of procedures each week, the ultrasound device was used one week and the landmark technique was used the next week. This was continued until we had 302 patients in each group. Thereafter, the ultrasound technique was used exclusively in an additional 626 patients. There was no provision for crossover in this study design. Because many patients had more than one procedure, it was possible that the same patient was cannulated using a different technique on separate occasions.

Ultrasound Technique

The neck area was prepped and draped steriley with the patient supine. A 7.5-MHz mechanical sector scan transducer (Dymax Corporation, Pittsburgh, Pa.) with a 5-cm standoff and focused at 6.5-cm depth was covered with ultrasonic gel, wrapped in a sterile plastic bag, and connected to a two-dimensional ultrasound device (Site-Rite, Dymax Corporation). The device used is a lightweight (6 lb), battery-powered, portable apparatus with a 2×2-in. CRT screen. Attached to the transducer is a needle guide (Figure 1). This is a triangular plastic structure with a groove in its center. The needle is put in the groove and fixed with the thumb, placed on the thumb rest. The angulation of the guide is such that the needle will intersect in the center of the ultrasound image at 1.5 cm below the transducer surface (Figure 2). By wrapping the transducer in a sterile sheath, sterilization of the transducer is avoided, and use of the device in consecutive patients is facilitated. The skin was then dampened with sterile saline solution and the transducer was placed parallel and superior to the clavicle, over the groove between the sternal and clavicular heads of the sternocleidomastoid muscle. This readily visualized the internal jugular vein and carotid artery (Figure 3, left panel). To enlarge the size of the internal jugular vein, the Valsalva maneuver was then performed (Figure 3, right panel). After anesthetizing the skin with 1% xylocaine, a 2-mm skin incision was made. A 19-gauge, 10-cm needle (Cook Corporation, Bloomington, Ind.) connected to a 10-mL syringe was advanced through the skin and fixed in the needle guide on the ultrasound transducer.

External Landmark Technique

The skin at the top of the triangle between the sternal and clavicular head of the sternocleidomastoid muscle was anesthetized with 1% xylocaine, and a 21-gauge, 10-cm "finder" needle connected to a 2-mL syringe was advanced through the skin at a 45° angle in the direction of the right nipple (for cannulation of the right internal jugular vein). When venous blood was aspirated, the finder needle was used to guide a 19-gauge, 10-cm needle connected to a 10-mL syringe. In all patients, a standard guide wire was advanced through the needle. The needle was then removed, and a catheter or sheath was placed over the wire and advanced into the internal jugular vein.

Data Collection and Analysis

Access time was defined as the time between penetration of the skin and aspiration of venous blood into the syringe. When multiple sticks were required, only the time when the needle was on the skin or advanced was taken into account. This provided an objective comparison between the two techniques. Taking the entire procedural time into account would have clouded the issue because other parameters such as nursing performance could affect the measurement. Preparation times for both techniques were very similar. The time it takes to wrap the transducer in a sterile sheath is compensated by a more rapid localization of the vein as compared with the landmark method. The access time
was measured in seconds by stopwatch by the nursing staff. Number of attempts (needle thrusts) and complications (carotid artery puncture, skin hematoma, brachial plexus irritation) were recorded. Carotid artery puncture was noted by forceful pulsatile expulsion of bright red blood from the needle. Brachial plexus irritation was recorded when the patient complained of pain radiating down the ipsilateral arm during advancement of the needle. The Student's t test for independent means, \( \chi^2 \) analysis, or Fisher's exact test where appropriate were used to determine differences between the two groups.

**Results**

In all except 34 patients (3.6%) in the ultrasound group, the right internal jugular vein was visualized and cannulated. The carotid artery was clearly visualized without neighboring venous structure or with a very small internal jugular vein in each of these 34 cases. All of these patients were cardiac transplant recipients and had had many prior cannulations for endomyocardial biopsies. We hypothesized that the absence of the vein probably represents thrombosis or occlusion, whereas a very small vein may be scarred by multiple access and loses its ability to expand during the Valsalva maneuver. We therefore feel confident that this does not represent a failure of ultrasound visualization. In all 34 of these patients, the left internal jugular vein was visualized and successfully cannulated. Twenty patients had at a previous sitting an unsuccessful attempt at internal jugular vein cannulation using the traditional landmark approach. In nine of these patients, the internal jugular vein was very small and did not increase in its diameter during the Valsalva maneuver or was not visualized despite excellent visualization of the carotid artery. In 11 of these patients, it was noted that the internal jugular vein was positioned more medially and overlying the carotid artery. Using ultrasonic guidance, venous access was uncomplicated in 11 patients.

Average access time was 9.8 seconds (2–68 seconds) using ultrasound. In 722 (77.8%) patients, the internal jugular vein was accessed on the first attempt (Table 1). It was noted that the internal jugular vein is actually compressed completely by the needle before the vessel is penetrated. The needle must be advanced a little deeper and then retracted slightly to be positioned in the center of the lumen. Failure to recognize this was the reason that more than one attempt was needed in some of these patients.

Four patients complained of a sharp discomfort radiating down the right arm during advancement of the needle. It was noted on ultrasound that the vein had to be compressed and displaced almost 1 cm before it was punctured by the needle. This probably caused pressure on the brachial plexus, resulting in the radiating discomfort.

Puncture of the carotid artery occurred in 16 patients. Most complications occurred early in our series or
FIGURE 3. Left panel: Two-dimensional ultrasound image of the right neck area with the transducer over the groove between the two heads of the sternocleidomastoid muscle parallel and superior to the clavicle. The internal jugular vein is only slightly larger than the carotid artery and is located more anteriorly and laterally. Right panel: Without changing the transducer position, the patient is asked to perform the Valsalva maneuver. This markedly increases the size of the internal jugular vein without affecting the size of the carotid artery. R, right; L, left; A, carotid artery; V, internal jugular vein.

during the learning curve of operators new to this technique. Only two visible hematomas resulted.

Results using the external landmark-guided technique are in sharp contrast to results obtained using ultrasound guidance. Access time was significantly longer (44.5 seconds; range, 3-1,000 seconds; p<0.001), more attempts were needed (2.5 seconds; range, 1-28 seconds; p<0.001), and successful cannulation on the first attempt occurred in only 116 patients (38.4%, p<0.001). Venous access was unsuccessful in 36 patients (11.9%, p<0.001), and the complication rate was significantly higher (p<0.001); carotid puncture occurred in 25 patients (8.3%), with 10 patients (3.3%) developing a visible hematoma (p<0.05) (Table 1).

| Table 1. Results of Ultrasound-Assisted Versus Landmark-Guided Technique |
|--------------------------|-----------------|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                          | n               | Access time (seconds) | Success rate | Carotid puncture | Brachial plexus irritation | Hematoma | Average number of attempts | Access with one attempt | Access with two attempts |
| Landmark                 | 302             | 44.5±129.5 (2-1,000) | 266 (88.1%)  | 25 (8.3%)        | 5 (1.7%)             | 10 (3.3%) | 2.5±2.7 (1-28)              | 116 (38.4%)             | 111 (36.8%)            |
| Ultrasound I             | 302             | 10.3±11.6* (1-67)   | 302* (100%)  | 8* (2.6%)        | 1* (0.3%)            | 0* (0%)    | 1.2±0.5* (82%)              | 248* (82%)              | 44* (14.6%)            |
| Ultrasound II            | 626             | 9.7±15.4* (1-68)    | 626* (100%)  | 8* (1.3%)        | 3* (0.5%)            | 2* (0.3%) | 1.4±0.9* (75.6%)            | 473* (75.6%)            | 92* (14.7%)            |
| All                      | 928             | 9.8±14.3* (2-68)    | 928* (100%)† | 16* (1.7%)       | 4* (0.4%)            | 2* (0.2%) | 1.3±0.8* (76%)              | 722* (76%)              | 136* (14.7%)           |

Access time and number of attempts are expressed as mean±1 SD (range); success rate, carotid puncture, brachial plexus irritation, hematoma, and one- and two-attempt success rate are expressed as the absolute number of patients and percentage of their group. Ultrasound I: first 302 patients; ultrasound II: additional 626 patients in whom ultrasound was used exclusively; all: ultrasound I and II. *p<0.001 vs. landmark.

†In 34 patients (3.6%), the right internal jugular vein was not visualized and the left internal jugular vein was successfully cannulated after visualization.
There were no incidents of pneumothorax, phrenic or laryngeal nerve irritations, neurological damage, or significant injury to the carotid artery in either group.

Fifteen operators performed fewer than 20 procedures (range, 1–19), and 14 operators performed more (range, 20–288) than 20. There was, however, no significant difference in access time or number of attempts between the two groups. This result indicates a very short and steep learning curve for this technique.

**Discussion**

This prospective study clearly demonstrates the superiority of ultrasound-assisted as compared with landmark-guided cannulation of the internal jugular vein.

Success rate, complications, number of attempts, and time needed to access the internal jugular vein using a blind, anatomic landmark-guided technique have been described.\textsuperscript{2,10–13} In a series of 100 patients, Daily et al.\textsuperscript{11} were unsuccessful in accessing the right internal jugular vein in 9% of patients. Of these nine patients, access of the left internal jugular vein was unsuccessful in one. The authors further reported that arterial puncture occurred “occasionally” and that the mediastinum was infiltrated in one patient (1%). In a larger series of 1,125 patients, Schwartz et al.\textsuperscript{12} successfully cannulated the internal jugular vein in 95.3% of patients, with a 4.2% arterial puncture rate; in that study, an 8F sheath was accidentally introduced into the carotid artery in five patients. In a series of 1,000 patients, Goldfarb and Lebrec\textsuperscript{13} reported a success rate of 99.3%, but in 4.3% the left internal jugular vein had to be cannulated after unsuccessful attempts at right-sided access. This high success rate came at the cost of multiple attempts, as only 57.3% of patients were accessed in one or two attempts (one attempt: 43.3%; two attempts: 14.0%). Carotid puncture rate was 7.4%, hematoma was 1%, hemothorax and Horner syndrome were 0.2% each, and dysphagia was 0.1%. Our control group of 302 patients in whom the landmark-guided technique was used compares favorably with this study, with 75% success rate with two attempts (one attempt: 38.4%; two attempts: 36.8%). Ultrasound guidance provides a significant improvement, with 93% success rate with two attempts (one attempt: 78%; two attempts: 14.7%). Other studies have shown a failure of cannulation rate of 7–19.4%, depending in part on the experience of the operator.\textsuperscript{2,13} Our failure rate of 11% in the external landmark group is similar to the published data. Sznajder et al.\textsuperscript{12} reported a complication rate varying by physician experience (house staff-attendings): arterial puncture, 6.7–33.3%; pneumothorax, 1.7–0.8%; and hematoma, 2.6–1.1%. The incidence of arterial puncture in our study (8.3%) using the external landmark method is in the range of the larger studies. This may reflect underestimation of its incidence in smaller studies. Recognition of this problem has led many groups to use a small-gauge “finder” needle to locate the internal jugular vein before engaging a larger 18- or 19-gauge needle through which a guide wire is passed.\textsuperscript{10} Using ultrasound guidance, the incidence of carotid puncture was very low (1.7%). This resulted in no further complications because it was readily visualized. There were no inadvertent introductions of a guide wire or sheath in the carotid artery. In several patients in whom carotid puncture occurred, it was noted that the internal jugular vein was overlying the carotid artery rather than being in the more lateral position. Because the internal jugular vein is compressed by the needle before it is actually punctured, advancing the needle resulted in puncturing the anterior wall of the carotid artery. This led us to adapt a modified technique in these cases by puncturing the internal jugular vein in a “sideways” fashion rather than perpendicular to the skin surface to avoid the carotid artery. Operator experience also may further decrease this complication, as it occurred only twice (two of 288, 0.7%) in the series of the operator with the largest experience. Brachial plexus irritation (pain radiating down the arm during needle advancement, without permanent damage) and minor hematomas occurred in both patient groups but occurred significantly less often in the ultrasound group. In our entire study of 1,230 patients, no serious complications such as pneumothorax occurred. As with any technique, adequate instruction is necessary. Twenty-nine operators participated in this study, and the results include the learning curve for each. Fifteen operators performed fewer than 20 procedures (range, 1–19) (Figure 4). When comparing access times and number of attempts as a group, there was no significant difference with the 14 higher-volume operators. These data illustrate that the ultrasound technique is easy to learn and rapidly produces an improvement over the landmark-guided method. However, it is apparent that a few operators performed much worse than the average. We believe that this finding reflects individual abilities, as is the case with any interventional technique.

The use of Doppler or ultrasound to guide access to the internal jugular and subclavian vein has been reported previously,\textsuperscript{4–8} and ultrasound has been applied to describe the anatomy of the internal jugular vein and to evaluate various techniques for percutaneous cannulation.\textsuperscript{14,15} These studies, however, represent a limited experience\textsuperscript{4–8}; they fail to adequately report the failure rate and incidence of complications\textsuperscript{4–8} and, most importantly, do not prospectively compare ultrasound with landmark-guided methods. A recent study prospectively

**Figure 4.** Bar graph shows mean number of needle thrusts (closed bar, left axis) and time for successful cannulation (open bar, right axis) of the internal jugular vein by 29 operators. The graph is arranged numerically in that the far left represents the individual operator with the least number of cases (n=1) and the far right represents the greatest number (n=288). Operators to the left of the arrow performed fewer than 20 cases, and operators to the right performed more than 20.
compared ultrasound guidance and external landmark technique in 27 critically ill patients. This study used standard, full-size echo equipment in a critical care setting in 17 patients. Despite this small number of patients, an impressive improvement in success rate and a reduction in the number of needle thrusts was reported compared with the traditional approach. An advantage of our approach is the use of a portable, easy-to-use instrument. The use of a dedicated transducer with optimized needle guide further enhances its utility and minimizes specialized training, resulting in short learning times. Our patient population of 1,230 is the largest prospectively studied series of internal jugular venous access and confirms the safety and efficacy of the technique. There is no doubt that the critically ill and high-risk patients benefit most from this technique, as illustrated by Malloy et al. However, this does not lessen its usefulness in all patients: Using the landmark technique, 24.8% of patients require more than two sticks for successful cannulation versus only 7.3% in the ultrasound group. Although the complication rate is low, the discomfort to the patient resulting from multiple sticks and switching sites because of unsuccessful cannulation is critically important.

We conclude that ultrasound guidance for access of the internal jugular vein significantly minimizes procedure time, reduces complications, and provides a very high success rate in an elective setting. Further studies will determine definitely whether ultrasound guidance should be used routinely in obtaining central nervous access.

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