

# Ultrasound Guidance versus the Landmark Technique for the Placement of Central Venous Catheters in the Emergency Department

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## Abstract

**Objective:** To compare ultrasound (US)-guided vs. landmark-guided techniques for central venous access (CVA) in the emergency department. **Methods:** This was a prospective study of consecutive patients enrolled at a university teaching hospital with an annual census of approximately 100,000. On even days patients had CVA with ultrasonic assistance; patients presenting on odd days had CVA via traditional landmark techniques. Ultrasound users were emergency medicine faculty or residents who completed a one-hour training session. A data collection tool with 17 variables was completed for each central line placed. Variables were compared using the independent t-test, Fisher's exact test, and the non-parametric Mann-Whitney U test. **Results:** Between August 1, 2000, and February 1, 2001, data for 122 subjects ( $n = 51$  for US, and  $n = 71$  for landmark) were collected. Variables with statistically significant differences are as follows. Mean ( $\pm$ SD) time from skin puncture to blood flash was 115 ( $\pm$ 184) seconds for the US group vs. 512 ( $\pm$ 698) seconds for the landmark group ( $p < 0.0001$ ). The mean number of CVA attempts in the US group was 1.6 ( $\pm$ 1.0) vs. 3.5 ( $\pm$ 2.7) in the landmark group ( $p < 0.0001$ ). Acute complications were comparable between groups. Comparisons for time, number of CVA attempts, and complications were done specifically for a subset of patients considered to be "difficult stick" due to predefined

criteria regarding body habitus or vascular disease. Patients considered to be "difficult sticks" required a significantly longer amount of time ( $p < 0.001$ ) for CVA via the landmark technique than patients considered to be "difficult sticks" who had CVA with ultrasonic guidance. Time to line placement for the landmark group was 462.7 ( $\pm$ 627) seconds vs. 93.3 ( $\pm$ 176) seconds in the US group. Comparing the same subset also revealed an increase in number of required CVA attempts for the landmark technique group. The number of acute complications in the "difficult stick" patients did not show statistical significance ( $p = 1.00$ ). The landmark group had 60% "difficult sticks," while the ultrasound group had 80%, although the difference was not statistically significant ( $p = 0.08$ ). **Conclusions:** Emergency physicians with limited training and experience are able to use ultrasound as an adjunct for central venous access. Ultrasound technology may decrease the number of CVA attempts required to cannulate a central vein and will decrease the amount of time required to cannulate the vein starting from the time when the needle is on the skin, after the ultrasound machine has been set up and turned on. These results are especially true for those patients considered to be "difficult sticks." **Key words:** ultrasound; central venous catheter; cannulation. *ACADEMIC EMERGENCY MEDICINE* 2002; 9:800-805.

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Emergency physicians (EPs) rely on their skill at establishing central venous access (CVA) for delivery of critical care medications, for volume resuscitation with saline or blood products, and for central cardiac monitoring and pacing.<sup>1</sup> The success rate, time to completion, number of CVA attempts, and rate of complications are all important aspects of this procedure.

Ultrasound (US)-guided CVA in the emergency department (ED) is an emerging application of real-time US technology but has received little comment in the emergency literature.<sup>1</sup> The use of US to assist internal jugular vein cannulation and to decrease the incidence of complications was first reported in 1984 by Legler and Nugent in the anesthesiology literature and subsequently in the surgical literature,<sup>2-4</sup> and compared favorably with the landmark

technique in groups of experienced physicians.<sup>2</sup>

In the ED of our university hospital, houseofficers (interns and residents) usually perform CVA. The purpose of this study was to determine whether US guidance could improve the success rate, time to completion, number of attempts, and rate of acute complications of central venous catheterization in the ED.

## METHODS

**Study Design.** This was a prospective study of the usefulness of US guidance in the placement of central venous catheters in ED patients. Institutional review board approval was obtained prior to initiation of the study.

**Study Setting and Population.** We used a consecutive sample of 122 patients who presented in need of CVA over a six-month period from August 2000 to February 2001. Patients presenting on even days had CVA with ultrasonic assistance, while those on odd days had central catheter placement via traditional landmark techniques.

**Study Protocol.** The study included all patients who presented to the ED with an acute medical or surgical problem that necessitated CVA, such as hypotension, need for blood product resuscitation, or dehydration, where peripheral access could not be obtained. The study excluded children (less than 14 years old) and pregnant women. "Time" began at the point when the needle touched the skin and ended when blood flash was observed in the syringe. Time to set up the US machine was not measured. The number of CVA attempts required to obtain blood, the number of acute complications, and other parameters were recorded on the data-gathering tool (Table 1).

A patient was considered to be a "difficult stick" if he or she had severe peripheral vascular disease, coagulopathy, obesity, abnormal anatomy, or a history of intravenous drug abuse. "Coagulopathy" was defined as a bleeding abnormality due to liver disease or for patients being maintained on coumadin. "Complications" included the formation of a hematoma or the occurrence of a pneumothorax, cannulation of the artery, or improper cannulation into the thorax or soft tissues. The "experience of the user" was defined by the number of landmark-technique central venous lines that he or she had successfully accomplished prior to the study, as documented by the preceptor on the data-gathering tool. "Experienced users" were arbitrarily defined as having performed more than 25 central lines.

Prior to the study, no users had experience obtaining CVA via ultrasonic guidance.

**Ultrasound technique.** The real-time US-guided technique was performed with a GE Log IQ 400 MD ultrasound machine and a 7.5-MHz linear probe. To maintain a sterile field, the probe was covered in a sterile sheath and sterile gel was used. The user held the probe with the left hand, localizing the artery and vein on the US image. While centering a large-bore needle under the middle of the probe, the user ascertained the trajectory of the needle and attempted cannulation. Once a flash of blood was encountered, the US probe was removed and standard Seldinger technique was followed. The "user" investigators were residents in postgraduate years 1 through 3. The "preceptors" were faculty in the emergency medicine (EM) residency as well as senior residents in EM with special interest in ultrasonography. Preceptors were responsible for physically obtaining the US machine and measuring outcome variables. As the user performed the procedure, the preceptor recorded the following variables: "time," beginning at the point when the needle touched the skin and ending when blood flash was observed in the syringe; the number of CVA attempts required to obtain blood; the number of acute complications (as defined above); and other parameters (Table 1). The time required to obtain and set up the US machine was not measured.

**Training.** Ultrasound training for the "user" included a one-hour didactic lecture as part of his or her residency training and a one-hour lecture from radiology faculty. The "preceptor" received the same training, and gained further experience as he or she did additional studies.

**Data Analysis.** Data were obtained from a total of 122 subjects. For three of the measured variables, data were obtained only from the US group. An independent t-test compared ages across the two groups. Due to skewness, the nonparametric Mann-Whitney U test (also known as the Wilcoxon test for independent measures) was used to compare both times and numbers of CVA attempts across the two groups. The 11 categorical variables were tested with a chi-square analysis, where sample size permitted, and Fisher's exact test for smaller sample sizes. For the post-hoc analysis, alpha was specified at 0.01 to adjust for multiple comparisons.

## RESULTS

Use of US resulted in more rapid blood flash in the US group compared with the landmark group.

TABLE 1. Patient Demographic and Clinical Variables across Groups

Variable	Overall (N = 71) Outcome in Landmark Group	Overall (N = 51) Outcome in Ultrasound Group	p-value*
Time—mean ± SD	512 ± 698 sec	115 ± 184 sec	<0.0001†
No. of central venous access attempts—mean ± SD	3.54 ± 2.68	1.55 ± 1.01	<0.0001
Patient “difficult stick”?			0.0846
No	24 (34%)	4 (8%)	
Yes	47 (66%)	47 (92%)	
Patient age—mean ± SD	43.8 ± 12.3 yr	49.1 ± 12.3 yr	0.0297
History of intravenous drug abuse?			0.8798
No	58 (85%)	44 (86%)	
Yes	10 (15%)	7 (14%)	
Improved detection of anatomy—yes	—	44 (88%)	
Increased ability to avoid complications—yes	—	45 (90%)	
Improved efficiency—yes	—	39 (78%)	
Coagulopathy?			0.7416
No	55 (81%)	40 (78%)	
Yes	13 (19%)	11 (22%)	
Approach			<0.0001‡
Internal jugular	9 (13%)	28 (55%)	
Subclavian	9 (13%)	1 (2%)	
Femoral	53 (75%)	21 (41%)	
Peripheral	0 (0%)	1 (2%)	
Patient had prior venous cutdown?			0.0040
No	65 (96%)	40 (78%)	
Yes	3 (4%)	11 (22%)	
Patient gender			0.0435
Male	41 (58%)	20 (39%)	
Female	30 (42%)	31 (61%)	
Complications from procedure?			0.7081
No	61 (86%)	45 (88%)	
Yes	10 (14%)	6 (12%)	

\* Chi-square was used, unless otherwise stated.

† The Wilcoxon nonparametric test for independent measures was used because of skewness.

‡ Fisher's exact test was used.

Mean (±SD) skin to blood flash time was 115 (±183) seconds in the US group versus 512 (±698) seconds in the landmark group. Fewer CVA attempts were required in the US group compared with the landmark group (average  $1.6 \pm 1.0$  attempts versus  $3.5 \pm 2.7$  attempts). The users remarked upon several subjective criteria, including improved anatomy definition by the US image (88%), avoiding complications by using the US image (90%), and improving efficiency of the procedure using US guidance (78%) (Table 1). Characteristics and experience of the users are described in Table 2.

The post-hoc analysis depicted in Table 3 compares results between inexperienced physicians (i.e., those having performed 25 or fewer central lines in their careers) and experienced physicians (i.e., those having performed more than 25 central lines in their careers) on subjects deemed “difficult sticks.” Whether the physicians were experienced or not, the ultrasound-guided technique resulted in absolute decreases in the time to blood flash and the number of CVA attempts. As expected, the inexperienced physicians required more time as well as an increased number of attempts in both the landmark group and the US-guided group.

**TABLE 2. Characteristics/Experience of the Users**

Variable	Overall (N = 71) Outcome in Landmark Group	Overall (N = 51) Outcome in Ultrasound Group	p-value*
User experience in landmark method			0.7252
Little experience	45 (63%)	29 (57%)	
Moderate experience	19 (27%)	17 (33%)	
Quite experienced	7 (10%)	5 (10%)	
User experience in ultrasound guidance			0.0520
None	59 (87%)	37 (73%)	
Some	9 (13%)	14 (27%)	
Emergency medicine resident			0.0122
No	34 (48%)	13 (25%)	
Yes	37 (52%)	38 (75%)	
Postgraduate year			0.6028
One	27 (38%)	15 (29%)	
Two	29 (41%)	23 (45%)	
Three or more	15 (21%)	13 (25%)	

\* Chi-square was used, unless otherwise stated.

### DISCUSSION

The use of US to guide CVA has been previously reported.<sup>2-5</sup> Ultrasound has been applied to describe the anatomy of the internal jugular vein and to evaluate various techniques for percutaneous cannulation.<sup>6,7</sup> These studies, however, represent a limited experience,<sup>2,3,5,8</sup> and do not prospectively compare US with landmark-guided methods.<sup>9</sup>

Denys and Uretsky<sup>10</sup> studied the normal anatomy of the internal jugular vein in 1993. The anatomy of the internal jugular vein was sufficiently aberrant in 8.5% of cases to complicate access by a landmark method, and five patients (2.5%) had thrombosed internal jugular veins. In our study, we did

not note any thrombosed veins. In the comments collected by US users, however, aberrant anatomy was noted as a contributing factor in difficulty accessing the vein.

The first report of combined real-time ultrasonographic imaging and internal jugular catheter placement was by Yonei and Sari<sup>2</sup> in 1986. They used a sterile 5-MHz probe to identify the internal jugular vein and carotid artery during placement of internal jugular catheters in the intensive care unit, and successfully catheterized 160 patients without complication or failure.

In 1990, Malloy and Shawker compared US guidance and external landmark technique in 27 critically ill patients.<sup>11</sup> Despite the small number of patients, an improvement in success rate and a reduction in the number of CVA attempts were reported compared with the traditional approach. Using the landmark technique, 24.8% of the patients required more than two attempts for successful cannulation versus only 7.3% in the US group. Also noted, the complication rate was low and patient discomfort resulted from multiple attempts and switching sites because of unsuccessful cannulation.<sup>11</sup>

Denys and Reddy<sup>12</sup> studied the use of US guidance in internal jugular vein catheterization in a larger, controlled comparison study. They compared 302 patients undergoing jugular vein puncture for placement of a central venous catheter in the cardiac catheterization laboratory. Results included significantly higher success rates, a lower number of CVA attempts, and a lower complication rate with US guidance. Hilty and Hudson<sup>1</sup> also reported a higher success rate, a lower number of CVA attempts, and a lower rate of arterial catheterization using real-time US catheterization vs. the standard landmark-oriented approach. Furthermore, the speed of access and the success rate remained stable over time. This suggests that even

**TABLE 3. Descriptive Statistics for Subjects Having "Difficult Sticks" Being Performed by Experienced and Inexperienced Physicians**

Variable	Group	N	Mean	Standard Deviation	Minimum	Maximum
Inexperienced Time (sec)	Ultrasound	21	115.71	±225.9	5	900
	Landmark	28	514.6	±770.5	9	3,600
No. of attempts	Ultrasound	21	1.48	±0.87	1	4
	Landmark	28	3.29	±2.79	1	10
Experienced Time (sec)	Ultrasound	11	56.8	±82.11	10	300
	Landmark	3	180.0	±120.0	60	300
No. of attempts	Ultrasound	11	1.36	±0.67	1	3
	Landmark	3	2.67	±2.08	1	5

limited experience with the US technique is associated with efficient, successful outcomes. Our data (Table 2) suggest that prior experience with the landmark technique does not decrease the usefulness of the US adjunct since, whether the physicians were experienced or not, the US-guided technique resulted in absolute decreases in the time to blood flash and the number of CVA attempts.

As previously reported,<sup>12-14</sup> the US-guided technique allowed a marked reduction in the access time (time necessary for the needle to go from skin to blood flash). All patients in Troianos et al.'s study<sup>13</sup> and 86% of patients in Slama and Novara's study<sup>15</sup> were cannulated within 3 minutes (180 seconds). In our trial, patients were cannulated in an average time of 116 seconds. It should be noted that the time to roll the US machine into the patient's room, plug it in, set the 7.5-MHz probe, and place a sterile sheath over the probe was not included in the above calculations. We estimate that this adds approximately 3 additional minutes to the setup time when using the US technology. Additionally, an average of 2.8 attempts were necessary with landmark guidance vs. 1.4 punctures with sonographic guidance in the 157 patients undergoing elective cannulation of the jugular vein in the preoperating room before surgery in the Troianos study. In our trial, the US-guided group received an average of 1.6 attempts and the landmark group 3.5 attempts to blood flash.

The complication rate of 12% in our US group is similar to that of Slama and Novara<sup>15</sup> and other published rates. The most common complication was arterial puncture, which was successfully treated by vessel compression without any further therapy. The complication rate varied according to the physician's experience: with a rate of 14.3% in the inexperienced group in the study by Sznajder et al.<sup>16</sup> The complication rate was lower with US than with the landmark method in the study by Denys and Reddy.<sup>12</sup> In our study, as in the Slama study, this complication rate was possibly due to the limited experience of young operators with the US technique.

Data comparing inexperienced physicians and experienced physicians on subjects deemed "difficult sticks" are presented in Table 3. Whether the physicians were experienced or not, the US-guided technique resulted in absolute decreases in the time to blood flash and the number of CVA attempts. As expected, the inexperienced physicians required more time and an increased number of attempts in both the US and the landmark groups. Interestingly, experience was less important in decreasing the number of access attempts using the US adjunct.

Other advantages to US guidance noted in the

literature suggest that as the practice of medicine becomes more concerned with outcome and cost of procedures, sonographic guidance becomes more attractive than landmark guidance. Prior studies support a decreased number of complications,<sup>13</sup> because fewer punctures are attempted, and fewer disposable supplies are used. Landmark-guided placement of subclavian catheters used 40% more catheter kits per patient than sonographically guided placement.<sup>17</sup> Finally, the discomfort to the patient resulting from multiple attempts and switching sites because of unsuccessful cannulation is important.

## LIMITATIONS

Since the time measurements in this study did not include the time it took to obtain and set up the US machine, it may take considerably longer to use US in those institutions where an US machine is not readily available. The time required to set up the US machine has been estimated by the authors to be relatively short, although it was not specifically measured in this study.

The "preceptors" were themselves EPs who had no prior US experience. The study therefore shows that EPs not only can do the procedure themselves, but also can teach it to other novice users with ease. The limitation is that the preceptors were not consistently performing the US-guided line placement. Because of this, it is impossible to say how US experience increases the efficiency or ease of using this technique. Admittedly, there was an inadvertent break in the study protocol, which is reflected in the data. Table 1 shows that the non-EM users did a larger number of landmark-guided procedures than the EM users, and they often used the femoral site. We believe that this occurred inadvertently because non-EM providers, when faced with the need for central access, possibly deferred the additional setup time required for the US approach, for the perceived "easy" access patient with excellent anatomic landmarks in the femoral region. While this was a break in protocol, the bias is that more patients with better anatomic landmarks (and therefore fewer "difficult stick" patients) exist in the landmark group. This is reflected in the fact that there was a statistically larger number of patients with prior venous cutdown in the US group ( $p = 0.004$ ) and a trend ( $p = 0.08$ ) suggesting a larger number of patients were considered to be "difficult sticks" in the US group. There was no follow-up of the subjects in the study, thus precluding the detection of delayed complications related to the procedure.

Of the 17 variables measured between the US and

landmark groups, statistical differences do exist. There was a slightly older age population in the US group (49.1 vs. 43.8 years), and there were more women in the US group (61% vs. 42%). Neither of these variables should affect the ease of line placement and group comparison.

## CONCLUSIONS

Based on our study, only limited teaching of basic ultrasound physiology and hands-on training are needed for the successful use of US guidance for CVA. This may be especially helpful in patients in whom landmarks are not visible or not palpable. Our results show that US guidance decreased the time it takes to perform CVA. Additionally, ultrasonic guidance resulted in a decreased number of CVA attempts. In light of the above finding, we believe that the use of US guidance could be recommended: 1) before CVA is attempted to define the site and dimensions of the vein, especially in difficult patients; 2) during access attempts to guide cannulation; or 3) after several minutes of unsuccessful cannulation using the landmark technique.

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