Original Contribution

Ultrasound guidance for central venous catheter placement: results from the Central Line Emergency Access Registry Database

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Abstract

Background: Ultrasound guidance of central venous catheter (CVC) insertion improves success rates and reduces complications and is recommended by several professional and regulatory organizations.

Methods: This is a prospective observational study using data extracted from the Central Line Emergency Access Registry database, a multicenter online registry of CVC insertions from medical centers throughout the United States. We compared success rates with ultrasound and with the anatomic-landmark technique.

Results: A total of 1250 CVC placement attempts by emergency medicine residents during the study period were selected from the Central Line Emergency Access Registry database. Because a few attempts (n = 28) were made to place lines in either the left or right supraclavicular locations, data on these attempts were eliminated from the analysis. A total of 1222 CVC attempts from 5 institutions were analyzed. Successful placement on the first attempt occurred in 1161 (86%) cases and varied according to anatomic location. Ultrasound guidance was used in 478 (41%) of the initial attempts. The remainder of placements were presumably placed using the anatomic-landmark technique based on visible surface and palpatory subcutaneous structures. Overall successful placement rate did not vary according to the use of ultrasound guidance, nor did it vary at different anatomic sites. However, ultrasound was found to be significant for reducing the total number of punctures per attempt ($P < .02$, $t = 2.30$).

Conclusions: Our study did not observe improved success with the use of ultrasound for CVC cannulation on the first attempt, but we did observe a reduced number of total punctures per attempt.
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1. Introduction

1.1. Background

Ultrasound (U/S) guidance of central venous catheter (CVC) insertion improves success rates and reduces complications [1] and is recommended by several professional and regulatory organizations [2]. Some authors advocate that all CVC attempts be performed using U/S guidance as opposed to the anatomic-landmark technique where a needle is inserted according anatomical landmarks [3].

1.2. Importance

Although there have been a number of studies regarding the use of U/S to cannulate the internal jugular (IJ) vein in other medical specialties, the number of studies in the emergency medicine (EM) literature remains small [4,5]. Most studies are from a single center and limited to the most skilled operators placing catheters under controlled circumstances in stable patients and may not reflect an accurate indication of the experience of emergency physicians who place catheters in less controlled settings in unstable patients. These emergent situations often mandate the placement of CVC in sites other than the IJ vein. Less is known about the use and utility of U/S guidance of CVC placement in these settings.

In 2005, we created the Central Line Emergency Access Registry (CLEAR), a multicenter Web-based registry located at www.clearsite.org, to collect data on the experience of emergency physicians with CVC placement. This experience is published in the *American Journal of Emergency Medicine*, "CLEAR: Central Line Emergency Access Registry, The CLEAR Project Protocol Methods Paper" [6].

1.3. Goals of this investigation

The primary goal of this investigation was to analyze the use of U/S guidance of CVC placement at various anatomic sites. The secondary goal was to determine if the use of U/S was associated with an improved rate of successful catheter placement.

2. Methods

2.1. Study design

This is a prospective observational study using data extracted from the CLEAR database, a multicenter online registry of CVC insertions from medical centers throughout the United States.

2.2. Setting

Data were submitted from 5 institutions. All participating centers were academic residency training programs. Partici-

pating centers ranged from university-affiliated programs to community-based residencies.

2.3. Study period

The data were collected from November 2005 until November 2007.

2.4. Selection of participants

In this analysis, we observed the experience of EM residents (postgraduate year [PGY] 1 through 3) in both the emergency department (ED) and intensive care unit (ICU) settings who attempted CVC placement in adult patients ($\geq$18 years old). Because of the observational nature of this study, a waiver of informed consent was obtained from participating centers. The institutional review board of each institution approved this study.

2.5. Methods of measurement

We defined an attempt as one operator attempting to place a CVC at one anatomic site. If a second site or operator was needed for successful insertion, this constituted a failed attempt. Although prior studies have chosen to define an attempt as 1 skin puncture or single pass of the needle, we feel that our definition describes the reality of CVC insertion in an emergent setting. Even the most skilled operators may require more than 1 skin puncture in their "attempt" to place a CVC. We also chose to record skin punctures per attempt to determine their association with overall success rates.

We defined 2 techniques when using U/S for CVC placement. Real-time guidance involves a sterile probe cover and continuous vein identification at all times during the insertion of the catheter. Ultrasound may also be used to identify and map the course of the vein (ie, IJ) and artery (carotid) before beginning the procedure. In this technique, the U/S probe is then removed and the operator uses the map generated by U/S as a guide for insertion.

2.6. Data collection and processing

After the insertion of a CVC, the resident physician was required to enter data variables into an online data entry form describing their particular CVC encounter. Variables collected in the data entry form include PGY level of physician, prior number of CVC insertions, anatomical site of placement, number of attempts, number of skin punctures per attempt, technique used (U/S guided vs landmark), hospital location (ICU vs ED), reason for insertion, immediate complications, and use of sterile technique.

At each CLEAR site, compliance with enrollment was assessed by quarterly reviews of log books and database entries. Each participating center was required to submit a

compliance plan on a quarterly basis with a target compliance of 75% or greater. Data from centers not meeting the minimum 75% compliance were eliminated from the data analysis.

2.7. Outcome measures

Successful placement required confirmation of catheter location by chest radiograph (for IJ or subclavian sites) or successful fluid infusion without extravasation (for femoral sites).

2.8. Primary data analysis

The primary analysis was performed to determine the rates of U/S-guided CVC placement. The secondary analysis was performed to determine whether successful placement varied with the use of U/S guidance. Data were stratified by anatomic location and number of attempts required for successful placement. Data were analyzed using SPSS software version 15.0. For the first attempt, a generalized linear model was used to analyze the impact of anatomic location and the use of U/S on the probability of a successful line placement. When working with frequent outcomes, such as a successful line placement in the current study, the odds ratio can greatly overestimate the relative risk. The binomial distribution and log link function were therefore used in building the generalized linear model so that the results can be interpreted as prevalence ratios. Dummy variables were created for the 5 locations of left femoral vein (FV), right FV, right IJ vein, left subclavian vein, and right subclavian vein. The left IJ vein location (the location with the lowest success rate) served as the reference category.

3. Results

This analysis examines the impact of anatomic location and the use of U/S on the probability of successful line placement. Because very few attempts were made to place lines in either the left or right supraclavicular locations, data on these attempts were eliminated from the analysis of the results.

Line placement success rates and U/S utilization were compared across anatomic location for the first attempt and again for the second attempt. A total of 1250 CVC placement

Table 1 Data from 5 medical centers

Medical center	No.	%
Christiana Care Health System	374	31
Lehigh Valley Hospital and Health Network	118	10
Maricopa Medical Center	422	35
University Medical Center Southern of Nevada	179	15
University of California, Davis Medical Center	129	11
Total	1222	100

Table 2a Success rates on the first attempt at placement

Location	U/S not used		U/S used		Overall	
	Rate (%)	No.	Rate (%)	No.	Rate (%)	No.
Left FV	88	68	95	21	90	89
Right FV	85	242	87	63	85	305
Left IJ vein	0	1	81	70	80	71
Right IJ vein	85	20	89	322	89	342
Left subclavian vein	83	150	0	1	83	151
Right subclavian vein	84	202	100	1	84	203
Overall	84	683	88	478	86	1161

attempts by EM residents during the study period were selected from the CLEAR database. A total of 1222 CVC attempts from 5 institutions were analyzed (Table 1).

Successful placement on the first attempt occurred in 1161 (86%) cases and varied according to anatomic location (Table 2a). Ultrasound guidance was used in 478 (41%) of the initial attempts. The remainder of placements were presumably placed using the anatomic-landmark technique based on visible surface and palpatory subcutaneous structures. Overall successful placement rate did not vary according to the use of U/S guidance, nor did it vary at different anatomic sites. However, U/S was found to be significant for reducing the total number of punctures per attempt ($P < .02$, $t = 2.30$) (Table 2b).

3.1. First attempt

Tables 2a and 2b compare success rates on the first attempt at placement for U/S cases and non-U/S cases within each anatomic location. The overall success rate was 86%. Across all anatomic locations combined, the success rates for non-U/S and U/S cases were similar (84% and 88% respectively; Fig. 1).

3.2. Second attempt

Tables 3a and 3b compare success rates on the first attempt at placement for U/S cases and non-U/S cases within each anatomic location. The overall success rate was 74%. Across all anatomic locations combined, the success rates for non-U/S and U/S cases were similar

Table 2b Number of punctures used

		Total punctures (attempt 1)	
		Mean	Punctures/attempts
U/S used (attempt 1)	No	1.7	1243/731
	Yes	1.5	735/490

$t = 2.30$, $P < .02$.

Fig. 1   Results of first 2 placement attempts (showing missing cases).

(70% and 81% respectively; $\chi^2_1 = 2.53$, $P < .11$). Again, U/S led to a reduction in the total number of punctures per attempt.

The results from the generalized linear model are shown in Table 4. These results indicate that, compared with all other locations, the left FV and right IJ vein locations are significantly more likely to result in successful placement. The use of U/S had no impact on placement success. Because of the limited numbers in many of the table cells, it was not possible to test the impact of U/S within specific anatomic locations.

There are many reasons why residents chose to use the landmark technique rather than the U/S-guided technique. In both the first and second attempts, insufficient time was cited most often as the reason for not using U/S. No access to a U/S machine is the second most common reason cited. Lack of training was the third most common reason for not using U/S in both attempts. Real-time direct visualization of anatomy was the main reason why U/S was used; otherwise, it was used only for vein location. The locations, preferences to use U/S, and reasons not to use a U/S in CVC placement are summarized in Tables 5 to 7.

4. Limitations

Because this is a Web-based multicenter registry that relies on an honor system for the acquisition of data, there are a few limitations inherent to this study. For instance, the sampling technique requires that data be entered voluntarily. Unfortunately, this may skew the results from a possible lack of documentation. In addition, subjects not as adept at CVC insertion may opt to stop entering their data. Our decision to

Table 3a   Success rates on the second attempt at placement

Location	U/S not used		U/S used		Overall	
	Rate (%)	No.	Rate (%)	No.	Rate (%)	No.
Left FV	52	21	75	4	56	25
Right FV	76	34	45	11	69	45
Left IJ vein	100	3	92	12	93	15
Right IJ vein	50	8	87	45	81	53
Left subclavian vein	72	25	100	1	73	26
Right subclavian vein	75	24	—	0	75	24
Overall	70	115	81	73	74	188

Table 3b   Number of punctures used

		Total punctures (attempt 2)	
		Mean	Punctures/attempt
U/S used (attempt 2)	No	1.7	218/128
	Yes	1.3	92/74

$t = 3.35$, $P < .001$.

Table 4 Summary of generalized linear model for the first attempt

	Lower confidence limit	Relative risk	Upper confidence limit	$P <$
Left FV	1.00	2.47	6.10	**.05**
Right FV	0.83	1.71	3.54	.15
Left subclavian vein	0.68	1.55	3.51	.29
Right subclavian vein	0.74	1.64	3.65	.23
Right IJ vein	1.01	1.76	3.08	**.05**
U/S	0.76	1.35	2.39	.30

There were no sufficient data to examine the impact of U/S within specific anatomic locations. The left IJ vein location was used as the reference variable.

include only sites with a high compliance rate is an effort to counteract underreporting.

These observational data cannot assign improved placement (reduced skin punctures or increased success) to the use of U/S in the ED. Our observations can detect only associations that provide hypotheses for further study.

There is an expected maturation of subjects with the use of both U/S guidance and the anatomic-landmark technique. Miller et al [5] notes that U/S training is quite easy, with rapid adaptation by the trainee. None of the authors suggest a range for which a provider acquires proficiency in the use of U/S-guided CVC placement. In the studies reviewed, providers were commonly given a 1- to 2-hour inservice on U/S utilization. With the landmark technique, it has generally been accepted that a provider is proficient after 10 to 30 successful cannulations. Essentially, more precise definitions of "experienced" are needed to adequately evaluate the role of U/S in CVC insertion.

We included subclavian vein insertion in the study, but very few were done via U/S in this study. Extrapolation to the use of U/S in CVC insertion based on the study findings is premature.

No standard definition exists in the literature with regard to success rates definitions as it related to skin punctures exist in the literature. We chose to describe both as best possible.

Future studies will evaluate complication rates (pneumothoraces and arterial puncture) with U/S vs non-U/S placement.

Table 5 U/S usage by anatomic location

Location	Cases using U/S	Total cases	%
Left IJ vein	73	74	99
Right IJ vein	326	350	93
Left FV	22	96	23
Right FV	64	314	20
Left subclavian vein	1	157	1
Right subclavian vein	1	210	0
Overall	487	1202	41

Table 6 Reasons for not using U/S

Reason	No.	%
Insufficient time for setup/use of U/S machine	275	37
No access to U/S in hospital setting where lines were placed	95	13
Not trained in U/S placement of central lines	37	5
Not mentioned	28	4
All other	304	41
Total	739	100

5. Discussion

Previous studies have been able to demonstrate a valid justification for the use of U/S-guided central venous access when cannulating the IJ vein. Several randomized controlled trials in settings other than the ED were able to show that the U/S-guided technique was superior to the landmark technique in obtaining successful catheterization [7,8]. In 1996, Randolph et al [1] published a meta-analysis of the literature that analyzed 208 randomized controlled trials of both arterial and venous cannulations. The authors concluded that the use of U/S when cannulating the IJ or SC veins significantly reduces the failure rate of catheter placement and the need for repeated attempts. In addition, they noted a reduction in complications of vessel cannulation by using U/S [1].

A few trials that have involved ED patients resulted in similar findings. The prospective, descriptive study by Hrics et al [9] is one of the earliest studies to focus on CVC placement in the ED. Like many of the other studies, the goal was to establish whether U/S-guided CVC placement was more efficacious than the landmark technique. In this study, however, the authors focused on the number of needle passes or punctures that occurred during each attempt. Patients were excluded if they presented as a trauma or cardiac arrest or if the site of placement was other than the IJ vein. These findings demonstrated that the number of punctures was less with U/S guidance, and there was increase in success on the first attempt. In addition, 2 patients had successful line placement after they were transferred into the U/S group when the landmark technique failed [9].

Although our study did not observe improved success with the use of U/S for CVC cannulation on the first attempt, we did observe a reduced number of total punctures per attempt. This may be important as Karakitsos et al [8] demonstrated a positive correlation between the

Table 7 Reasons for using U/S

Reason	No.	%
Real-time direct visualization of anatomy	444	92
U/S used only for vein/landmark location	39	8
Total	483	100

number of skin punctures and the number of CVC-related bloodstream infections.

Other studies cite additional reasons to justify use of U/S. The study by Karakitsos et al [8] found 5 different anatomical variants of the IJ and common carotid while analyzing the efficacy of U/S vs the landmark technique. Subsequently, it is noted that U/S can help identify for which patients CVC insertion may be difficult and possibly lead to increased morbidity while attempting to cannulate the IJ vein [8]. In addition, Abboud et al [10] reviewed various radiographic studies demonstrating multiple deviations in FV and femoral artery anatomy. Interestingly, a 1997 study of FV cannulation during cardiac arrest with the use of U/S found that during chest compressions, there was an increase in FV diameter. Therefore, the practice of palpating for a pulse to identify landmarks may not lead the operator to the correct location. Furthermore, pulsatile blood seen after cannulation may not necessarily be indicative of arterial puncture [11]. Because the FV is a preferred location for CVC insertion, especially in emergent situations, U/S can help identify problematic insertions. Ultimately, this could lead to a decrease in the number of punctures and, therefore, CVC related bloodstream infections.

When achieving central venous access through the subclavian approach, the use of U/S poses a challenge. Because of the deep location of the vein at this site and the presence of the clavicle, the U/S probe is more difficult to maneuver and may cause undue discomfort for the conscious patient. The inherent difficulty for U/S use at this site is a possible reason for the lack of data regarding efficacy. This was seen in our analysis as it was the fourth most common reason that residents cited for choosing not to use U/S.

There are many reasons why providers choose to use the landmark technique over the U/S-guided technique. Providers were asked to identify the reasons for not placing the catheter using U/S guidance. Answer choices listed in the data entry form were insufficient time for setup/use of U/S machine, no access to machine, not trained in use of U/S, subclavian line, femoral line, wanted to practice blind/landmark technique, easily identified anatomy, and cardiopulmonary resuscitation. In our study, the most common reason for not using U/S was insufficient time. However, there were no specific parameters for the measurement of time. The study by Miller et al [5] found that the time required for successful cannulation from when the needle first touches the skin is effectively reduced with U/S. Time was measured from the point when the needle firsts touches the skin to when the initial flash of blood is first observed in the syringe. The time necessary to obtain and set up the machine was not considered [5]. Theoretical reasons for the lack of time to use U/S may include "crash" central line placements in trauma or medical code situations where immediate venous access is required. Other studies have similar findings, but unfortunately, there is considerable variability with time measurement. Prior studies have found a positive effect of U/S guidance on successful placement of CVCs with regard to time. Further investigations should specifically measure the time component by focusing on the time necessary to acquire the machine at bedside, power up the device, and prepare the U/S for dynamic vs landmark identification techniques. Such investigations into the lack of time for U/S use would also focus on the second most common reason for lack of U/S application: lack of U/S availability. Lack of availability may include insufficient numbers of machines in large-volume EDs or ICUs.

The third most common reason was insufficient training for the use of U/S. Several articles mentioned the issue of training and skill required for U/S use and feared dependence on technology. Feller-Kopman [7] proposes an alternative to the fear of becoming dependent on technology by suggesting "that ultrasound enhances ones understanding of anatomy and perhaps makes the operator more skilled at placing central catheters when ultrasound is not available." Miller et al [5] conducted a prospective study where both resident and attending physicians in the ED were provided with a total of 2 hours training on the use of U/S for CVC placement. With consideration to both time and success rate, the authors found improvement regardless of past experience and training [5]. In our study, resident physicians frequently chose insufficient training as a barrier to U/S use. This may be related to lack of formal didactic or hands-on training in the use of U/S for CVC placement. It may also be related to lack of experience among more senior attending physicians who are less familiar with using U/S to guide CVC insertion.

In summary, we observed that EM residents who reported to the CLEAR database on their CVC placement attempts used U/S approximately 41% of the time on first attempt. We also observed that U/S had no effect on first attempt successful placement rates, but there were a reduced number of skin punctures. Finally, we observed that the success rates on second attempt did not change when U/S was used, and again, the number of punctures was reduced.

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