A Needle Guide Device is Better than a Free Hand Technique for Ultrasound Guided Cannulation of the Internal Jugular Vein: Results from a Simulation Study

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Citation

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Abstract

Background: Ultrasound is becoming the standard of care for the placement of central venous lines. Several studies have shown a reduction of needle passes and improved success rates when ultrasound is used over traditional blind techniques. There are no studies to date comparing the use of a needle guide to a freehand technique with ultrasound.
Methods: Practitioners ranging from medical students to attending anesthesiologists were randomized to either a needle guide (NG) or freehand (FH) group. Each subject was asked to insert an 18-gauge needle into the internal jugular vein of a patient simulator. Outcomes were time to completion, number of needle attempts, and major complications defined as either cannulation of the carotid or inserting the needle far enough to potentially cause a pneumothorax. Odds ratios (OR) were estimated using unadjusted chi-squared tests and adjustment for patient covariates were performed using logistic regression.
Results: 61 practitioners were randomized. Only 16% of subjects in the NG group needed more than one attempt compared with 83% in the FH group (OR 0.04, 95% CI 0.0 to 0.15, p<.001); Similarly, 6.5% of subjects in the FH group took longer than 30 seconds compared with 27.6% for the NG group (OR 0.18, 95% CI 0.0 to 0.85, p<.001). There were four complications in the FH group and none in the NH group (OR 0.0, 95% CI 0.0 to 0.83, p=0.03). Previous experience, based on a lifetime estimate of the number of central lines inserted with and without ultrasound, was not associated with either a reduction in the number of attempts or in the time to successfully cannulate the internal jugular vein.
Conclusion: In this simulation, the use of a needle guide improves the placement of central venous catheters by reducing time to successful cannulation, by reducing the number of attempts, and by reducing the number of complications. This advantage is not modified by prior experience.

INTRODUCTION

The placement of central venous catheters is a common anesthesia practice with an estimated 5 million central lines being placed per a year ([1]). The placement of a central venous catheter represents an opportunity for significant iatrogenic injury, including pneumothorax and carotid puncture ([2]).

The use of ultrasound to facilitate the performance of central venous access has been suggested to represent a potential standard of care ([2,3,4]). Several studies have shown the benefit of ultrasound when used in placing central lines, mainly in the reduction of needle passes and the reduction of complications when compared to traditional “blind” anatomical techniques ([3,4,5,6]). These benefits have been demonstrated in several studies to be further amplified in novice practitioners when compared with experts ([1,4,5]) and have lead to the recommendation by several national committees that ultrasound should be used for all central venous access procedures whenever available ([2,4]). However, the best practice model for the use of ultrasound has yet to be determined. A common technique for central line placement entails the real-time use of ultrasound in which the needle is guided toward and visualized entering into the short axis image of the IJ. In regional anesthesia techniques and central venous access, two approaches have emerged regarding the orientation of the needle with respect to the ultrasound beam.) The in-plane approach generates a long-axis view of the needle, allowing full visualization of the shaft and tip of the needle. The out-of-plane view generates a short axis view of the needle. With the out-of-plane view, the operator can not confirm that the needle tip is being

imaged (rather than part of the shaft), and, therefore, the needle location is often inferred from tissue movement. The in-plane approach tends to be favored for single injections (such as nerve blocks), with the out-of-plane technique facilitating catheter placement.

When using the real-time out-of-plane view, the operator must decide between the use of a “needle guide” or a “free-hand” approach. The needle guide system helps to secure the needle onto the transducer and force it to travel a pre-determined path towards the vein. In the free hand technique, the operator uses his or her own skill and judgment to pick a needle trajectory which successfully crosses the ultrasound beam and enters into the vein. Critics of the free hand technique suggest that the limitations of short axis imaging of the needle result in difficulty in cannulation, progressing past the target structure, multiple attempts, and an increase in performance times. The critics of the needle clip technique suggest that it is an unnecessary step, thereby consuming additional resources, and may not always place the needle in the most optimum position.

Part of our motivation for this study was to test a point of view expressed by senior colleagues who argue that experience cannulating the IJ obviates the need to use a needle guide technique.

The aim of this randomized prospective study is to determine if there are any meaningful differences between the needle guide technique and the freehand technique in terms of accuracy and speed when obtaining central venous access in an advanced patient simulator. In addition we sought to determine if these differences were related to experience.

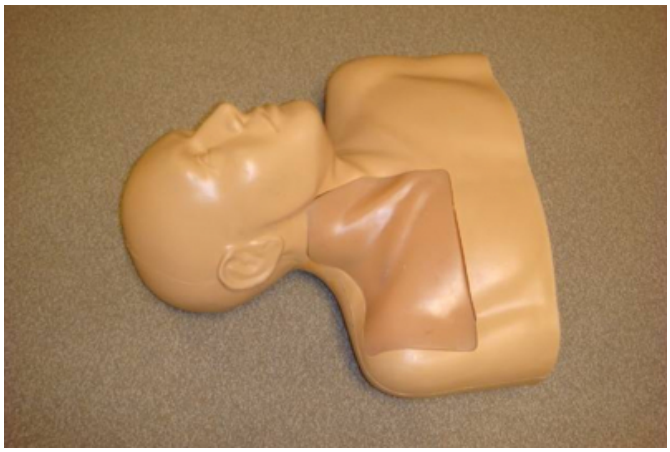
METHODS

This study was approved by the Committee for the Protection of Human Subjects at Dartmouth Medical School. Inclusion criteria included any practitioner, resident, nurse anesthesia provider, or medical student having the potential to place a central line in clinical practice. Subjects were asked to report level of training (attending, anesthesia resident, nurse) as well as the total number of central lines they had placed and the total number performed with ultrasound.

Subjects were randomized by computer-generated numbers into one of two groups: group NG represented the needle guide technique and group FH represented the free hand technique. Each subject was asked to place an 18 gauge cutting needle within the right internal jugular vein (Figure 1) on a patient simulator (SimANDY, Blue Phantom, Kirkland, WA), using real-time ultrasound guidance (SiteRite III, Bard Access Systems, Salt Lake City, UT).

Figure 1

Figure 1: Patient simulator used for cannualting the internal jugular vein



The simulator's anatomy was validated by the manufacturer using anatomy text and research articles describing the location of neurovascular structures in relation to the patient's visualized anatomy and related structures. The dynamic responses of the simulator (such as the pulsating carotid artery) are designed by obtaining two-dimensional and m-mode imaging data from human subjects. For this particular simulation, the prototype is a healthy patient with normal cardiac output.

In both groups the ultrasound images of the internal jugular vein and carotid artery were reviewed with the participants. The carotid was pulsatile with the internal jugular lying 2.5 cm from the skin. The internal jugular was anterior and lateral to the carotid (Figure 2). In the Needle Guide group, the needle was inserted by one of the authors into the 2.5 cm clip already attached to the transducer (Figure 3). This set up was then handed to the participant who was instructed to cannulate the internal jugular. In Free Hand Group, no clip system was attached and the participant was handed the naked transducer and asked to cannulate the internal jugular vein.

Figure 2

Figure 2: Ultrasound image of patient simulator demonstrating carotid artery (CO) and internal jugular vein (IJ)

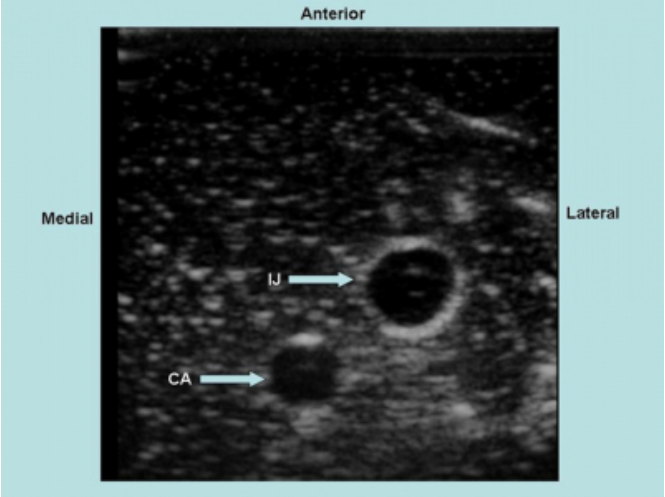
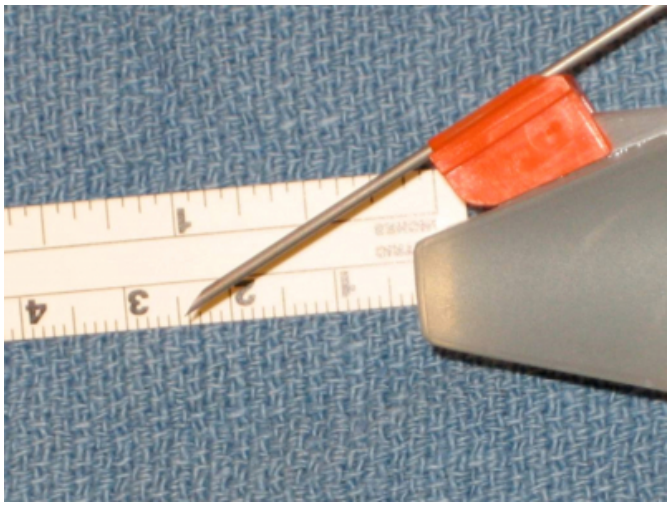


Figure 3

Figure 3: Needle guide for use with ultrasound transducer.



The subjects were videotaped (Sony, Handycam, DCR-SR40, Japan) as they attempted to insert the 18 gauge needle into the right internal jugular vein. The time to complete insertion, which was defined as the time elapsed from the needle first touching the skin to the aspiration of venous fluid, was recorded from the video review. IJ fluid was blue and carotid fluid was red based on color dye that had been added to the internal reservoir. Also documented by the reviewers were the number of needle passes or attempts, defined as any redirection of the needle once placed into the simulator. The investigators were also observed for any qualitative compromising behaviors that could possibly result in patient injury such as “hubbing” the needle (simulating a potential pneumothorax) or a carotid puncture.

STATISTICAL ANALYSIS AND POWER

The primary endpoint was whether or not more than one attempt was needed to cannulate the internal jugular vein. Assuming a success rate of 90% in the Needle Guide group and 50% in the Free Hand group, a power of 0.85 and a Type I error rate of 0.05, we required at least 27 subjects per group. Additional endpoints included the number of attempts, the time to successful cannulation, and the presence of a complication.

Odds ratios were tested using the unadjusted chi-squared analysis. Continuous variables were analyzed using either a non-parametric or Student's t-test on the appropriately transformed variable. Logistic regression was used to model the binary outcomes using experience, gender, and training as covariates. Generalized linear models were used to model time to successful cannulation with time modeled on the log scale to account for skewness. 95% confidence intervals are reported. $p<0.05$ was used to indicate statistical significance without adjustment for multiple comparisons

RESULTS

Sixty participants were enrolled with 29 subject randomized to the Free Hand group. Demographics of the participants are presented in Table 1. The distribution of attending anesthesiologists was similar in the two groups (38% FH vs 39% NG) as was the distribution of residents (31% FH vs. 39% NG). However, there were more nurse anesthetists in the FH group (28% vs. 6%, p=0.03). While the mean number of lifetime central lines was slightly higher in the FH group (575 FH vs. 419 NG, p=0.56), the number of lifetimes central lines under US was higher in the NG group (110 FH vs. 28 NG, p=0.02)

Figure 4

Table 1: Baseline Characteristics. * P-value<0.05. For continuous variables, medians and intraquartile ranges (IQR) are reported. For binary data, mean and counts are reported. Comparisons are odds ratios (OR) for binary data and median difference otherwise. Resident in anesthesia. Certified registered nurse anesthetist.. Includes 4 medical students, 1 intern, and 1 non-anesthesia resident. Estimated number of central lines placed by the practitioner. Estimated number of ultrasound guided central lines placed by the practitioner

Variable	Percent median	n or IQR	Percent median	n or IQR	OR or Difference *a*	95% CI	p-value
Gender(male)	64.5%	20	62.1%	18	1.11	(0.34,3.61)	0.84
Training							
Attending	38.7%	12	37.9%	11	1.03	(0.32,3.33)	.95
Resident *b*	38.7%	12	31.0%	9	1.40	(0.43,4.70)	.53
CRNA *c*	6.5%	2	27.6%	8	0.18*	(0.02,1.06)	.03
Other *d*	16.1%	5	3.4%	1	5.38	(0.54,263)	.1
Central lines placed *e*	60	(6,400)	100	(24,250)	-6	(-73,45)	.49
Central lines placed with ultrasound *f*	35	(3,100)	16	(2,40)	13	(0,49)	.075

The number of attempts to successfully insert the needle in the internal jugular vein on the patient simulator is summarized in Table 2. In the NG group, only 16% needed more than one attempt compared with 83 % of the FH group (OR=0.04, 95% CI 0.01 – 0.18, p<0.001). No participant needed more than two attempts in the NG group whereas in the FH group, 58.6% (p<0.001) needed more than two attempts and 24.1% (p<0.001) needed more than five attempts

Figure 5

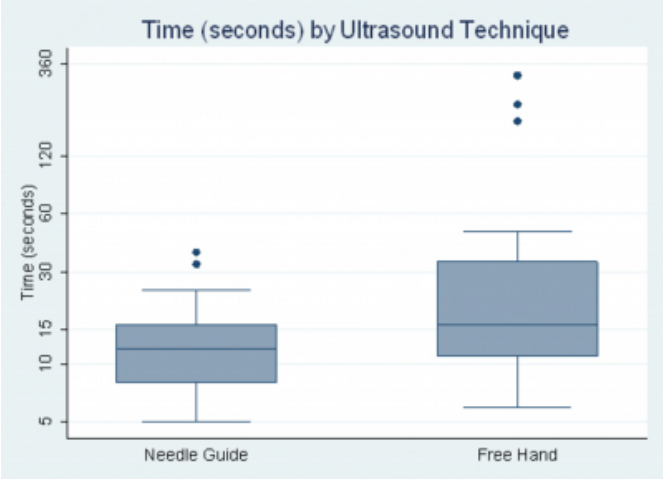
Table 2: Outcomes. * p-value<0.05, ** p<0.01, *** p<0.001. For continuous variables, medians and intraquartile ranges (IQR) are reported. For binary data, mean and counts are reported. Comparisons are odds ratios (OR) for binary data and median difference otherwise Major complication defined as either cannulation of carotid or hubbing the needle.

	Needle Guide (N=31)		Free Hand (N=29)		Comparison		
Variable	Percent or median	n or SD	Percent or median	n or IQR	OR or Difference *a*	95% CI	p-value
Major Complications *b*	0.0%	0	13.8%	4	0.00*	(0.00,0.83)	.03
Time (sec)	12	(8,16)	16	(11,34)	-4	(-9,0)	.056
Time >30sec	6.5%	2	27.6%	8	0.18*	(0.00,0.85)	.028
Time >60 sec	0.0%	0	10.3%	3	0.00	(0.00,1.15)	.066
Attempts >1	16.1%	5	82.8%	24	0.04***	(0.01,0.15)	<0.001
Attempts >2	0.0%	0	58.6%	17	0.00***	(0.00,0.09)	<0.001
Attempts >5	0.0%	0	24.1%	7	0.00**	(0.00,0.42)	<0.01

The NG also results in successful cannulation more quickly. Figure 4 shows the time difference between the two groups with a median time and 75th percentile time in the FH group of 16 and 34 seconds compared with corresponding times of 12 and 16 seconds in the NG group. Table 2 provides the comparisons. Only 6.5% of subjects took longer than 30 seconds with the NG versus 27.6% of FH subjects (OR 0.18, 95% CI 0.02 – 1.06, p=0.03. On average, the NG group achieved success almost 30 seconds sooner (95% CI -54.7,-0.1, p=0.05).

Figure 6

Figure 4: Boxplot for the time to successful cannulation using the needle guide technique (N=31) or the free hand technique (N=29).



A major complication was defined as an action that would most likely have produced a carotid puncture or a pneumothorax. In the FH technique group there was one carotid puncture on the simulator that was evidenced by the aspiration of red blood. There were also three “hubbings” of the needle that would have placed the needle tip in the patient's lung cavity. There were none of these behaviors observed in the NG group giving a complication rate of 13.8% in the FH group versus 0% in the NG group (p=0.032)

The impact of lifetime experience on the number of attempts is illustrated in Figures 5 and for lifetime experience with ultrasound in Figure 6. Two conclusions can be drawn from these graphs. First, the number of attempts is lower at all levels of experience using the NG technique with at most two attempts required. This relationship holds when experience is based on either the total number of central lines or on the total number of central lines placed under ultrasound guidance. Second, with the FH technique, experience does not appear to reduce the number of attempts required. Again, this relationship holds independent of how experience is measured.

Figure 7

Figure 5: Number of attempts until successful cannulation by reported lifetime experience placing internal jugular central lines. Lines are smoothed averages of the number or attempts.

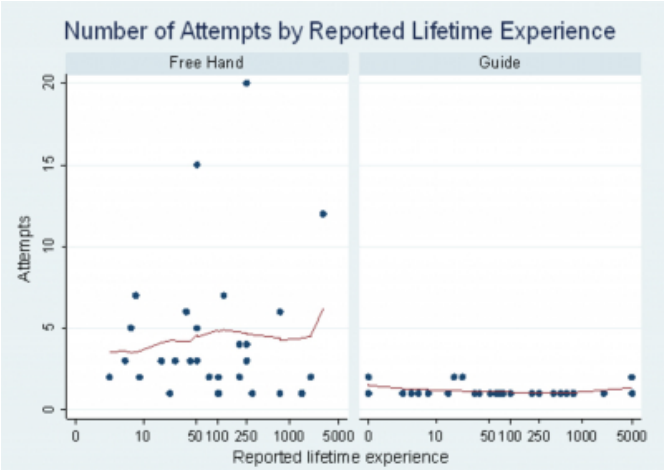
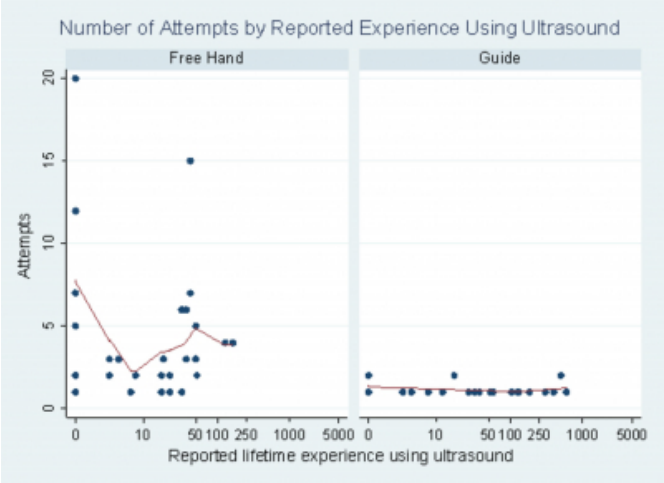


Figure 8

Figure 6: Number of attempts until successful cannulation by reported lifetime experience placing internal jugular central lines using ultrasound. Lines are smoothed averages of the number or attempts.



In order to more fully understand the efficacy of the needle guide, multivariate logistic regression models were used to estimate the impact of experience and level of training. The results are presented in Table 3. The unadjusted odds of more than one attempt is 25 times higher in the FH group (95% CI 6.42 – 97.07, p<0.001). Adjusting for level of training, gender, and experience with central lines does not diminish, and in fact increases, the effect (OR 44.57, 95% CI 7.4-268.3, p<0.0001).

Figure 9

Table 3: Multivariate logistic regression to predict more than one attempt required for successful cannulation. *** p-value<0.0001.. Resident in anesthesia. Certified registered nurse anesthetist.. Includes 4 medical students, 1 intern, and 1 non-anesthesia resident. Estimated number of ultrasound guided central lines placed by the practitioner on log scale

Variable	OR	95% CI	p-value
Unadjusted Model			
Guide (FH)	24.96***	(6.42 - 97.07)	<0.001
Adjusted Model			
Guide (FH)	44.57***	(7.40 - 268.28)	<0.001
Gender(male)	0.27	(0.04 - 1.75)	.17
Central lines with Ultrasound *d*	1.38	(0.74 - 2.58)	.31
Training			
Resident *a*	2.15	(0.35 - 13.26)	.41
CRNA *b*	7.23	(0.37 - 141.22)	.19
Other *c*	10.14	(0.35 - 297.15)	.18

DISCUSSION

Despite the enthusiasm behind the use of ultrasound to facilitate central venous access, little data exists regarding best practice. Likely, the most popular technique of using ultrasound is the real-time, out-of plane approach in which the IJ is imaged on short-axis. This technique has the distinct limitation in that the needle will cross the ultrasound beam only once, resulting in a short axis cut of the needle. This image may not represent the tip of the needle, but rather the shaft of the needle. If the operator chooses an angle of insertion in which the needle crosses the ultrasound beam posterior to the vein, then they will never see the needle prior to puncture of the vein. Further, in the out-of-plane approach, the operator can have challenges in determining whether the needle is too far lateral or medial with respect to the target vein. These issues are compounded by the tendency of the operator to advance the needle when it is not visualized on the screen ([7]). With the out-of-plane needle guide system, the idea is to pre-measure the depth of vein, choose a clip that forces the needle to cross the ultrasound beam at the depth of the target vein. In addition, needle guide systems (as the one we used in our study), have a dotted line on the screen that corresponds to the center of the ultrasound beam; when this dotted line is bisected through the structure of interest, inaccuracies in the lateral and medial perspectives are theoretically eliminated.

To our knowledge, only one other study ([12]) has examined the impact of a needle guide on IJ cannulation. In that prospective study in humans, there was also a higher rate of cannulation after the first pass with a needle guide (68.9% versus 80.9%), but unlike the present study did not demonstrate any difference in major complications. The present study also differs in that we also examined time to perform successful cannulation as well as incorporating lifetime experience as a predictor.

We recognize several limitations to this study and its translation to clinical practice. First, this study is only an approximation to placing central lines in actual patients. The model we used does not duplicate the variability between patients with respect to surface anatomy or with respect to the location of the internal jugular vein. In addition, the model we used represents an ideal patient in that the neck is easily accessible and the IJ and carotid are easily seen and well separated. It may be the case that for some patients the free hand technique is superior. Second, we were unable to observe any advantage that could be attributed to lifetime experience, either with or without ultrasound. We expected to see that the superiority of the needle guide would be less apparent for providers who had placed a large number of central lines, but this was not the case. It could well be that recent experience is a more predictive measure or that providers do not accurately recall experience in a reliable way.

If the simulation data collected in this study are reflective of ultrasound guided IJ access in actual clinical practice, several conclusions can be drawn. First, the use of a needle guide reduces the time to gain access. Second, needle guide devices reduce the number of attempts independent of practitioner experience. This result has obvious patient safety implications since fewer needle passes translates into less risk of complications ([4]). Further, in awake patients, a reduction in needle attempts could easily reduce patient dissatisfaction. Third, clinical experience does not obviate the benefit of the needle guide. Both the number of attempts and the time to successful insertion appears to be rather constant over a very large range of experience as our subject's experience ranged from none to over 5000 central line placements.

We conclude that needle guided devices should be standard of care for internal jugular cannulation independent of prior experience.

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