

A Comparison of Internal Jugular Vein Cannulation by Ultrasound-Guided and Anatomical Landmark Technique in Resource-Limited Emergency Department Setting

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Abstract

Background and Objectives: Central venous catheter placement is a frequently performed procedure in emergency medicine as well as critical care unit. We aimed to compare real-time ultrasonography (USG)-guided and the traditional anatomical landmark (AL) technique for the insertion of internal jugular vein (IJV) catheters in an emergency department (ED) setting. **Materials and Methods:** Patients requiring IJV catheterization were prospectively recruited over a period of 1 year at a single center. Cannulation was done either by the AL or USG technique, according to ED physician's discretion. A preset pro forma was completed for each central line placed. Variables were compared using the independent *t*-test, Fisher's exact test, and the nonparametric Mann-Whitney U-test. **Results and Discussion:** Seventy patients were enrolled, of which 35 patients underwent IJV cannulation by USG-guided technique (USG group) and 35 patients by the AL technique (AL group). There were a 100% success rate (35/35) for cannulation in the USG group and a 91.4% success rate (32/35) in the AL group. The catheter was placed on the first attempt in 17 (48.6%) patients in the AL group and 32 (91.4%) patients in the USG group. In the AL group, there were three failed cannulation attempts in comparison to the USG group. The mean start to flash time for the AL technique was 16.59 s (± 10.67) and 4.86 s (± 2.18) in the USG group. The mean cannulation time was 305.88 s (± 66.84) in the AL group and 293.03 s (± 71.15) in the USG group. A total of seven acute complications were noted, of which 2 (5.7%) in the USG group and 5 (14.3%) in the AL group. **Conclusion:** The real-time USG guided technique significantly reduces the number of attempts to cannulate, has a higher first-pass success rate, a quicker flash time, and fewer complications when compared to the AL technique. In EDs equipped with USG, insertion of IJV catheters under real-time USG guidance should become the standard of care.

Keywords: Central venous catheterization, emergency department, jugular vein, ultrasonography

INTRODUCTION

Central venous catheter (CVC) placement is a frequently performed procedure in emergency medicine (EM) as well as critical care unit. It is performed to obtain venous access for procedures such as central venous pressure (CVP) monitoring, insertion of a pulmonary artery catheter, administration of fluids, drugs, and for total parenteral nutrition.^[1] Despite frequent training and practice, central line placement is associated with complications such as pneumothorax, hemothorax, tracheal injury, air emboli, hydrothorax, chylothorax, catheter malpositioning, catheter-associated infection, thrombosis, arterial puncture, and even cardiac perforation.^[2]

There are two traditional techniques for central venous line insertion: anatomical landmark (AL) technique and ultrasonography (USG)-guided technique. Studies conducted in anesthetic, cardiac, and intensive care settings have shown that real-time USG-guided central line placement, particularly through the internal jugular vein (IJV), can lead to a decrease in complications, and in some cases, a faster insertion time.^[3]

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Received: 08-01-2019 Revised: 25-02-2019 Accepted: 21-03-2019 Available Online: 13-05-2019

Access this article online

Quick Response Code:



Website:
www.jmuonline.org

DOI:
10.4103/JMU.JMU_2_19

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How to cite this article: Kunhahamed MO, Abraham SV, Palatty BU, Krishnan SV, Rajeev PC, Gopinathan V. A comparison of internal jugular vein cannulation by ultrasound-guided and anatomical landmark technique in resource-limited emergency department setting. *J Med Ultrasound* 2019;27:187-91.

This study aimed to measure and compare the success rate, time to completion, number of central venous access attempts, and acute complications during IJV catheterization by the AL technique and real-time USG-guided technique in emergency department (ED) setting. Although several studies exist which compare real-time USG-guided IJV cannulation with the AL technique in different settings, only few of these studies have been validated in an ED setting in India.^[4] Intention of conducting this study was to extrapolate the advantages of a portable USG device for central venous access in a resource-limited ED setting. The term “resource-poor or constrained setting” defines a locale where the capability to provide care for life-threatening illness is limited.^[5] This study was conducted in the ED of a referral mission hospital, in South India, a 40-bedded ED, which caters to 300 patients (internal audit data) on an average daily basis with two EM physicians on a shift and is resource limited in terms of availability of personnel, infrastructure available, and staff-to-patient ratio.

MATERIALS AND METHODS

Study design and setting

This was a prospective observational study conducted at the ED of a tertiary care teaching hospital (Jubilee Mission Medical College and Research Institute, Kerala, India) over a period of 1 year (April 2017–April 2018) after approval from the Institutes Ethical Committee (IEC no: 05/17/IEC/JMMC & RI).

Study population

We included adults of age 18 years or above presented to the ED, who required central venous access through IJV as part of their treatment and consented to be part of the study. The ED physician solely decided the need for central vein access and the appropriate method (USG or AL method) according to the patients’ clinical condition. The investigator had no role in determining the need for central vein access, the site of placement or the method, but could only record the parameters observed.

Patients <18 years, patients with suspected cervical spine injury or penetrating injury to the neck, patients with coagulopathy, local site infections or burns, and the head-and-neck cancer patients were excluded from the study. The participants were followed up till 12 h of central line insertion for any acute complications.

Sample size calculation

Based on predicted successful cannulation from previous literature, of 78% for the AL technique and 98% with USG guidance ($P = 0.05$; 80% power) and the hospital incidence data, we estimated a sample size of 70.^[6] The study was proposed to continue recruiting consecutive patients till a sample of at least 35 was met in each group.

Variables and definitions

Operator

Experienced residents or faculty in ED who were well trained and had successfully placed >25 IJV CVCs were

called “Operator”. All operators had additionally undergone a standardized certified ultrasound-based venous access course.^[7]

Flash time

Flash time was defined as the time interval between skin puncture and observing blood at the syringe hub.

Cannulation time

It was taken as the time interval between observing blood at the syringe hub and confirming backflow of blood at all three ports in the triple lumen catheter.

Attempt

It was defined as the introducer needle’s entry into the skin and its removal from the skin. The procedure was considered successful if the IJV was cannulated and resulted in successful aspiration of blood.

Failure

The procedure was considered a “failure” if the operator was unable to perform cannulation of the IJV after a maximum of three attempts.

Complications

Acute complications, such as skin hematoma, arterial puncture, pneumothorax, hemothorax, and catheter malposition, were observed for a period of 12 h.

Procedure

Anatomical landmark technique

In this technique, apex of the triangle formed by the two heads of the sternocleidomastoid muscle and the clavicle serves as a landmark. The IJV runs deep to the sternocleidomastoid muscle and then through this triangle before it joins the subclavian vein to become the brachiocephalic vein.^[8] After the landmarks are identified, sterile precautions are taken and local anesthesia is administered. The patient would be placed in the Trendelenburg position with the head rotated 45° away from the site of cannulation. An 18G introducer needle is advanced past the apex of the triangle, in the direction of the ipsilateral nipple, at an angle of 20°. Once blood is freely aspirated, the syringe is removed from the needle. The guide wire is then advanced through the needle into the vessel and the catheter is placed using the Seldinger technique and secured in place using sutures.

Ultrasonography-guided technique

The patient is placed in the Trendelenburg position, with the head slightly rotated to the contralateral side. Using USG, the anatomical location and patency of the IJV are assessed and guided by real-time USG imaging, the introducer needle mounted on a syringe is inserted into the IJV [Figure 1]. Once blood is freely aspirated, the USG probe is set aside and the syringe is removed from the needle. The procedure is further completed as mentioned in the AL technique.

Equipment used

Standard triple lumen CVC was used for cannulation in all patients. The position of the CVC was confirmed by a chest radiograph at the end of the procedure. The real-time USG-guided technique

was performed with a single dedicated USG machine (SonoSite Edge® Portable Ultrasound Machine) and a 13–6 MHz linear probe for the entire duration of the study. The whole procedure was carried out according to the standard ED protocol.

Data collection process

At the end of each procedure, the operator recorded the data which included patient demographics, operator details, method of insertion, indication for central line insertion, number of attempts, success or failure, time to completion (flash time and cannulation time), and acute complications.

Outcome measurement

The primary outcome measured was the successful cannulation of IJV. The secondary outcome measured included the flash time, the cannulation time, the number of cannulation attempts, and acute complications.

Data analysis and interpretation

Numerical variables were expressed as mean and standard deviation. Categorical variables were expressed as frequency and percentages. To test the mean differences in the study variables (flash time and cannulation time) between different techniques, Mann–Whitney U-test was applied; whereas for comparison of operator characteristics, one-way ANOVA and Kruskal–Wallis test were applied. To test the association of study variables with each technique, Chi-square or Fisher’s exact test were applied. The statistical software, namely, International Business Machines Statistical Package for the Social Sciences (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. IBM Corp., Armonk, NY, USA) was used for the analysis of the data. Microsoft Word and Microsoft Excel (2013 version) were used to enter data and generate graphs, tables, and charts.

RESULTS

Seventy patients were enrolled for the study, of which 35 (50%) patients underwent CVC placement by the AL technique and 35 (50%) patients by the real-time USG-guided method. Among

the 70 patients, 54.3% were male and 45.7% were female. In the USG group, 60% (*n* = 21) were male and 40% (*n* = 14) female, whereas in AL group, there were 49% (*n* = 17) of males and 51% (*n* = 18) of females. Mean age in the USG group was 46.74 (±16.36) and in the AL group, it was 50.41 (±17.93) years.

Patients who required central venous access were diagnosed to have septic shock (25.7%), polytrauma with hemorrhagic shock (17.1%), burns (20%), and other illnesses [Table 1]. Indications for CVC placement in these patients were extensive fluid resuscitation (41%), multiple drug administration (41%), difficult peripheral intravenous access (38%), frequent blood sampling (31%), CVP monitoring (28.6%), vasopressor infusion (10%), and electrolyte correction (10%) [Figure 2].

Using the real-time USG technique, 35 out of 35 patients (100%) were cannulated successfully, whereas 32 of 35 (91.4%) cannulations were successful with the AL technique. There was an 8.6% more chance of successful CVC placement in

Table 1: Provisional diagnosis

Provisional diagnosis	Method		Total, <i>n</i> (%)
	USG (<i>n</i> =35), <i>n</i> (%)	AL (<i>n</i> =35), <i>n</i> (%)	
Sepsis/septic shock	8 (22.9)	10 (28.6)	18 (25.7)
Acute respiratory distress syndrome	2 (5.7)	2 (5.7)	4 (5.7)
Polytrauma with hemorrhagic shock	8 (22.9)	4 (11.4)	12 (17.1)
Burns	6 (17.1)	8 (22.9)	14 (20)
Diabetic ketoacidosis	6 (17.1)	3 (8.6)	9 (12.9)
Chronic liver disease with peripheral edema	1 (2.9)	3 (8.6)	4 (5.7)
Postpartum hemorrhage with hemorrhagic shock	1 (2.9)	1 (2.9)	2 (2.9)
Cardiogenic shock	1 (2.9)	3 (8.6)	4 (5.7)
Spontaneous intracranial hemorrhage	1 (2.9)	1 (2.9)	2 (2.9)
Organophosphate poisoning	1 (2.9)	0 (0)	1 (1.4)

USG: Ultrasonography, AL: Anatomical landmark



Figure 1: Ultrasound-guided right internal jugular vein central venous catheter insertion in a patient

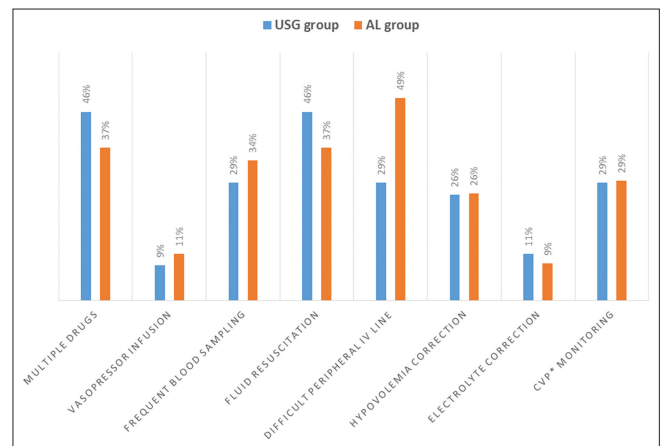


Figure 2: Indication for central venous catheter insertion. *Central venous pressure

USG method ($P = 0.239$). The average number of attempts resulting in successful insertion was 1.74 for the AL technique and 1.08 for USG-guided technique [Table 2].

The catheter was inserted on the first attempt in 49 of 70 (70%) patients, of which 17 (48.6%) patients in the AL group and 32 (91.4%) patients in the USG group [Table 3]. A difference of 42.8% was observed during the first attempt which included 21 unsuccessful IJV catheterizations, 18 in the AL group, and 3 in the USG group. Thirteen patients were cannulated on the second attempt, of which 10 (28.6%) in the AL group and 3 (8.6%) in the USG group. A third attempt was required in 5 (7.14%) patients in the AL group. In the AL method, there were three patients who could not be catheterized even after three attempts and were considered as failed attempts.

The mean start to flash time for the AL technique was 16.59 (± 10.67) s; for USG method, it was 4.86 (± 2.18) s. The mean cannulation time for the AL technique was 305.88 (± 66.84) s; for USG method, it was 293.03 (± 71.15) s [Table 4].

Mean flash and cannulation time were calculated for both techniques among all the ten operators [Table 5]. As the USG cannulation time and flash time observations failed to meet the normality criteria and homogeneity of variances test, Kruskal–Wallis test was performed. Results showed that in USG method, there was no statistically significant difference among all the operators in either mean cannulation time (χ^2 (df = 9) = 8.541, $P = 0.481$) or mean flash time (χ^2 (df = 9) = 7.788, $P = 0.556$).

Table 2: Success rate comparison

Success rate	Method		P
	USG (n=35), n (%)	AL (n=35), n (%)	
Success	35 (100.0)	32 (91.4)	0.239
Fail	0	3 (8.6)	

USG: Ultrasonography, AL: Anatomical landmark

Table 3: Comparison of number of attempts taken for successful cannulation

Number of attempts	Method		P
	USG (n=35), n (%)	AL (n=35), n (%)	
1	32 (91.4)	17 (48.6)	<0.001
2	3 (8.6)	10 (28.6)	
3	0	8 (22.9)	

USG: Ultrasonography, AL: Anatomical landmark

Table 4: Comparison of flash time and cannulation time

Variables	Method	n	Mean	SD	P
Flash time [#]	USG	35	4.86	2.18	<0.001
	AL	32	16.59	10.67	
Cannulation time [#]	USG	35	293.03	71.15	0.425
	AL	32	305.88	66.84	

[#]In seconds. SD: Standard deviation, USG: Ultrasonography, AL: Anatomical landmark

There was also no statistically significant difference in mean flash time (χ^2 (df = 9) = 4.285, $P = 0.892$) and mean cannulation time as determined by one-way ANOVA (F (9, 22) = 1.368, $P = 0.261$) among all operators in AL method.

There were 7 (10%) acute complications in the study, of which 5 complications in the AL group (14.3%) and two complications in the USG group (5.7%). In the AL group, there were 1 hematoma (3%), 3 carotid artery punctures (9%), and 1 catheter malposition (3%). In the USG group, there were 2 hematomas (6%).

DISCUSSION

The key findings of the study were a significant reduction in flash time and fewer number of venous access attempts with the USG-guided method ($P < 0.001$). Mean flash time was 16.59 (± 10.67) s in the AL group and 4.86 (± 2.18) s in the USG group, whereas the mean cannulation time in the AL and USG group was 305.88 (± 66.84) and 293.03 (± 71.15) s, respectively. Although the flash time proved to be markedly shorter with the USG-guided technique (4.86 (± 2.18) s versus 16.59 (± 10.67) s), the cannulation time was similar between both techniques and did not have any statistical significance ($P = 0.425$). This may be because the procedure in either technique, once flash of blood is observed at the syringe hub, is the same. Earlier studies have also shown that, regardless of experience, USG guidance resulted in absolute decrease in the time to blood flash and the number of central venous access attempts.^[9]

Only 48.6% of patients in the AL group could be cannulated on the first attempt, a third attempt was required in 5 patients (7.14%) in the AL group, and there were three individuals in the AL group in whom cannulation was a failure. Whereas using USG to guide cannulation, 91.4% of patients were cannulated on the very first attempt in the ED. In a study by Denys *et al.*, IJV cannulation with USG guidance was successful at the first attempt in 77.8% of patients in critical care setting.^[10] Several previous studies suggest that there is higher incidence of mechanical complications when the number of attempts for successful CVC increases.^[11,12] The incidence of complications after three or more insertion attempts was significantly increased according to the McGee and Gould review of CVC complications.^[13] Therefore, the number of attempts to successful venipuncture and catheter placement is important.

USG-guided IJV catheterization in the ED had a 100% success rate (35/35) compared to a 91.4% success rate (32/35) in the AL group. There was no statistical significance in terms of success rate between the two groups ($P = 0.239$), in contrast to the study conducted by Hrics *et al.* where they found that successful venipuncture significantly improved with USG guidance.^[14]

The reason for having equal success rate with either technique in the study might be due to the experience of our operators who were equally comfortable with each technique. The study did not find a statistically significant difference between the total complication rates of the two groups either. These findings

Table 5: Comparison of operator characteristics

Operators (n=10)	Total number of cannulations (n=70)		Mean flash time (SD)#		Mean cannulation time (SD)#	
	USG	AL	USG	AL	USG	AL
Operator 1	4	3	5.50 (1.73)	270.50 (68.92)	270.50 (68.92)	358.66 (82.51)
Operator 2	3	7*	6.33 (4.16)	311.33 (130.67)	311.33 (130.67)	331.00 (71.38)
Operator 3	2	5	4.00 (0.00)	213.50 (04.95)	213.50 (04.95)	298.00 (83.66)
Operator 4	2	5*	4.50 (3.54)	324.00 (104.65)	324.00 (104.65)	259.75 (57.86)
Operator 5	5	5	6.20 (2.59)	325.00 (79.58)	325.00 (79.58)	317.60 (24.48)
Operator 6	3	3*	6.00 (3.61)	296.33 (64.39)	296.33 (64.39)	214.50 (20.51)
Operator 7	3	2	3.66 (1.15)	300.33 (67.10)	300.33 (67.10)	332.50 (45.96)
Operator 8	6	2	4.33 (1.37)	269.16 (64.68)	269.16 (64.68)	312.00 (55.15)
Operator 9	5	1	4.00 (0.71)	323.00 (63.17)	323.00 (63.17)	377.00 (00.00)
Operator 10	2	2	3.00 (0.00)	260.00 (15.56)	260.00 (15.56)	257.00 (60.81)

*Flash and cannulation time were not calculated for three unsuccessful cannulations in AL group, #In seconds. SD: Standard deviation, USG: Ultrasonography, AL: Anatomical landmark

were comparable with the results from the study of Dolu *et al.*^[15] In terms of demographic data, no significant difference was noted between the groups.

Limitations

We attempted to standardize the initial start time by defining it as the time that skin puncture with the needle commenced; and in the process ended up excluding the time to set up the USG machine and probe preparation for the USG technique. An experienced operator was defined in our study as having performed >25 successful IJV catheter insertions, this may not always reflect the operator's real experience. The study was further limited by a small sample size. Studies with larger sample size would be more beneficial in determining the complications better. The patients were followed up only till 12 h and hence, the delayed complications of the procedure were not studied.

CONCLUSION

The real-time USG guided technique significantly reduces the number of attempts to cannulate, has a higher first-pass success rate, a quicker flash time, and fewer complications when compared to the AL technique. This may vastly improve procedural comfort for patients as well as ED staff and thus, we highly recommend that ED physicians make use of a valuable tool like USG in inserting CVC. Although clinically significant, there were no statistically significant differences between the groups either in terms of complications, success rate, or time to completion of the procedure. Further larger sample studies may provide more substantial evidence into the use of USG-guided CVC placement in a resource-limited ED setting.

Acknowledgment

The authors would like to acknowledge the contribution of Dr. Tijo George and Mr. Unnikrishnan for the statistical analysis done.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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