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Comparison of the Landmark Technique and the Static Ultrasound-Guided Technique for Subclavian Vein Cannulation in Adult Patients

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ABSTRACT

Background: Role of ultrasound has been established in the central venous cannulation of Internal Jugular Vein but not in the cannulation of subclavian vein. This study aimed to determine whether static ultrasound guidance increases the efficiency and safety of subclavian vein catheterization in comparison to the landmark technique in a heterogeneous population at a tertiary care facility.
Methods: Patients receiving standard care were observed, with outcomes from those guided by the ultrasound (US) technique compared to those who underwent landmark (LM) technique and analyzed. In the landmark group, subclavian catheter insertion involved prepping the chest, injecting lidocaine, puncturing the vein, inserting a guide wire, followed by dilation and catheter threading and placement. In the US group, after standard preparation, ultrasound located the vein, marked its course, and pulse wave Doppler confirmed it. Catheterization followed without real-time guidance.
Results: Study included 113 participants, with 56 in the landmark group and 57 in US group. Baseline characteristics, including demographics, cannulation side, and urgency, were similar between groups. First-pass success rates were higher in US group, though not significantly different (p=0.248). Attempts for SV cannulation and time for cannulation showed no significant differences (p=0.47, p=0.193 respectively). No significant difference was observed in complication rates between the two techniques.
Conclusion: Static ultrasound-guided central venous catheterization of the SV showed similar first-pass success rates, attempts, and cannulation times to the conventional landmark-based technique. Complications such as arterial puncture, hematoma, and malposition were observed in both groups, but there was no statistically significant difference between the techniques.

Keywords: Subclavian vein; Ultrasonography, interventional; Catheterization, Central Venous

INTRODUCTION

Central venous catheter placement is sacrosanct in management of various illnesses. In practice, there are three main sites where central venous catheterization can be done, namely subclavian vein (SV), internal jugular vein (IJV) and femoral vein, each having its own advantages and disadvantages. SV catheterization has many advantages, including large diameter, lack of valves, its patency and a constant position. Central venous catheterization in the SV includes lesser risk of catheter-related infections and thrombosis than IJV or femoral vein[1]. The classical or landmark technique is performed based on pre-existing anatomical locations, and blind insertion and trail until sprout of blood is observed. The use of real-time ultrasound or Doppler ultrasound has been advantageous in catheterization when compared to classical technique in success rate, number of attempts, failures, and the occurrence of mechanical complications[2]. However, it is observed that in emergent cases, there is a time lapse between the benefits and actual implementation of real-time sonography clinically. This delay arises from concerns that real-time sonography cannot be practiced in all hospital settings, such as emergency department where there are equipment or logistical constraints, and may require significant investments in hardware and training[3]. A portable ultrasound can be used to establish landmarks and then set aside, freeing up space for other procedural needs.The authors conceived that while real time sonography might be time consuming, does a “look and go” (static location of SV) technique offers advantages over the landmark technique. Research on the use of ultrasound for central venous catheter placement via the subclavian approach in Indian settings is limited. Additionally, there is an absence of studies conducted in hospitals representing the diverse demographic profile of the national population.

MATERIAL & METHODS

A prospective observational study was conducted to evaluate and compare the success rates and complications associated with two central venous catheterization methods: the traditional landmark-based technique and the ultrasound-guided technique. This study was performed at an intensive care unit of a zonal hospital located in the Northeast region of India.

The study included all patients aged 18 to 70 years who required central venous catheterization and were admitted to the ICU. The anesthesiologists at this tertiary care hospital have been using both the techniques and have more than 5 years of experience in central venous catheterization.

Sample size calculation: Based on 1st pass success rates in previous studies using static ultrasound and landmark technique[4], we calculated a sample size estimate of 98 (49 in each group) for a 95% confidence interval & an 80% power of the study.

However, 113 patients were enrolled in the study, 56 with Landmark technique and 57 with ultrasound-guided technique, after obtaining written informed consent from February 2020 to May 2023. Patients unfit for Trendelenburg position or prior radiotherapy, or breast surgery and those with standard contraindications to central venous cannulation such as active local soft tissue or skin infection, coagulopathy were excluded.

Techniques of Cannulation

After approval from the ethics committee (No. 5418/2020, dated 14 Sep 2019), patients were recruited and observed based on their standard care approach, with those receiving ultrasound (US) guidance compared to outcomes from a well-matched historical cohort who received the standard landmark (LM) technique. The physicians performing the cannulation had more than five years of experience in central venous catheterization. No augmentation techniques like Valsalva maneuver were employed in either of the groups.

LM group

To insert a catheter into the subclavian vein using the landmark technique, the patient was positioned supine. The area of the chest on the same side as the insertion site was prepared with povidone-iodine. The patient was then placed in a Trendelenburg position at an angle of 10 to 15 degrees. Lidocaine (2 percent) was injected into the infraclavicular puncture site using a 22-gauge needle. A subclavian vein puncture was performed using an 18-gauge needle, and correct placement was verified by the appearance of venous blood in the syringe attached to the needle. A guide wire was then advanced through the needle into the vein, after which the needle was removed. A dilator was then threaded over the wire and removed. Finally, a 7-French triple-lumen catheter was advanced over the wire, which was then removed, and venous blood return through the catheter confirmed successful placement. No augmentation techniques like Valsalva maneuver were employed in either of the groups.

US group

For catheterization with ultrasound guidance, the skin and chest wall were cleaned and draped according to standard procedures to maintain sterility. The transducer and its lead were disinfected, and the probe was covered with a sterile sheath and gel. A 7.5 - 12MHz linear-array ultrasound probe, connected to a real-time ultrasound unit, was utilized to assess the depth and diameter of the subclavian vein at the clavicle level, check its patency, and mark its position on the skin. The probe was positioned longitudinally just below the lateral part of the clavicle until both the axillary/subclavian artery and vein were identified in the long axis view. It was then shifted 2 cm medially to the angle of the clavicle where the subclavian vein was located. Pulse wave Doppler was employed to confirm the vein. Once identified, the vein's projected path was marked on the skin at two points. The standard cannulation procedure was followed without real-time ultrasound guidance for catheter placement. The time taken to obtain and set up the ultrasound machine was not recorded.

Data Collection & Definitions

To reduce observer bias, data were collected by ICU staff who were not involved in performing the cannulation. They independently timed the procedure using a stopwatch and recorded the number of attempts and any complications. In our ICU workflow, machine preparation occurs concurrently with other sterile preparations. Therefore, it does not contribute to a significant delay in overall procedure time.

Success was defined as the correct placement of central venous catheter inside the vein, which includes both successful guidewire placement and the subsequent advancement of the catheter over the guidewire. This was confirmed by a post procedure Chest X-ray while mal positions, if any, were counted. An attempt was defined as the need for taking a second skin puncture, and up to 5 redirections were counted as single attempt as long as a second skin puncture was not required. Time for cannulation was counted from the time to skin puncture to successful placement of a guidewire. The ICU staff used a stopwatch to time the procedure, starting the clock when the needle first punctured the skin. They recorded the number of skin entries, redirections, and the duration until successful guidewire placement. Catheter days was calculated with day of insertion counted as day 1 till the removal of catheter or mortality. CLABSI was defined as laboratory-confirmed bloodstream infection occurring in a patient with a central line that has been in place for at least 48 hours, with no other apparent infection source as per the Center for Disease Control and Prevention. Arterial puncture was confirmed if the operator felt increased pressure or by removal of syringe & bright red blood jetting out or. Hematoma was palpated for after end of procedure and again after 2 hrs. Hemothorax or pneumothorax was confirmed by post procedure X-ray. Failure was defined as the inability to successfully pass a guidewire after 3

attempts, or if the guidewire is successfully placed but the central venous catheter could not be advanced over it.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp. The results of the study were expressed as mean ± SD or percentages. Descriptive analysis along with t-test and chi-square tests were used to analyze the differences between two techniques and p value of ≤ 0.05 was considered significant. There was no missing data in any study variable from 113 study participants.

Permission was sought from appropriate authority for conduct of our study and ethical clearance taken from institutional ethics committee. The guidelines as per Helsinki declaration and good clinical care were followed.

RESULTS

Among the 113 individuals enrolled in the study, 56 were assigned to the landmark group, while 57 were assigned to the US group. The baseline characteristics of the study participants, including patient demographics, the side of cannulation, and the urgency of central venous catheter placement, were comparable between the two groups (p>0.05) (Table 1). No notable differences were observed in age, gender, the side of cannulation, or operator experience between the groups.

Table 1: Demographics characteristics

Characteristics	Landmark (56)	USG (57)	p-value (<0.05 significant)
Age in Years (Mean ± SD)	47.32 ± 17.4	49.26 ± 17.24	0.553[a]
Gender (M/F)	30/26	28/29	0.636
Successful Cannulation	56 (100%)	57 (100%)	-
Side (L/R)	12/44	16/41	0.414 [b]
Situation (Elective/Emergency)	35/21	34/23	0.756[b]

a-Independent sample t test b-Chi Square test

Table 2: Comparison of Number of attempts, cannulation time & first pass success between the two techniques

Characteristics	Landmark (56)	USG (57)	p-value (<0.05 significant)
Number of attempts (Mean ± SD)	1.25 ± 0.437	1.19 ± 0.398	0.470[a]
Time for cannulation in seconds (Mean ± SD)	20 ± 9.45	22.4 ± 9.616	0.193[a]
Catheter Days	11 ± 4.7	11.4 ± 4.92	0.643[a]
First Pass Success	40 (71.4%)	46 (80.7%)	0.248[b]

a-Independent sample t test b-Chi Square test

Table 2 presents the parameters related to subclavian vein cannulation. Although the first-pass success rate was greater in the US group (80.7% vs. 71.4%) compared to the LM group, the difference was not statistically significant (p=0.248). Further, Cohen's effect size value (d = .23) suggested low practical significance. In our study risk of type 2 error was reduced with adequate sample size. The average number of attempts for SV cannulation did not show significant differences between the two groups (p=0.47). While the time for cannulation was slightly higher in the ultrasound-guided (US) group (22.4±9.6 seconds) compared to the landmark technique (20±9.45 seconds), this difference was not statistically significant (p=0.193). Notably, there were no failures.

Table 3: Comparison of complications between the two techniques

Characteristics	Landmark (56)	USG (57)	p-value (<0.05 significant)
Arterial Puncture	4 (7.1%)	2 (3.5%)	0.389[b]
Haematoma	2 (3.6%)	1 (1.8%)	0.548[b]
Pneumothorax	0	0	0
Malposition	1 (1.8%)	2 (3.5%)	0.569[b]
Catheter Days	11 ± 4.7	11.4 ± 4.92	0.643[a]
Infectious Complications	5 (8.9%)	5 (8.8%)	0.977[b]
Complication Rate	7/56 = 12.5 %	5/57 = 8.77%	1.890[b]

a-Independent sample t test b-Chi Square test

Table 3 depicts the comparison of the complications of the two techniques. Vascular complications were more frequent in the landmark group, with 4 cases of arterial puncture and 2 cases of hematoma, in contrast to the US group, which had 2 and 1 case, respectively. There were no instances of hemothorax or pneumothorax in either group. Post-procedure X-ray confirmation revealed 2 cases of malposition in the US group, while the landmark group had a single malposition. However, the differences in frequency and complication rates following these two techniques were not statistically significant. Notably, the incidence of central line-associated bloodstream infection (CLABSI) cases, as per the defined criteria, was similar in both groups.

Results demonstrate that static ultrasound guidance for subclavian vein cannulation offers comparable first-pass success, procedural efficiency, and complication rates to the landmark-based technique, without significant improvements. While ultrasound slightly reduces complications like arterial puncture and hematoma, these differences are not statistically significant. Importantly, ultrasound does not increase the risk of central line-associated bloodstream infections when properly standardized. These findings highlight that static ultrasound-guided cannulation is a viable alternative to landmark techniques, particularly in patients with challenging anatomy or higher risk of complications, but does not substantially outperform traditional methods in routine practice.

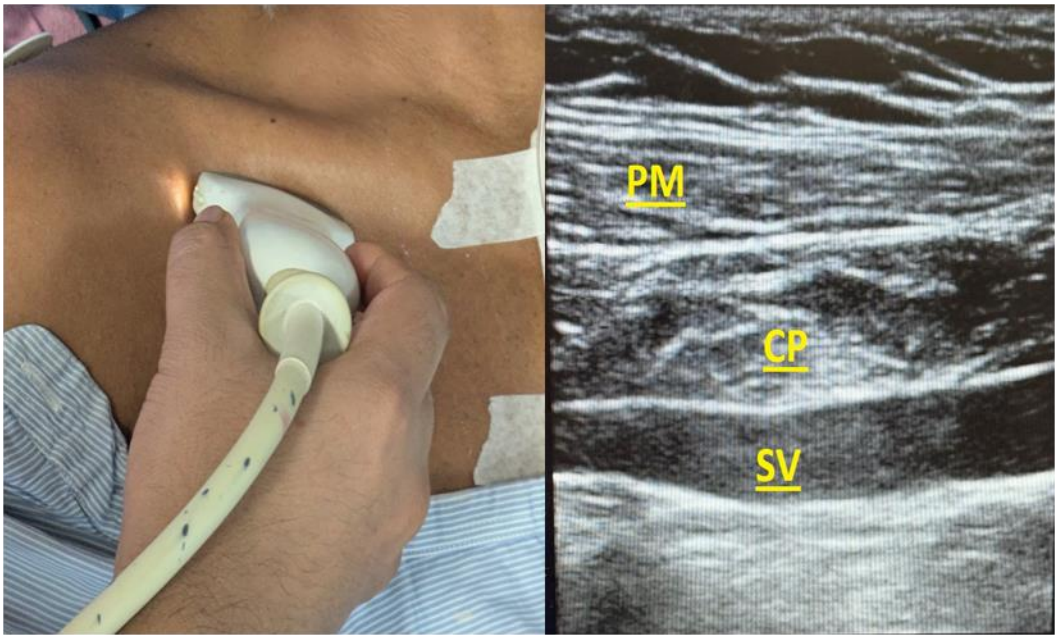

Figure 1: Left image: Placement of probe in the infraclavicular fossa.
Right image: Ultrasound image of the longitudinal axis view if of the Subclavian Vein.
PM: Pectoralis Major muscle, CP: Clavipectoral Fascia, SV: Subclavian Vein

DISCUSSION

Central venous cannulation is now a crucial component of modern anesthesia and critical care practices. Traditionally, a landmark-based approach has been used for cannulating both the internal jugular and subclavian veins. However, ultrasound-guided cannulation has proven to be safer and associated with fewer complications. Various European and American societies have recommended it as a critical technique for IJV cannulation[5,6,7]. However studies regarding subclavian vein cannulation and the benefit of ultrasonography, if any, are limited especially in the Indian population. Our study was designed to compare static ultrasound-guided cannulation of Subclavian vein to the landmark guided technique.

The static assessment of the patient`s anatomy was chosen for this study for various reasons. Firstly, it requires very limited training[4]. Secondly, it quickly identifies any obstacles to successful cannulation, such as anatomical abnormalities. The clinician can use static US to identify the target vein, assess its depth, size, and relative position to surrounding structures (like arteries and nerves), and mark the skin surface directly over the vessel. This minimizes the need for complex equipment and enables clear identification of the target vessel while avoiding nearby structures. Lastly, the procedure of cannulation remains the same as with landmark cannulation but avoids the learning curve required for the "hand-eye" coordination needed to master the use of dynamic ultrasound technique. This helped us include experienced anesthesiologists who were trained without access to ultrasonography. Our study shows that static ultrasound-guided technique of SV cannulation achieved comparable first-pass success rates, average number of attempts, and cannulation times when compared to the landmark-based technique. All patients were successfully cannulated in both techniques as there was no embargo on the number of attempts allowed in each group.

Our study measured the first-attempt success rate, as it is a key indicator of overall success and potential complications. A higher first-attempt success rate typically leads to a reduction in average cannulation time per patient. While the US group showed a higher percentage of first-attempt success, the difference between the two techniques was not statistically significant—71.4% for the LM group and 80.7% for the US group (p=0.248). These findings are similar to those reported by Palepu et al.[8], who found first-attempt success rates of 71.4% for the LM group and 82.4% for the US group. It is pertinent to note that the above study cannulated the SV with dynamic technique of ultrasonography. They had a similar parameter to define first-pass success but had only 28 patients in LM group & 17 patients in the US group. These findings suggest that the percentage of first-pass success is higher in the US group, irrespective of the technique, be it dynamic or static. A Cochrane review for the same showed a similar first pass success of 68.6% for LM & 74.1% for the US group[9].

The number of needle passes is closely linked to failure rates and complications[8]. Mansfield et al.[10]observed that the complication rates increased from 4.3% with a single pass to 24% when more than two passes were required. In our study, the average number of attempts in both techniques were similar, and there was no statistical difference in the LM (1.25 ± 0.437) & the US group (1.19 ± 0.398) (p value 0.47). This was comparable to previous studies, with the average number of attempts ranging from 1.2 to 1.9 in the LM group & 1.1 to 1.7 for the US group[8,11,12]. Milinget al.[4] found the average number of attempts for LM & US group to be 5.2 & 2.9, respectively. This is explained from the fact that they counted each repositioning or realignment of the puncture needle as a separate event.

Major complications of central venous cannulation include arterial puncture and hematoma formation. Other complications include but are not limited to hemothorax, pneumothorax, hemomediastinum, thoracic duct injury, misplaced or stuck guide wire, and cannulation of arteries of the neck[13,14, 15]. The overall complication rate in our study (composite of all reported complications) was 12.5% for LM group and 8.7% for US group, which was comparable to previous studies. Palepu et al.[8] reported a complication rate of 14.3% for LM & 11.8% for the US group. Lefrant et al.[16] reported 15.1% as the complication rate in patients requiring SVcannulation using the LM technique. Like our results, Subramony et al.[17] also reported no difference in the rate of complications while using the static US technique in comparison to LM in the cannulation of the SV. Fragou et al.[11] reported a complication rate of 36.3 % for the LM group & 11.5 % for the US group. This high rate of complications is explained by the

fact that they studied brachial plexus injury, phrenic nerve injury, and other complications, which this study did not include. In our study, the rates were not statistically significant between the groups, since the technique of cannulation remained the same in both groups, unlike in the other studies that used dynamic ultrasound technique.

The cannulation of SV is slightly more challenging than the IJV. The IJV is a superficial vein, and the carotid artery is easily palpable. The SV in contrast does not have a palpable "beating" artery to locate the vein. A Cochrane review on IJV cannulation found that the overall complication rate was 13.06% with the landmark (LM) technique, compared to 4.1% with the ultrasound technique, resulting in a relative risk (RR) of 0.29, which indicates a 71% risk reduction when using the ultrasound method[18]. Similarly, a meta-analysis by Hind et al.[19] reported a relative risk of 0.43 for total complications, also favoring the use of the ultrasound technique. Similar results are not reported in the cannulation of the SV. In our study, inadvertent arterial puncture was the most common complication, which occurred in 7.1% of the LM group & 3.5 % in the US group. Similar rates of arterial puncture were reported in other studies[8,11,20]. In our study, hematoma formation was observed in 3.6% of patients in the LM group and 1.8% in the US group. Comparable rates of arterial puncture have been reported in other studies, with the incidence of hematoma in LM technique ranging from 3.6% to 5% and the US technique ranging from 0% to 1%, respectively[8,20]. Malposition was seen in 1.8% in the LM group & 3.5 % in the US group in our study. Palepu et al.[8] reported 7.2% mal positions in the LM group and 3.6% in the US group. This was statistically insignificant in both the studies. Our study reported no cases of pneumothorax. Similarly low rates were reported in other studies ranging from 0% to 6% for the LM group and 1% to 3.6% for the US group[8,20]. There were no cases of hemothorax in our study. Palepu et al.[8] and Gaber et al.[20] also had no incidence of hemothorax.

The complication of central venous cannulation has direct association with patient's BMI, operator experience & hypovolemia[21,22,23]. Operator experience was standardized in our study by selecting anesthesiologist with minimum five years' experience in a tertiary care setting, thus ensuring adequate experience in both techniques of SV cannulation. Thus, it can be inferred that the complications arose from the inherent risks associated with the technique itself. It is important to note that the rates of CLABSI were similar in both groups (8.9% for LM & 8.8% for the US group). To the best of our knowledge, no other study has compared the rates of CLABSI with the introduction of an extra "load" of the ultrasound probe. This finding shows that protocoled use of ultrasonography does not increase the chances of CLABSI in patients undergoing central venous cannulation.

We compared our findings with those of Lalu et al., who conducted a systematic review and meta-analysis on ultrasound-guided subclavian vein cannulation[24]. The above study did a subgroup analysis of 9 studies utilizing dynamic or real-time sonography. They found no significant differences in the rates of failed catheterization, first-pass success or number of attempts between landmark and real-time sonography in these aspects which was consistent with our results using static ultrasonography method. However, real-time US was associated with fewer complications, likely due to the continuous visualization of critical structures, such as the pleura, throughout the procedure.

We examined current practice guidelines for central venous catheter insertion, aiming to implement them in all hospitals. Among various guidelines, the earliest, from the American Society of Echocardiography and Cardiac Anesthesiologists in 2012, strongly advocated real-time ultrasound for central venous catheterization in the IJV (category A, level 1 evidence), while it was not recommended for subclavian vein

cannulation (category A, level 3 evidence). Similarly, a task force by the American Association of Anesthesiologists in the same year recommended real-time ultrasound guidance for vessel localization and venipuncture when selecting the IJV for cannulation, although they indicated that real-time ultrasound "may" be used for subclavian or femoral vein selections. Both guidelines did not endorse the use of dynamic ultrasound due to insufficient evidence. Our study investigated whether the static ultrasound technique can bridge the gap between "blind" cannulation and real-time imaging.

The International Liaison Committee on Ultrasound Vascular Access also issued guidelines in 2012, suggesting routine ultrasound guidance for short-term and long-term central venous access, without specific recommendations for internal jugular and subclavian access. The Association of Anesthetists of Great Britain, in their 2016 guidelines, recommended real-time ultrasound for IJV cannulation but noted limited evidence for its use in other central venous access sites. A structured review and recommendations published in 2017 advocated for ultrasound in all IJV cannulations but suggested a limited role for ultrasound in subclavian cannulations. The American Society of Anesthesiologists updated their practice guidelines for central venous cannulations in January 2020. The guideline maintains the recommendation for ultrasound in vessel localization and venipuncture for IJV cannulation and also suggests ultrasound for SV cannulation whenever possible.

The prevalent theme across numerous review articles and practice guidelines highlights the importance of ongoing training in landmark-based techniques, especially given that younger generations of anesthesiologists have early access to ultrasound machines in their careers[25,26]. As technology advances and more technologically adept anesthesiologists in the sub-continent embrace technology, further enhancements in success rates and reductions in complications for central venous catheterization across all insertion sites are likely to occur.

CONCLUSION

Static ultrasound-guided central venous catheterization to SV does not improve overall first-pass success or complication rate compared to the conventional landmark-based technique. Both techniques showed similar first-pass success rates, attempts, and cannulation times. Although the US group had a higher percentage of first-pass success, it wasn't statistically significant compared to LM (71.4% vs. 80.7%). Complications like arterial puncture, hematoma, and malposition occurred in both groups & there was no statistical difference in the groups. Inadvertent arterial puncture was the most common complication. Importantly, the rates of central line-associated bloodstream infection were also similar in both groups if protocoled preparation of ultrasonogram probe is done.

This study focused on the static technique of ultrasound visualization, and the dynamic technique, which has gained popularity in the IJV cannulation was not studied. Further studies on dynamic visualization of SV should be explored.

Declaration by Authors

Ethical Approval: Approved

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