ORIGINAL ARTICLE

Anatomical Landmark Guided versus Ultrasound-Guided Technique for Subclavian Vein Cannulation in Critically Ill Patients

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Abstract:

Background: Central Venous Access (CVA) is a common requirement in the critically ill patient for a variety of indications including Central Venous Pressure (CVP) monitoring, haemodialysis, placement of pulmonary artery catheters, cardiac pacing and for administration of drugs especially vasoactive, chemotherapy agents and parenteral nutrition. Traditionally, Central Venous Catheter (CVC) placement is performed using Landmark (LM) technique and is associated with complications like arterial puncture, pneumothorax, hemothorax, air embolism, catheter embolism, and cardiac arrhythmias. Use of Ultrasound (US) is currently indicated for various clinical situations to reduce complication rate of LM technique. *Aim and Objectives:* The purpose of this study was to determine whether US guidance could improve the success rate, number of attempts, and rate of acute complications like inadvertent arterial puncture, hematoma formation, and pneumothorax of subclavian venous catheterization. *Material and Methods:* Sixty patients in need of central venous catheter were prospectively randomized in two groups of 30 each. In the LM group patients were catheterized using the LM method and in US group patients were catheterized by real-time US-guidance. Number of attempts, success rate, access time and complications like accidental subclavian artery puncture, haematoma formation, pneumothorax, were recorded. p values <0.05 were considered statistically significant. *Results*: In the US group 30 (100%) of patients were successfully cannulated with the US guidance while the landmark technique was successful in 26 (86.66%) of patients. In the US group the success on first attempt was 83.33 % which was a significantly higher from 56.67% achieved in the LM group (p=0.025). The average number of attempts for successful cannulation in the US group was 1.16 ± 0.4, while in the LM group it was 1.56 ± 0.9 with statistically significant difference (p=0.046). Access time was 27.26 ± 04.62 seconds in the US group, while the access time was significantly more in the LM group 36.56 ± 17.35 seconds (p=0.0062). *Conclusion:* US guidance during subclavian vein catheterization increases overall and first attempt success, improves access time with reduced average number of attempts and complications.

Keywords: Central Venous Cannulation, Central Venous Access, Central Venous Pressure, Subclavian Vein, Landmark,

Introduction:

Central Venous Access (CVA) is a common requirement in the critically ill patient for a variety of indications including Central Venous Pressure (CVP) monitoring, haemodialysis, placement of pulmonary artery catheters, cardiac pacing and for administration of drugs especially vasoactive, chemotherapy agents and parenteral nutrition [1]. Typical sites for placement of central venous catheter are internal jugular, subclavian, and femoral veins [1].

Since its original description over 60 years ago, by Aubaniac, the subclavian vein has been an important vessel for central venous cannulation [2]. Most important advantage of Subclavian Vein Cannulation (SCV) over other sites is better patient comfort. Other advantages include its large diameter, absence of valves, ability to remain patent in a relatively constant position, fewer cases of thrombosis and infectious complications [3-5].

The Seldinger technique for Central Venous Catheter (CVC) placement is well known and followed routinely [6]. Briefly, the procedure involves introducing a percutaneous needle into the vessel, passing a guide wire through the needle, and then placing the catheter over the guide wire and inserting it into the blood vessel [6].

Traditionally, CVC placement has always been performed using Landmark (LM) technique based on the knowledge of anatomic structures and palpation of arteries next to the veins, but with associated complications that may vary between 5% and 19% like arterial puncture, pneumothorax, air embolism, catheter embolism, hemothorax and cardiac arrhythmias [7-8]. The above mentioned complications may occur due to little experience of the doctor or due to anatomical abnormalities such as obesity, vascular thrombosis, congenital anomalies and tumours [8]. Use of Ultrasound (US) is therefore currently indicated for various clinical situations and used routinely for central venous puncture to overcome complication rate of LM technique. It enables visualization of the correct position of the vein, its size, patency and eventual thrombosis, which is especially useful in patients with difficult anatomical characteristics [8-9].

The purpose of this study was to determine whether US guidance would improve the success rate, number of attempts, and rate of acute complications like inadvertent arterial puncture, hematoma formation, and pneumothorax of subclavian venous catheterization.

Material and Methods:

This prospective, randomized, comparative study was carried out in the Surgical Intensive Care Unit of Acharya Vinoba Bhave Rural Hospital (AVBRH), Sawangi (Meghe), Wardha from October 2017 to February 2018. Permission was obtained from hospital ethical committee and informed consent was obtained from the patients' relatives to carry out the procedure.

Inclusion criteria consisted of sedated and mechanically ventilated fresh patients for CVC placement in whom adequate peripheral venous access were unobtainable and patients requiring central venous access as a part of clinical management e.g. invasive hemodynamic monitoring, inotropic supports, dialysis and long term parenteral nutrition. Patients with subcutaneous emphysema, fractured clavicle, coagulopathy, undergoing radiation therapy, skin inflammation at the insertion site, urgent patients, and patients with raised intracranial pressure were excluded from the study.

60 patients in need of central venous catheter were prospectively randomized in two groups of 30 each via computer-generated random-number table. Block randomization was used to ensure equal numbers of patients in these groups [10].

Group LM (n=30): patients were catheterized using the LM method.

Group US (n=30): patients were catheterized by real-time US-guidance.

Subclavian vein was cannulated in all patients via Infraclavicular approach and cannulation was performed under nonemergency conditions. All the cannulations were performed by consultant anaesthetist with more than 3 years experience in ICU and who had undergone workshop on role of ultrasonography in emergency medicine and hands-on training.

Patients to be catheterized were placed in supine position with head turned to the opposite side. Roll towel was kept between interscapular regions with a head down position. Anterior region of neck and upper chest was cleaned with povidone-iodine solution. All aseptic precautions were taken used by the operator. Procedure site was isolated with sterile towels. Lignocaine plain 1% solution (3-4 ml) was injected to anaesthetize the puncture site and subcutaneous tissue.

Group LM Technique:

Standard infraclavicular approach was used by selecting point of needle entry 1 cm below the clavicle at the junction of middle and medial third of the clavicle with the needle directed towards the suprasternal notch. The return of venous blood into the syringe attached to the needle confirmed entry into the vessel. Then, the double lumen catheter was placed by means of the Seldinger's technique.

Group US Guided Technique:

The area was prepared and draped under sterile conditions as described previously. A mindray US machine (model Z5) equipped with a high-resolution 7.5-MHz transducer was used. The transducer was first covered with an ultrasonic gel and then wrapped in an intraoperative sterile sheath. The US method applied for the SCV catheterization was by infraclavicular approach on the longitudinal axis. The needle was advanced slowly such that its trajectory and/or tip could be detected superficially. The needle was advanced in real-time toward the lumen of the vein, on the longitudinal axis, the needle entered the lumen of the vessel either at the level of the axillary vein or at the point where the latter continued medially as the SCV, this was dependent on the angle of penetration and the depth from the skin surface that the vein is located. Also, the course of the needle was dependent on the adjustments performed by the operator to visualize its trajectory on the longitudinal axis. The guidewire was advanced according to the Seldinger's technique. Thereafter, the ipsilateral Internal Jugular Vein (IJV). and the contralateral SCV were scanned to identify possible misplacements. Romsons Centro® 7 Fr double lumen central venous catheters was used in the study. A normal chest radiograph was used to assess the placement of the catheter's tip after the procedure (which is less than 2.9 cm caudal to the right tracheobronchial angle to avoid intracardiac placement) as previously described [11].

Following observations were recorded: Number of attempts, success rate, access time and complications like accidental subclavian artery puncture, haematoma formation, pneumothorax, were also recorded. Each skin puncture was defined as an attempt and maximum 3 attempts were allowed in either technique. When after skin puncture, needle advancement and needle withdrawal there wasn't a return of venous blood from the targeted vein, an unsuccessful attempt was declared. After three unsuccessful attempts the procedure was terminated at the given site and declared unsuccessful. In case of failure, alternate approach (internal jugular) was used for catheterization.

Access time was defined as the time between penetration of skin and aspiration of venous blood into the syringe. Preparation times for both techniques were not similar, taking into account that in the US group around 120 seconds were added as a result of scanning the area before performing the actual penetration. Access time was measured in seconds by a stopwatch by other physicians and the number of attempts and complications were recorded.

Mechanical complications like arterial puncture, pneumothorax and hematoma were made note of. A pulsatile flow of bright red blood from the needle was considered to be a sign of arterial puncture. In such cases the needle was withdrawn from the skin and manual pressure was applied until haemostasis was achieved. Hematoma formation on the skin access site bigger than 1 cm in diameter was recorded. A radiographic examination of the lungs was made 6 hours after the procedure to check the catheter's position and check for pneumothorax. Complications if any, were managed according to the standard protocol.

The end point was to compare the real-time US method versus the LM technique in the routine cannulation of the SCV.

Sample Size

$$(n) = Z^2_{\alpha/2} \frac{pq}{E^2}$$

Where n = sample size, $Z^2\alpha/2$ = level of significance i.e. 0.95,

p= prevalence, q= 1-p,

E= allowable errors (10% of p)

In previous study success rate was 74% in first attempt in conventional group (non US), So taking this 74.2% (p=0.74) and E=10% of p, in above formula, the required sample size is around 30 for each group.

Statistical Analysis:

Comparison of data was done using the Statistical Package for the Social Sciences (SPSS for Windows, version 17). Categorical data was analysed using Chi-square test while continuous data was analysed using Student's unpaired t-test. p values <0.05 was considered statistically significant.

Results:

Demographic characterises and site of subclavian vein cannulation of the study patients are presented in this Table 1.

Table 1: Demographic Data

Characteristics	LM Group (n=30)	US Group (n=30)	*P*
Age (Years)	50.16 ± 7.35	51.1 ± 8.48	t=0.30;p=0.76
Gender (Male/Female)	24/06	22/08	χ^2=0.36; p= 0.54
Cannulation side (Left/ Right)	28/02	26/04	χ^2=0.72;p=0.39
Body Mass Index	20.30±1.34	19.86±1.19	t=1.34; p=0.18

Sixty patients were included in this study, 30 in each group. Mean age of the patients in LM Group was 50.16 ± 13.35 years and in US Group it was 51.1 ± 10.48 years. Males outnumbered females in both the groups, the percentage of male was 76.67% while that of female was 23.33% amongst the total number of patients included in the study. Mean BMI of the patients in LM Group was 20.30 ± 1.34 kg/m^2 and in US Group it was 19.86 ± 1.19 kg/m^2. Right sided subclavian vein catheterization was done in maximum number of patients in both the groups (90%). The patients were comparable with respect to age, gender, BMI and cannulation side as the difference was not statistically significant (p> 0.05).

Results of outcome measured using LM technique are in contrast to the US method (Table 2). In the US group 30 (100%) of patients were successfully cannulated with the US guidance while the LM technique was successful in 26 (86.66%) of patients, the difference was statistically significant (p=0.040). In the US group the success on first attempt was 83.33 % which was a significantly higher from 56.67% achieved in the LM group (p=0.025). The average number of attempts for successful cannulation in the US group was 1.16 ± 0.4, while in the LM group it was 1.56 ± 0.9. There was a statistically significant difference in the average number of attempts between groups (p=0.046). Access time i.e. skin puncture to return of blood in syringe was 27.26 ± 04.62 seconds in the US group, while the access time was significantly more in the LM group, it was 36.56 ± 17.35 seconds (p=0.0062).

In US group only 1(3.33%) patient had haematoma formation in whom second attempt for cannulation was required, whereas in LM group rate of complications were significantly

Table 2: Outcomes of LM and US Groups

Outcome Measured	LM Group (n=30)	US Group (n=30)	*P*
Access time (sec)	36.56 ± 17.35	27.26 ± 04.62	t=2.83;p=0.0062
1st attempt success rate (n)	17 (56.67%)	25 (83.33%)	χ 2 = 4.992;p=0.025
Success rate (n)	26 (86.66%)	30 (100%)	χ^2=4.21 ;p=0.040
Average number of attempts	1.56±0.9	1.16±0.4	t=2.03;p=0.046

Table 3: Complications of LM and US Groups

Complications	LM Group (n=30)	US Group (n=30)	*P*
Pneumothorax (n)	1	0	χ^2=3.97; p=0.046
Artery puncture (n)	3	0	
Haematoma (n)	2	1	

more, total 6(20%) had complications,1% developed pneumothorax, 2% had haematoma and in 3% patients there was a subclavian artery puncture (p= 0.046) (Table 3).

Discussion:

The subclavian vein is the preferred site for cannulation as it offers multiple advantages as compared to other common alternatives for central venous access. These include fewer cases of thrombosis, infectious complications, better patient comfort and increased ability to remain patent in hypovolemic states [3, 5, 14].

With respect to number of attempts required for successful cannulation of subclavian vein, in the US group the success on first attempt was 83.33% which was significantly higher from 56.67% in the LM group, p value being <0.05 (χ^2 = 4.992: p=0.025). The average number of attempts for successful catheterization in the US group was 1.16 and in the LM group it was 1.56. There was a statistically significant difference in the average number of attempts between the two groups with p<0.05.

In accordance with the results of our study compared with other studies, it was found to have similar results. In a study conducted by Gualtieri *et al*., 44% catheters were successfully placed using LM technique as compared to 92% with the use of US, the difference being statistically significant (p=0.0003) [15]. In another study by Sharma *et al*. in 76% of the patients the axillary vein was successfully punctured with the help of US imaging in first attempt and the axillary vein was successfully catheterized in 96% of the cases under US guidance [9]. Miller *et al*. in their study found out that the mean number of attempts in the US group was 1.6 as compared to 3.5 in the LM group (p=0.0001). Other researchers also observed that real time US guidance during SCV cannulation can achieve higher success rate with less number of attempts [16-18].

In our study, 30/30(100%) were successfully catheterized in the US group whereas in the LM technique 26/30(86.67%) were successfully catheterized. The difference between the two groups was statistically significant (p<0.05). Failed catheterization was noticed in 4(13.33%) patients in the LM group. In the study conducted by Fragou *et al.* in 100% of patients in the US group subclavian vein cannulation was achieved as compared to 87.5% in the LM group [12]. Similar results were obtained by Bose *et al*., in 92.3% patients they were able to cannulate subclavian vein successfully by US [16]. After their meta-analysis, Brass *et al.* and Kim and Koyfman found 14% failed catheterization in the LM group. These results were comparable with our study.

Access time was defined as the time between penetration of skin and aspiration of venous blood into syringe. Preparation time was being non similar in the two groups. On the average 27.26 ± 4.62 seconds were needed from skin puncture to blood return in the US group. However, in the LM group the time was 36.56 seconds which significantly increased due to increased number of attempts. Similar results were obtained by Fragou *et al*. in which access time was 26.8 ± 12.5 seconds which was significantly less as compared to 44.4 ± 54.9 seconds [12]. While in another one such study conducted by Sazdov *et al*. average access time was 13.6 ± 11.6 seconds in the US group as compared to 20.1 ± 20.3 seconds in the LM group, the difference was statistically significant.

There was only one complication (3.33%) in the US group while there were 6(20%) complications

in the LM technique group. Haematoma was encountered in 1 patient (3.33) in the US group whereas second attempt for cannulation was required in 3(10%) in the LM group. Zero occurrence of pneumothorax was reported in both the groups. Results were statistically significant (p=0.046). In a study conducted by Sharma *et al*., artery puncture occurred in 1.5% patients during LM technique [9]. All the complications were more in the LM group as compared to US group [12]. Sazdov *et al*. observed the complication rate with the LM method which was 14.5% versus 4% with real time US guidance p<0.05. Other studies also showed significantly higher complication rates in the LM group as compared to US group.

In our study, all cannulation of SCV was done in Surgical Intensive Care Unit (SICU) under nonemergency conditions. We used the longitudinal axis for real-time US-guided technique, the aim was to avoid the transfixion of the vein and enable the detailed visualization of the vessel's course [12]. LM method is based on the knowledge of anatomic structures and palpation of arteries which are usually placed next to the veins. Major drawback is that it cannot account for anatomic variations and venous thrombosis which is common at CVC insertion site in critically ill patients [13]. US has the advantage that it can facilitate central venous cannulation in special conditions where LM technique based on palpation of arterial pulse is not possible.

Conclusion

From our study we reached the conclusion that US guidance during subclavian vein catheterization improves access time, increases overall and first attempt success with reduced complications as compared to the LM method. We believe that US guidance should be encouraged for all subclavian venous cannulation in patients and thereby improving patients' safety and quality of care.

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