

An Ultrasound Guided Technique of Central Venous Catheterization versus Anatomical Landmark Guided Technique in Medical Intensive Care Patients

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ABSTRACT

Background: Central venous catheterization (CVC) is an important procedure in the practice of emergency medicine. Insertion of CVC is amongst the most frequently performed invasive procedures in ICU. In severely ill and long-stay patients, inserted CVCs enable relatively safe and painless application of parenteral nutrition, long-term antibiotics, chemotherapy, intravenous fluids, and blood components and are also used for repetitive blood sampling. Furthermore, CVCs are used for invasive hemodynamic monitoring, hemodialysis, plasmapheresis and in case of shortage of a peripheral access. With the increasing availability of bedside ultrasound, emergency physicians have begun to incorporate this new technology to reduce error and improve patient care. **Objective:** To compare the outcome of an ultrasound guided technique versus an anatomical landmark guided technique for central venous catheterization. **Patients and methods:** The present study was performed on one hundred patients of both sexes; the study was conducted at El-Husseïn University Hospital. They were scheduled for insertion of central venous line for various purposes. The patients were assigned into two groups each group formed of fifty patients (n=50). Group (A): Anatomical guided technique for insertion of CVC, Group (B): Ultrasound guided technique for insertion of CVC. Patients with local infection, known vascular abnormalities, untreated coagulopathy (INR more than 1.5, platelets less than 50000/mm³) and age less than 16 years old were excluded from the study. **Results:** A total of 100 patients were included. The outcome of each group was recorded regarding success rate, number of attempts and access time in seconds. The use of ultrasound guided central venous catheterization has better outcome and higher-safety in comparison to anatomical landmark-based technique. Ultrasound guidance elevated significantly the success rate of central venous catheterization than anatomical landmark-based technique. In addition, the access time was reduced in a significant trend by using ultrasound guidance. In the same manner the average number of attempts needed for accessing the vein was limited significantly when Ultrasound guidance was applied. The incidence of hematoma formation, arterial puncture and malposition was reduced in a significant trend by using ultrasound guidance in comparison to landmark-based techniques. When comparing ultrasound guidance to anatomical landmark-based guidance we found that all mechanical complications were significantly lower when central venous catheterization was carried out by means of ultrasound guidance. **Conclusion:** Ultrasound examination of the region of interest offers some additional information compared to clinical examination as Position of the vessel, Patency of the vessel, Size of the vessel and Stenosis or hematoma. The implementation of ultrasound guidance improves success and reduces complication rate during central venous catheterization. **Keywords:** Central, Venous, Catheterization, Ultrasound, Anatomical, Landmark, Guided, Technique.

INTRODUCTION

Central venous catheters (CVCs) have now become indispensable in intensive care units and operating rooms. Insertion of CVC is amongst the most frequently performed invasive procedures. In severely ill and long-stay patients, inserted CVCs enable relatively safe and painless application of parenteral nutrition, long-term antibiotics, chemotherapy, intravenous fluids, blood components and are also used for repetitive blood sampling. Furthermore, CVCs are used for invasive hemodynamic monitoring, hemodialysis, and plasmapheresis and in case of shortage of a peripheral access⁽¹⁾. By definition, these devices involve placement of a large-bore catheter into one of the body's main central veins either by conventional method or Ultrasound guided. Ultrasound (U/S) technology has many uses in clinical medical

practice and with improvement importability and cost-effectiveness its use has further expanded. In many facilities, the use of ultrasound when placing central venous catheters has become increasingly popular. Ultrasound guidance of CVC insertion improves success rates and reduces complications⁽²⁾. Ultrasonography was introduced into clinical practice in the early 1970 and is currently used for a variety of clinical indications⁽³⁾. In this study we aim to compare the outcome of an ultrasound guided technique versus an anatomical landmark guided technique for central venous catheterization.

PATIENTS AND METHODS

The present study was performed on one hundred patients of both sexes; they were scheduled for insertion of central venous line for various purposes. They were assigned into two groups each group formed

of fifty patients (n=50). GROUP (A): Anatomical guided technique for insertion of CVC. GROUP (B): Ultrasound guided technique for insertion of CVC. **The study was approved by the Ethics Board of Al-Azhar University.**

Exclusion criteria: Patients with local infection, known vascular abnormalities, untreated coagulopathy (INR more than 1.5, platelets less than 50000/mm³) and age less than 16 years old were excluded from the study.

Methods: Patients were submitted to the study after proper assessment including history for the cardio-respiratory disease and bleeding tendency. Investigations by complete blood picture, coagulation profile and chest x-ray was done. Pre procedures preparations were done by insertion of an intravenous cannula (20 G). Oxygen through the nasal catheter was applied and reassurance was done. Electrocardiogram (ECG), non-invasive blood pressure (NIBP) and oxygen saturation (SpO₂) were connected to the patient. Before insertion, sedation and local anesthesia at the site of insertion were administered.

Techniques:

(A) Anatomical landmark guided technique: The internal jugular vein (IJV): The vein is remarkably constant in position. It descends through the neck from a point halfway between the tip of the mastoid process and the angle of the jaw to the sternoclavicular joint. All patients were positioned in Trendelenburg's position & head-down to increase the size of the vein and turned no more than 45° to the opposite side. The procedure was performed under aseptic condition; the site of insertion was draped after sterilization with bovidone iodine 10% followed by 70% isopropyl alcohol. There are numerous approaches for IJV catheter.

1 -Anterior approach: puncture at the top of the junction where the sternal and clavicular heads of the sternocleidomastoid muscle meet, lateral to the carotid impulse, directing the needle at the ipsilateral nipple .

2-Low approach: puncture just lateral to the carotid impulse, just above the jugular notch on the medial clavicle.

3-Posterior approach: the tip of the needle and the catheter are introduced into the vein about two fingerbreadths above the clavicle at the posterior border of the sternocleidomastoid muscle, direct the needle in internal jugular approach downwards at 30° to the skin; advance the needle

towards the suprasternal notch, pulling back on the plunger of the syringe all the time.

In all techniques the next steps is the same as following: 1-Insert the guide wire into the needle and into the vein, advance the guide wire, there should be no resistance. 2-Use a dilator: be very careful not to advance it too far - only far enough to expand the space between the clavicle and first rib. 3-Place the catheter over the wire and advance it through the skin, into the vein, then confirmed by chest X-ray after procedure. 4- Suture the catheter in place.

The femoral vein: In the upper thigh, the vein is between the common femoral artery and femoral canal and therefore occupies the middle compartment of the femoral sheath. Place the patient in the supine position, with the inguinal area adequately exposed to allow identification of anatomic landmarks. Decontaminate the area by painting it widely with povidone-iodine. Identify the inguinal ligament and the femoral arterial pulsations; identify a point approximately 1 cm below the inguinal ligament and 0.5-1 cm medial to the femoral arterial pulsation, mark this point as the site to percutaneously access the femoral vein. The next steps are the same as IJV:

B) Ultrasound guidance technique: By using Siemens (Acuson X300) with) VF10-5 linear transducer). As the steps of anatomical method but vein detected by Ultrasound guided method, use Real-time two-dimensional ultrasound guidance for central venous catheterization; under complete aseptic technique, the probe is then placed on the patient's skin perpendicular to the vessels in vertical line along the vein and the target vessel is identified. The vein is identified with several techniques, including ease of compressibility; the vein is usually larger and not pulsatile unlike the artery, and a low - pitched, continuous venous hum for the vein. The vessel is punctured exactly in the axis of the center of the probe. A "pop" followed by the continuous sound of blood aspiration can often be heard when the vessel is entered. The needle can be seen and then puncturing the vessel during correct placement.

There are two basic approaches to ultrasound guidance:

1-In Plane Approach: With the in-plane approach, the entire tip and shaft of the advancing needle are visible. There are several advantages to the in-plane approach. It provides the most direct visualization of the needle tip and injection. The amount of unimaged needle path is typically small. The needle tip is visualized before advancement.

One disadvantage is the long needle path, which results in more tissue for the needle to cross.

2- Out of Plane Approach: With the out-of-plane technique, the needle tip crosses the plane of imaging as an echogenic dot. There are several advantages to the out-of-plane approach to regional block. Therefore, the out-of-plane approach provides a natural transition from one form of guidance to another. The out-of-plane approach uses a shorter needle path than in-plane approaches. With this approach just the needle tip is visualized and the remainder of the needle is off screen. One disadvantage of the out-of-plane approach is the extent of the unimaged needle path (structures that may lie short of or beyond the scan plane). If the needle tip crosses the scan plane without recognition, it can be advanced beyond the scan plane into undesired tissue.

Once the vessel has been punctured and the guide wire passed, the ultrasound can be used to visualize the guide wire in the lumen of the vessel. Ultrasound may be used to aid correct guide wire placement and avoid migration of the guide wire or catheter into the ipsilateral vein. Post-procedure plain x-ray immediately after insertion for each patient to confirm position of catheter and early detection of complications.

The following parameters (data) were assessed: 1. Demographic data (age, sex, height and BMI). 2. Hemodynamic data (blood pressure, pulse and SpO₂) was measured pre and post insertion. 3. Duration: in seconds for insertion of CVC (the time in seconds between insertion of the needle and the end of fixation of catheter). 4. Number of attempts: for insertion of CVC (more than 3 attempts was excluded). 5. Success rate: indicate for number of success rate in each group of CVC. 6. Complications of CVC insertion: a. Malposition of the catheter. b. Subcutaneous haematoma. c. Arterial puncture. d. Pneumothorax. e. Haemothorax. f. Cardiac arrhythmias

Statistical Analysis: Comparison between numerical data in two studied groups was performed using T test. Comparison between categorical data was performed using Chi square test. Statistical package for the social sciences (SPSS) computer program (version 20) was used for data analysis. Data were statistically described in terms of mean \pm standard deviation (\pm SD) or number (%). For comparison between both groups, a difference in variables was expressed by P value (≤ 0.05 is significant, > 0.05 is non-significant, and < 0.01 is highly significant).

RESULTS

As regard the previous data, there were no statistically significant differences between the studied groups as regard age, weight, height and sex (P-value > 0.05). See table1.

Table (1): Patients' demographic characteristics (Group (A), and (B)).

	Group (A) (n=50)	Group (B) (n=50)	P-value
Age (years)	40 \pm 20.01	40 \pm 19.71	0.950
Weight (kg)	70.62 \pm 10.81	69.62 \pm 10.81	0.998
Height (cm)	169.03 \pm 9.03	170.03 \pm 9	0.997
Sex: N (%)			
Male	29 (58%)	32 (64%)	0.891
Female	21 (42%)	18 (36%)	

As regard the hemodynamic data, there were no statistically significant differences between the studied groups as regard BP, Pulse and oxygen saturation. (P value > 0.05). See table 2

Table (2): Patients' hemodynamic characteristics (Group (A) and (B)).

Means \pm SD	Group (A) (n=50)		Group (B) (n=50)		P-value
	Pre	Post	Pre	Post	
BP (mmHg) *	109 \pm 17	110 \pm 18	108 \pm 20	107 \pm 15	0.78
Pulse (Cycle/min)	79 \pm 7	78 \pm 8	76.6 \pm 7	80 \pm 6.8	0.45
SpO ₂	95 \pm 3	95 \pm 4	96 \pm 2	94 \pm 4	0.56

* mmHg = millimeter Mercury.

As regard the previous discussed data, there were statistically significant difference between group (A) and Group (B) regarding success rate, access time and number of attempts. (P value < 0.05) See table 3.

Table (3): Success rate, access time (seconds) and number of attempts (Group (A), (B)).

	Group (A) (n=50)	Group (B) (n=50)	P-value
Success rate	43 (86%)	50 (100%)	0.015*
Access time(seconds)	441.4 \pm 117.04	286.86 \pm 94.53	0.004*
Number of attempts	2.53 \pm 0.63	1.46 \pm 0.74	0.002*

*= P< 0.05 between the two groups which is significant.

According to the previously discussed data, the incidence of complications among the groups; shows statistically significant difference between group (A) and Group (B) regarding incidence of subcutaneous hematoma, arterial puncture, malposition, failure of insertion, however, there were no significant difference between the studied groups as regard the incidence of cardiac arrhythmias, pneumothorax, hemothorax and cardiac tamponade. See table 4.

Table (4): Comparison of complications in (Group (A) and (B).

	Group (A) (n=50)	Group (B) (n=50)	P-value
Hematoma	10 (20 %)	0	0.005*
Malposition	2 (4 %)	0	0.45
Arterial puncture	10 (20 %)	0	0.005*
Cardiac arrhythmias	10 (20 %)	7 (14%)	0.370
Failure of insertion	6 (12 %)	0	0.032*
Pneumothorax	0	0	0
Hemothorax	0	0	0
Cardiac tamponade	0	0	0

*= P< 0.05 between the two groups which is significant.

DISCUSSION

Central venous catheters (CVCs) are required to carry out numerous treatment plans for adult patients. Many life-threatening conditions require reliable and stable access for the infusion of medications and drawing of blood samples⁽⁴⁾.

In the current study we considered the anatomical landmark-based technique as a standard to compare the ultrasound technique, for each patient the initial patient characteristics, outcome, and incidence of mechanical complications were reported.

The statistical differences regarding patient characteristics (age, sex, weight, height) among the two groups are insignificant and come in

agreement with *Cavanna et al.*⁽⁵⁾. The statistical differences regarding pre and post hemodynamics (Bp, Pulse and SpO₂) are insignificant; this result comes in agreement with *Zhang et al.*⁽⁶⁾.

In the current study, the ultrasound guidance technique elevated significantly the success rate; on the other hand, it reduced significantly the number of attempt of central venous catheterization than anatomical land mark-based technique. This result comes in agreement with *Sulek et al.*⁽⁷⁾ where they found better success rate and reduced number of attempt in the ultrasound guided technique. Also *Skippen and Kissoon*⁽⁸⁾ found that experience in the use of ultrasonography guidance for CVCs will reduce the number of attempts. *Palepu et al.*⁽⁹⁾ found that the use of U/S technique reduce failure rate. *Brass et al.*⁽¹⁰⁾ found that using of ultrasound increase the success rate and reduce the number of attempts.

On the other hand, *Vucevic et al.*⁽¹¹⁾ found that ultrasound guidance needs longer time than anatomical land mark-based technique which comes in disagreement with the current study .

In the current study U/S guidance technique reduce significantly the access time of central venous catheterization than anatomical land mark-based technique which comes in agreement with *Hind et al.*⁽¹²⁾.

Contrary to these findings, *Gilbert et al.*⁽¹³⁾ found that ultrasound guidance needs longer time than landmark-based techniques.

In the current study, U/S guidance technique reduced significantly the mechanical complications of central venous catheterization than the anatomical landmark-based technique. This result comes in agreement with *Slama et al.*⁽¹⁴⁾ compared internal jugular cannulation by both techniques in a geriatric group of seventy-nine patients and found no case of cannulation failure when ultrasound was used however the incidence of arterial puncture didn't change from landmark technique. Also *Caiozzo*⁽¹⁵⁾ and his working group found that the use of U/S technique reduced the incidence of mechanical complication. *Turker*⁽¹⁶⁾ and his colleagues carried out a study on three hundred eighty cases of internal jugular vein cannulation and reported significantly lower incidence of arterial puncture and hematoma among the ultrasound group. *Agarwal et al.*⁽¹⁷⁾ compared incidence of arterial puncture and pneumothorax between ultrasound technique and landmark technique during internal jugular catheterization in eighty patients. They reported no case of carotid puncture or pneumothorax in the ultrasound group versus four cases of arterial puncture and one case of pneumothorax in the landmark group. *Zhang et al.*⁽⁶⁾ compared the two techniques in one hundred cases of internal jugular venous cannulation. No incidence of arterial puncture or hematoma formation in the ultrasound group while four cases of arterial puncture and another four cases of hematoma occurred in landmark group. *Brass et al.*⁽¹⁰⁾ they found the using of ultrasound reduce mechanical complications.

On the other hand, *Gratz et al.*⁽¹⁸⁾ showed no changes in the incidence of complications with U/S guidance and no changes in complication rate this result comes in disagreement with our study.

CONCLUSION

The implementation of ultrasound guidance improves success and reduces complication rate during central venous catheterization. Ultrasound-guided central venous catheter placement has been shown to be superior to the anatomical landmark technique as it reduces both the number of needle passes required for

successful placement and the incidence of all complication such as subcutaneous hematoma, arterial puncture, malposition, failure of insertion, pneumothorax, hemothorax and cardiac tamponade.

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