Dynamic ultrasound guidance versus landmark technique in internal jugular central line insertion in mechanically ventilated patients

Altayar Ashraf [(1)], Abouelela Amr [(1, 2)], Sewify Khaled [(1)],El-Sirafy Mohamed[(3.4)], Khaja Mohiuddeen [(5)]
Amr Mohammed Farghaly Mohammed[(5)], Ashraf Amin Mohammed Hussein[(1)]

(1) King Fahd Military Medical Complex, ICU department, Dhahran, Saudi Arabia
(2) Alexandria University, Critical Care Medicine Department, Alexandria, Egypt
(3) King Fahd Military Medical Complex, Radiology Department, Dhahran, Saudi Arabia
(4) Alexandria University, Radiology Department, Alexandria, Egypt
(5) King Fahd Military Medical Complex, Anesthesia &ICU Department, Dhahran, Saudi Arabia
altayar.ashraf@gmail.com, amrela313@yahoo.com, drsewafie@hotmail.com, sirafy@yahoo.com, drkhaja@gmail.com, farghely@yahoo.com, ashraf_amin32@yahoo.com

Abstract: It is sometimes difficult to establish central venous catheter (CVC) in intensive care unit (ICU) setting especially in mechanically ventilated patients and it can be associated with complications in up to 10% and failure to get access in up to 33% using the landmark technique (LMT). The aim of this study is to compare between ultrasound technique (UST) and landmark technique (LMT) in insertion of internal jugular CVC by experienced intensivists in ICU mechanically ventilated patients. This prospective randomized trial was carried out on 200 ICU mechanically ventilated patients at King Fahd Military Medical Complex, Dhahran, Saudi Arabia. Patients were randomly categorized into 2 groups: LMT group (100 patients) and UST group (100 patients) for insertion of CVC in the internal jugular vein. All procedures in UST group were done by experienced intensivists using dynamic ultrasound guidance by single hand technique. Comparison between the 2 groups was done regarding the success rate, number of attempts, duration of the procedure and incidence of complications. The number of successful CVC trials was 98/100(98 %) in UST group which was significantly higher than the LMT group 87/100 (87%) (p= 0.018). The number of attempts was 1.2 in UST group which was significantly lower than the LMT group (1.64) (0.000). The duration of guide wire in the vein in seconds was significantly lower in UST versus LMT group (35.27 & 45.71respectively) (p= 0.004). The whole duration of the procedure was also significantly lower in UST versus LMT group (91.94 & 114.19 respectively) (p= 0.000). Regarding complications, 3 patients developed pneumothorax in LMT group versus no patients in UST group (p= 0.115). Arterial puncture happened in 3/100 patients in LMT group versus 1/100 in UST group (p=0.96). The incidence of catheter related blood stream infection (CRBSI) is 10/100 patients in UST group versus 26/100 in LMT group (p=0.02). We concluded that insertion of internal jugular CVC in ICU mechanically ventilated patients using UST technique is superior to LMT in term of higher success rate, less number of attempts and shorter duration of the procedure while no significant difference was detected between the 2 groups regarding the occurrence of complications except for CRBSI which was significantly less in the UST group.

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1. Introduction

Central venous catheters are inserted for several reasons, including haemodynamic monitoring, delivery of blood products and drugs (for example, chemotherapy and antibiotics), haemodialysis, total parenteral nutrition, and management of perioperative fluids. These procedures are performed in a wide range of locations within the hospital and at various insertion sites on the body. Central venous access is commonly attempted at the internal jugular vein, subclavian vein, femoral vein, or arm veins, using peripherally inserted central catheters. Safe puncture of a central vein (venipuncture) is traditionally achieved by passing the needle along the anticipated line of the vein using anatomical landmarks on the skin's surface (the landmark method).[(1)]

Although these catheters can be life saving, they are also associated with significant risk. This risk is heightened by a number of factors, including patient characteristics (e.g., morbid obesity, cachexia, or local scarring from surgery or radiation treatment), patient setting (e.g., patients receiving mechanical ventilation or during emergencies such as cardiac arrest), co-morbidities (e.g., bullous emphysema or coagulopathy), the variable training and experience

of the clinicians who perform the procedure, and the method of insertion (e.g., percutaneous insertions are often performed "blind" and rely on anatomic landmarks).[2,3]

Many anatomic landmark-guided techniques for IJV puncture have been described since 1966. [4] It has been suggested that ultrasound guidance could be beneficial in placing central venous catheters (CVCs) by
improving the success rate, reducing the number of needle passes, and decreasing complications. Also, employment of ultrasound imaging may identify patients in whom central venous access may be more difficult and/or in whom consequences of complications could be more serious. Although the ultrasound method has compared favorably with the landmark technique, its widespread use has been hampered by the impracticality of specially designed ultrasound devices or sterile scanner manipulation, unavailability of equipment, and lack of trained personnel. [5, 6]

The aim of this study is to compare between ultrasound technique (UST) and landmark technique (LMT) in insertion of internal jugular CVC by experienced intensivists in ICU mechanically ventilated patients.

2. Material and Methods

This prospective randomized trial was carried out on 200 ICU mechanically ventilated patients at King Fahd Military Medical Complex, Dhahran, Saudi Arabia, starting from June 2012 till June 2013.

Figure 1. Insertion of Central line with U/S guidance (Single operator)

Patients were randomly categorized into 2 groups: LMT group (100 patients) and UST group (100 patients) for insertion of CVC in the internal jugular vein using the seldinger technique.

Informed consent was taken from the patients' next of kin in the 2 groups and coagulation profile was checked before insertion of CVC. For patients with abnormal coagulopathy, the procedure was postponed until the correction of coagulopathy.

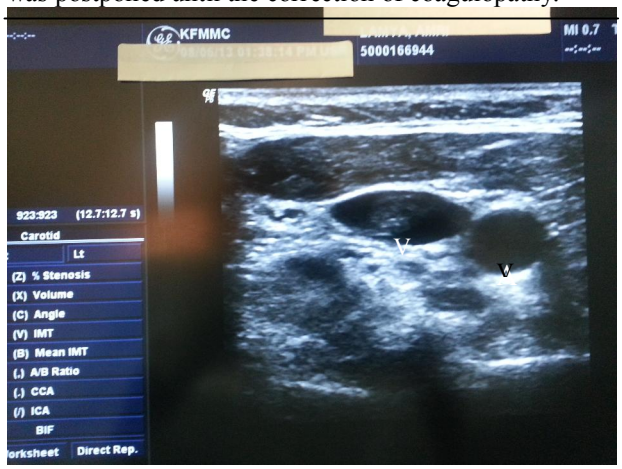

Figure 2. Anatomical relationship between Artery (A) and vein (V)

In the landmark technique, the skin at the top of the triangle between the two heads of the sternocleidomastoid muscle was cleaned and sterilization with disinfectants and appropriate draping was done. Then, local anesthetic was applied by a small needle. The CVC needle was directed at a 45° angle in the direction of the nipple of the same site of insertion. Aspiration of blood into the syringe attached to the needle confirmed entry into the internal jugular vein. A guide wire was then advanced through the needle into the vein, and the needle was removed. The CVC was placed over the wire and advanced into the vein. [7]

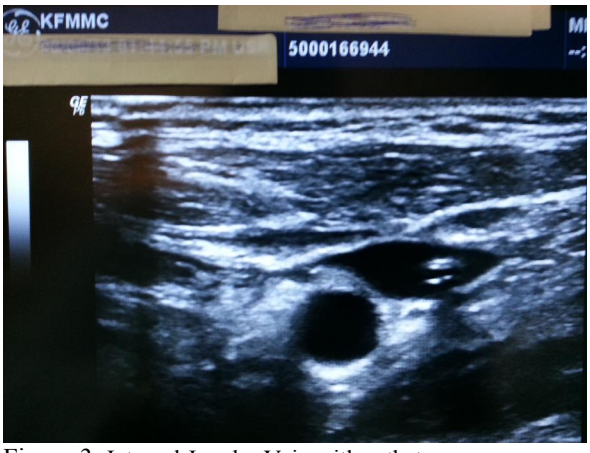

Figure 3. Internal Jugular Vein with catheter

All procedures in UST group were done by experienced intensivists who received training on ultrasound guided central venous cannulation using

dynamic ultrasound guidance by single hand (one operator) technique. (Fig 1)

In the ultrasound group, the skin of the neck was prepared in the same way as in landmark technique. Then linear (vascular) ultrasound probe covered by sterile sheath is applied by the non-dominant hand of the intensivist. Ultrasound two-dimensional (2D) imaging (by M-turbo, L05323, Sonosite, USA) was used to localize the IJV, evaluate its patency and compressibility, and identify whether there is any thrombus in the vein.(Fig 2) Cannulation was done by the dominant hand of the intensivist under continuous dynamic observation of real-time 2D images obtained by placing the transducer parallel and superior to the clavicle, over the groove between the sternal and clavicular heads of the sternocleidomastoid muscle. Then the placement of CVC is done through the same way as in the landmark technique. [8] (Fig 3)

Chest X- ray was done in all patients in the two groups after the procedure to verify the correct positioning of the CVC and to detect possible complications as pneumothorax or haemothorax.

Patients with prior recent catheterization (last 7 days), previous difficulties or complications during catheterisation, skeletal deformity, patients with previous surgeries or scarring in the neck and patients who need central venous cannulation under emergency situations as during cardiac arrest were excluded from the study.

Comparison between the 2 groups was done regarding the success rate, number of attempts, duration of the guide wire in the vein, the whole duration of the procedure and incidence of complications. The wholeduration of the procedure is defined as the time between penetration of skin and the insertion of the catheter.

Data were expressed as mean ± standard deviation. The Student *t* test for independent means, χ^2analysis, or Fisher exact test where appropriate were used to identify differences between the two groups. Correlations between continuous variables were assessed using the Pearson correlation coefficient. For ordinal data, the Spearman rank correlation was used. A *p* value (two-sided in all tests) of <0.05 was considered significant. SPSS software was used.

3. Results

The baseline characteristics of the two studied group is shown in table (1), no significant statistical difference was noticed between the two groups regarding age, sex number of previous attempts, site of catheterization and the body mass index (p = 0.640, 0.892, 0.822, 0.732, 0.932) respectively

Table (2) shows the success rate of the technique in both groups. The ultrasound group shows significant higher success rate as it was successful in 98/100 (98%) versus 87/100 (87%) in the landmark technique (p= 0.018).The number of attempts of cannulations ranged from 1 to 3 trials in the UST group with a mean of 1.2 ± 0.32 which was significantly better than LMT group as it was ranging from 1 to 4 with a mean value of 1.64 ± 0.44 (p= 0.000). The duration of the guidewire in the vein ranged from 10 to 95 seconds with a mean of 35.27 ± 17.46 in the UST group versus 7 to 120 seconds with a mean of 45.71 ± 28.77 in the LMT group (p= 0.004) . The whole duration of the procedure was also significantly shorter in the UST group as it ranged from 25 to 180 seconds with a mean value of 91.94 ± 38.73 versus 10 to 300 seconds with a mean value of 114.19 ± 62.32 in the LMT group (p = 0.000).

Table (1): Comparison between the two studied groups according to baseline characteristics

	Landmark Technique (LMT) "n=100"		Ultrasound Technique (UST) "n=100"		Test of sig.
	No	%	No	%	
Sex **Male** **Female**	**78** **22**	**78.0** **22.0**	**74** **26**	**74.0** **26.0**	χ^2**p = 0.640**
Age **Min. – Max.** **Mean ± SD**	**28 – 81** **60.88 ± 13.61**		**32 – 77** **59.90 ± 10.68**		**t p = 0.892**
Mean number of previous cannulations attempts	**1.32±0.45**		**1.41± 0.3**		**t p = 0.822**
Site of catheter insertion **Right** **Left**	**77** **23**		**80** **20**		χ^2**p = 0.732**
Body Mass Index **Min. – Max.** **Mean ± SD**	**24 – 38** **29.88 ± 8.61**		**21.5 – 42** **31.90 ± 9.38**		**t p = 0.932**

p: p value for comparing between the two studied group; χ^2: Chi square test; t: Student t-test

Table (2): Comparison between the two studied groups according to success of technique

	Ultrasound Technique (n=100)		Landmark Technique (n=100)		p
	No	%	No	%	
Number of successful trials	**98**	**98**	**87**	**87**	0.018
Number of attempts Min. – Max. Mean ± SD	1-3 1.2 ± 0.32		1-4 1.64 ± 0.44		0.000
Duration of guidewire in the vein (seconds)					
Min. – Max. Mean ± SD	10.0 – 95.0 35.27 ± 17.46		7.0 – 120.0 45.71 ± 28.77		0.004
Whole duration of the procedure (seconds) Min. – Max. Mean ± SD	25.0 – 180.0 91.94 ± 38.73		10.0 – 300.0 114.19 ± 62.32		0.000

Table (3): Comparison between the two studied groups according to incidence of complications

Complications	Ultrasound Technique (n=100)		Landmark Technique (n=100)		Test of sig.
	No	%	No	%	
Pneumothorax	0	0	2	2	P = 0.115
Arterial (Carotid) puncture	1	1	3	3	P = 0.96
Catheter related blood stream infections (CRBSI)	10	10	26	26	p = 0.02

The incidence of the complications related to the procedure is shown in table (3), two patients in the LMT group developed Pneumothorax which was diagnosed by chest X- ray post procedure and was treated by inserting chest tube while no patients developed pneumothorax in the UST group (p = 0.115). No cases of haemothorax were detected in all patients in both groups. Arterial puncture happened in one patient in the UST group and in three patients in the LMT group (p = 0.96). However, it was not clinically significant in the 4 patients as no serious hematoma occurred and responded to manual compression to stop further exsanguination. The incidence of catheter related blood stream infections (CRBSI) was significantly lower in the UST group as it happened in 10/100 patients (10%) versus26/100 (26%) in the LMT (p = 0.02).

4. Discussion

The use of CVCs might be associated with adverse effects that are sometimes hazardous to patients and expensive to treat. [9] Mechanical complications are reported to occur in 5% to 19% of patients, infectious complications in 5% to 26%, and thrombotic complications in 2% to 26%. [10, 11]

This relatively high incidence of complications triggered the use of advanced imaging technique as ultrasound guidance for insertion of CVCs. The beginning of this strategy was difficult as it was done through the interventional radiologists only, then the situation was changed as the application of ultrasound usage is increasing every day in ICU and it became a mandatory part of training for intensivists in many centers to master the basic ultrasound examination in ICU as well as the

ultrasound guided procedures as pleurocentesis and insertion of vascular catheters. protocols have been developed that use portable ultrasound (US) devices to provide bedside imaging of the central veins during catheter placement. The advantages associated with US-guided CVC placement include detection of anatomic variations and exact vessel location (for example, the carotid artery is anterior to the internal jugular vein in 3% to 9% of patients), avoidance of central veins with pre-existing thrombosis that may prevent successful CVC placement, and guidance of both guidewire and catheter placement after initial needle insertion.[12]

Medical ultrasound devices may be used to locate a vein in two ways. Real time ultrasonography generates a two dimensional grey scale image of the vein and surrounding tissues. Continuous wave Doppler ultrasonography generates an audible sound from flowing venous blood, with no information on depth of the vessel. [13]

The success rate of internal jugular venous cannulation in the current study was 11% higher in the ultrasound group (98% versus 87%) which is more or less comparable to the study done by Dimitrios Karakitsos et al [14] study which was done on 450 patients in each group and the success rate was significantly better in ultrasound group (100%) versus (94.5%) in the landmark technique. The same findings are applied in Dimitrios Karakitsos et al [14] study regarding the average number of trials which was 1.1 in the UST group versus 2.6 in the LMT group which is matching with our study results which showed also significantly less number of trials in the UST group. I n another study done by Tercan et al [15] to compare between adult and paediatric population in ultrasound guided central venous catheterization, the results in the adult group are more or less similar to our study as the success rate was 99.4% and the number of punctures was ranging from 1 to 3 with a mean of 1.05 ± 0.23. The duration of the procedure in the landmark technique is almost identical in our study as it was 45.71 ± 28.77 seconds and Dimitrios study as it was 44 ± 95 seconds, both studies also showed significant shorter time in the ultrasound group but it was much shorter in Dimitrios study being only 17.1 ± 16.5 seconds versus 35.27 ± 17.46 seconds in our study, this significant difference can be explained by variable degree of training on the usage of ultrasound, it seems that physicians inserting the central lines in Dimitrios study are mastering the ultrasound in a very professional way especially that they performed the procedure for 450 times in the study which gave them more chance for being well trained. In our institute, 8 intensivists were applying the procedure all of them received official training on ultrasound and they were able to perform the procedure effectively and safely although a little bit slow. Also, inaccurate recording of the procedure time might be a contributing factor to the difference between the 2 studies.

As regards the complications, the incidence of complications in our study, 2 patients (2%) developed pneumothorax in the landmark technique while no cases of pneumothorax in the ultrasound group. In Dimitrios et al study the pneumothorax also was zero in the US group and 2.4 % (11/450 patients) in LMT group. In another study done by Gordon et al[16] on the ultrasound puncture of the internal jugular vein where 869 cases were included, no recorded cases of pneumothorax. All these data are matching together and pointing to the fact that the use of ultrasound during internal jugular vein cannulation by experienced trained personnel may be able to eliminate the risk of a serious and potentially fatal complication as pneumothorax. The Carotid artery puncture happened only once (1%) in the US group and 3 times (3%) in LMT group with no serious hematoma in our study while the incidence of carotid puncture in Dimitrios et al study was 1.1% with 0.4% occurrence of hematoma in the US group versus 10.6% and 8.4% in the landmark technique. Although the incidence in the UST group was similar in both studies but the arterial puncture and hematoma formation was significantly high in Dimitrios et al study. In Tercan et al study the carotid artery puncture and hematoma happened in 4 patients (0.5%) While in Gordon et al study the arterial puncture happened in 13 patients (1.5%) with only one patient who developed hematoma.[14,15,16] The slight discrepancy between the incidence of arterial puncture in different studies can be explained by different sample size and also by different levels of technical skills of the personnel involved in the different studies. The only reported as significantly lower complication in the UST group in our study was the catheter related blood stream infections (CRBSI) which was 26% in the LMT group and only 10% in the UST group (P= 0.02*). The same incidence was found in the ultrasound group in Dimitrios et al study (10.4%) and (16%) in LMT group. Again, the ultrasound technique achieved a significant reduction in the CRBSI which is well known as a nightmare to all intensivists as it is endangering the life of their critically ill patients.

The simplicity and high success rate of the ultrasound technique in the insertion of central venous catheters as well as the lower incidence of complications create a greater tendency for more and more application of this technique as a gold standard of practice in many hospitals especially for internal jugular vein cannulation. This strong and growing evidence encourage many investigators to advance

their practice to include the subclavian vein cannulation by ultrasound assistance also although it is well known that its visualization and cannulation through the ultrasound technique is more difficult compared to the internal jugular vein. A recent study published in 2011 by Fragou M et al[17] investigates the ultrasound technique versus the landmark technique in subclavian vein cannulation. The results showed that Subclavian vein cannulation was achieved in 100% of patients in the ultrasound group as compared with 87.5% in the landmark one ($p < .05$). Average access time and number of attempts were significantly reduced in the ultrasound group of patients compared with the landmark group ($p < .05$). In the landmark group, artery puncture and hematoma, hemothorax, pneumothorax, brachial plexus injury, phrenic nerve injury, and cardiac tamponade were all increased compared with the ultrasound group ($p < .05$). Catheter misplacements did not differ between groups. In this study, the real-time ultrasound method was rated on a semiquantitative scale as technically difficult by the participating physicians. They concluded that ultrasound-guided cannulation of the subclavian vein in critical care patients is superior to the landmark method and should be the method of choice in these patients Which is the same result in almost all studies done for internal jugular cannulation with the only difference noted previously related to the difficult technique in the subclavian route which definitely needs more training and experience.

We believe that using the ultrasound technique for central venous cannulation is a really promising and excellent advance in the critical care practice in the last few years. However, if this task is not preceded by adequate official training , it may result in more complications and our advice for intensivists to use their basic skills to insert central line by the landmark technique until they get the opportunity for ultrasound training.

The limitations of our study are related to two main points. The first point is the relatively small sample size which makes our conclusions especially in comparison of the complications inconclusive. The second point is related to the ultrasound training of the participating physicians in the study as all of them were trained but in different places and different durations.

The final conclusion of this study is that the insertion of internal jugular vein catheters in ICU mechanically ventilated patients using UST technique was superior to LMT in term of higher success rate, less number of attempts and shorter duration of the procedure while no significant difference was detected between the 2 groups regarding the occurrence of complications except for CRBSI which was significantly less in the UST group.

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Corresponding Author:
Dr. Amr M. Abouelela
Department of Critical Care Medicine
Faculty of Medicine, Alexandria University, Egypt
ICU department of King Fahd Military Medical Complex, Dhahran, Saudi Arabia
E-mail: amrela313@yahoo.com

Information of Authors

Dr. Ashraf Shamekh Altayar
Consultant intensivist. ICU department
King Fahd Military Medical Complex,
Dhahran, Saudi Arabia
Mail: KFMMC, PO box 946, Dhahran, KSA
Cell Phone: 00966502919750
E-Mail: altayar.ashraf@gmail.com

Dr. Amr Mohamed Abouelela
Ass. professor of Critical Care Medicine.
Critical Care Medicine Department.
Faculty of Medicine , University of Alexandria.
Consultant Intensivist. ICU department
King Fahd Military Medical Complex,
Dhahran, Saudi Arabia
Mail: KFMMC, PO box 946, Dhahran, KSA
Cell Phone: +966532843194
E-Mail: amrela313@yahoo.com

Dr. Khaled Sewify
Consultant intensivist & head of ICU department
King Fahd Military Medical Complex,
Dhahran, Saudi Arabia
Mail: KFMMC, PO box 946, Dhahran, KSA
Cell Phone: +966544802229
E-Mail: drsewafie@hotmail.com

Dr. Mohamed El-Sirafy.
Lecturer of Radiology.
Faculty of Medicine.
Alexandria University, Egypt.
Consultant Radiologist,
King Fahd Military Medical Complex,
Dhahran, Saudi Arabia.
Mail: KFMMC, PO box 946, Dhahran, KSA
Cell Phone: +966542529141
E-Mail: sirafy@yahoo.com,

Dr. Khaja Mohiuddeen
Anaesthesia and ICU Department
King Fahd Military Medical Complex,
Dhahran, Saudi Arabia
Mail: KFMMC, PO box 946, Dhahran, KSA
Cell Phone: +966530657911
E-Mail: drkhaja@gmail.com

Dr. Amr Mohammed Farghaly Mohammed
Anaesthesia and ICU Department
King Fahd Military Medical Complex,
Dhahran, Saudi Arabia
Mail: KFMMC, PO box 946, Dhahran, KSA
Cell Phone:+966541267214
E-Mail: farghely@yahoo.com

Dr. Ashraf Amin Mohammed Hussein
ICU Department
King Fahd Military Medical Complex,
Dhahran, Saudi Arabia
Mail: KFMMC, PO box 946, Dhahran, KSA
Cell Phone:+966536189329
E-Mail: ashraf_amin32@yahoo.com

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