Ultrasound guidance versus anatomical landmarks for subclavian vein catheterization: a prospective study

Echoguidage versus repérage anatomique pour le cathétérisme de la veine sous-clavière: étude prospective

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Abstract

Background: Several clinical practice guidelines strongly support the use of ultrasound guidance (USG) for internal jugular vein catheterization. The level of evidence concerning the use of USG for subclavian vein (SCV) cannulation remains low.

Aim: To compare the effectiveness and safety of USG and anatomical landmarks approaches for cannulation of SCV.

Methods: This was a prospective randomized study. Patients aged over 18 years old who requiring elective central venous catheterization were included. Non-inclusion criteria were thrombosis of the vein or major coagulopathy. All catheterizations were performed by two anaesthesiology residents. Patients were randomized into two groups: ultrasound guidance group (US group) and anatomical landmarks (LM group). The main outcome was the success rate. The secondary outcomes were the first attempt success rate and the incidence of complications.

Results: Seventy patients were included (35 in each group). The success rate was higher in US group compared to LM group without statistical significance (100% vs 85.7%; p=0.054). The first attempt success rate was significantly higher in the US group (82.9% vs. 40%; p<10-3). The incidence of mechanical complications was significantly lower in the US group compared to LM group (5.7% vs. 37.1%; p=0,001).

Conclusion: according to our study, US guidance for SCV catheterization seems to be an interesting alternative to anatomical landmarks approaches

Key-words: catheterization, subclavian vein, ultrasonography, intensive care units.

Résumé

Introduction : L'échoguidage en temps réel de la veine jugulaire interne est recommandé par les sociétés savantes. Cependant, peu d'études ont évalué l'apport de l'échoguidage pour le cathétérisme de la veine sous-clavière (VSC).

Objectif : Comparer le cathétérisme de la VSC par échoguidage en temps réel par apport au repérage anatomique externe.

Méthodes : Il s'agit d'une étude prospective randomisée. Les patients âgés ≥ 18 ans proposés pour cathétérisme veineux central en dehors d'un contexte d'urgence ont été inclus. Les critères de non-inclusion étaient la thrombose de la VSC ou une coagulopathie sévère. Toutes les procédures ont été effectuées par deux résidents. Les patients ont été randomisés en deux groupes : groupe échoguidage (GE) et un groupe cathétérisme par voie classique (GC). Le critère de jugement principal est le taux de succès global. Les critères de jugement secondaires étaient le taux de succès dès la première ponction et le taux de complications.

Résultats : Soixante-dix patients ont été inclus (35 dans chaque groupe). Le taux de succès global était plus élevé dans le GE par apport au GC mais statistiquement non significatif (100% vs 85,7% respectivement ; p=0,054). L'échoguidage en temps réel a permis d'augmenter significativement le taux de succès dès la première ponction (GE : 82,9% vs GC : 40% ; p<10-3) et de diminuer significativement l'incidence globale des complications mécaniques (GE : 5,7% vs GC : 37,1% ; p=0,001).

Conclusion : Selon notre étude, l'échoguidage en temps réel pour le cathétérisme de la VSC semble être une alternative intéressante par apport au repérage anatomique externe.

Les mots clés : cathétérisme veineux central, échographie, veine sous-clavière, unité de soins intensifs.

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INTRODUCTION

The central venous catheterization (CVC) is a commonly performed procedure in anesthesiology and intensive care (1). Subclavian vein (SCV) has many advantages compared to the internal jugular vein (IJV) namely improved patient's comfort, easier nursing care, lower rates of catheter-related blood stream infection and easier access in cervical trauma with needed collar (2-3). However, given its anatomical relationship with subclavian artery and pleura, the cannulation of SCV could be associated with severe complications such as pneumothorax or hemothorax (4-5).

Several meta-analysis and recent clinical practice guidelines strongly support the use of ultrasound guidance (USG) for IJV-CVC (6). Indeed, a reduction in complications and an improvement in first pass success have shown when USG was used in comparison with the anatomical landmarks method for IJV cannulation (7-8).

The level of evidence concerning the use of USG for subclavian vein (SCV) cannulation remains low despite the results of various scientific publications demonstrating the interest of USG in reducing the rate of complications (9).

The aim of this study was to compare the effectiveness and safety of USG and anatomical landmarks approaches for cannulation of SCV in adult intensive care unit (ICU).

METHODS

This was a prospective randomized study, conducted in the ICU after obtaining approval by the local ethics committee and registration in the ClinicalTrials.gov database (NCT04690296).

We enrolled all patients older than 18 years requiring elective CVC after obtaining a written informed consent from the patient or trusted person. The exclusion criteria were the vein thrombosis, major blood the coagulation disorders, cannulation site infection.

Patients were randomly divided according to computer generated randomized table into two groups. A group underwent real time USG-SCV catheterization (US group) and the other group received anatomical LM catheterization (LM group).

All procedures were performed by tow anesthesiology residents trained in central venous catheter placement, each of whom had performed at least 15 CVC using both techniques before standing the study. All procedures were supervised by experimented operator.

All patients were placed in slightly Trendelenburg position. The operators stood beside the patient. They underwent ultrasound scanning of the infraclavicular area to detect an eventual venous thrombosis.

The anterosuperior region of the chest was prepared in a sterile way. In the LM group, we chose the Aubaniac technique to cannulate the SCV (10). The needle was inserted 1 cm inferior and laterally to the junction of the medial one-third and lateral two-thirds of the clavicle, it was passed below the clavicle and above the first rib and it was advanced parallel to the floor, through the subclavian muscle, until it entered the SCV.

In the US group, we chose the infraclavicular approach with long axis view (11).

A portable ultrasound unit (Mindray M7®, Shenzhen, China) equipped with a 12 MHz linear transducer was used. The probe was covered with ultrasonic gel and wrapped in a sterile sheath. The first step was to visualize the SCV and the artery in a short axis view. Then, maneuvers of the transducer were performed to expose the axillary vein and in its continuation till the SCV on the longitudinal axis to achieve an optimum plane of catheterization. The probe was handled by the non-dominant hand. The needle was introduced slowly with the dominant hand so that its tip's trajectory could be detected superficially. It was advanced in real-time toward the lumen of the vein, on the longitudinal axis, while it was directed toward the acoustic shadow of the thoracic rib underneath. This leads to minimize the risk of damaging the pleurae and the lung in case of vein transfixion. Hence, the needle entered the lumen of the vessel either at the level of the axillary vein or at the level of its medial continuation by the SCV.

In the both techniques, the intravascular position of the needle was assessed by venous blood reflux. The guidewire and the catheter were advanced according to the Seldinger technique (12).

Chest X-ray was used to evaluate the position of the catheter tip and to detect pneumothorax. Hematoma was detected by ultrasonography.

Demographic characteristics, presence of risks factors for difficult CVC (obesity defined by BMI ≥ 30, anterior catheterization and difficulty of a previous puncture) and side of cannulation were recorded for all patients.

The primary outcome was the the success rate defined as the proportion of the correct placement of the guidewire into the intended vein obtained within four attempts. Failure was defined by a number of attempts greater than or equal to five.

The secondary outcomes were: the first attempt success rate defined as the proportion of the correct placement of the catheter into the intended vein with single skin puncture, the access time (access time was recorded from the first skin puncture to venous blood aspiration) , the number of attempts, redirections rate, number of redirections, access time (defined as the time between the skin puncture and the reflux of venous blood) and complications rate such as hematoma, pneumothorax, arterial puncture and misplacement of the catheter.

Statistical analysis

Sample size was calculated assuming a difference of proposition of success rate at 20% with a statistical power of 0.85 (alpha=0.05). The precise sample size estimation was 33 per group.

Statistical analyses were performed using SPSS 20.0 software. Normal distributions of continuous variables were compared using Student t-test .Mann-Whitney U test was used for continuous variables without normal distribution. Categorical variables were compared using the $\chi 2$ test and Fisher exact test. Data were expressed as mean ± SD or as median (25th percentile – 75th percentile). A p value (two-sided in all tests) of 0.05 was considered significant. A linear regression was used to evaluate the relation between access's time and patient's range.

RESULTS

Seventy procedures were analyzed, 35 in each group. Demographics characteristics and clinical data were similar in both groups (table 1).

Table 1. Baseline characteristics of the study population

		Group LM	Group US	p
Age (years) [a]		44 ± 18	48 ± 20	NS[b]
Sex (male/female)		26/9	26/9	NS[c]
BMI (kg/m^2)	>30	4 (11,4%)	7 (20%)	NS[c]
	< 30	31 (88,6%)	28 (80%)	NS[c]
Side (Right/Left)		15/20	16/19	NS[c]

[a] Mean±SD; NS: not significant; [b] Student t-test; [c] Fisher exact test.

The success rate was higher in the USG compared to the LMG without statistical significance (100% vs 85.7%, respectively; p=0.054). However, in obese subgroup including 7 patients in USG and 4 patients in LMG, the success rate was significantly higher in US sub group than LM sub group (100% vs 21%, respectively; p=0.024).

The first attempt success rate was significantly lower in Group LM compared to Group US (40% versus 82.9% respectively; p=<10-3).

The USG group was associated with a shorter access time than LM group (19s [14-40] vs 48s [15 – 70] respectively; p=0.028).

We also recorded in US group a significant lower number of attempts compared to group LM (1[1-1] vs 2[1-4], respectively; $p<10^{-3}$) as well as redirection rate of needle (68.6% vs 14.3%, respectively; $p<10^{-3}$).

The overall mechanical complications rate was significantly lower in USG group than the LM group (5.7% vs 37.1%, respectively; p=0.001). We recorded 2 cases of misplacement of the catheter in the homolateral IJV in USG group. No case of hematoma, pneumothorax or arterial puncture were observed in the last group. In the LM group, there were 5 cases of arterial puncture (14.3%), 9 cases of hematoma (25.7%), 2 cases of pneumothorax (5.7%) and one case of misplacement of the catheter.

The evolution of the access time as a function of the rank of the patients in the 02 groups showed that there is a statistically significant relationship in the US group with r=0.5854 and p=0.00022 (figure1). While in the standard group, this relationship is very weak (r=0.24) and statistically not significant (p=0.2) (figure2).

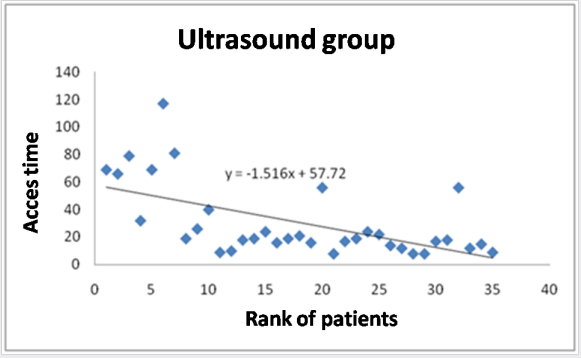

Figure 1. Evolution of reflux times according to the rank of patients in the ultrasound-guidance group.

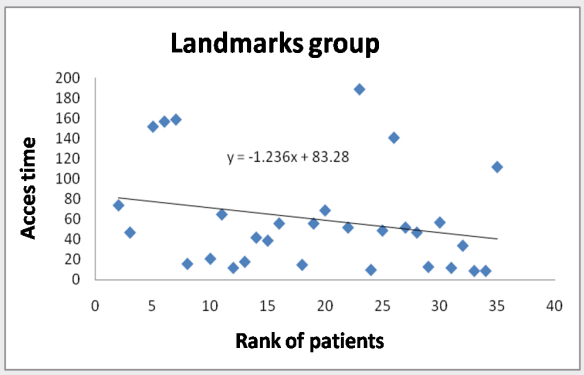

Figure 2. Evolution of reflux times according to the rank of patients in the landmarks group.

Table 2. Outcome measures in the ultrasound group vs. the landmark group

	US group	LM group	p
Success rate	100%	85,7%	0.054[b]
Success rate in subgroup obesity	100%	25%	0.024[b]
First attempt Success rate	82,9%	40%	0.000[b]
Number of attempts[a]	1 [1-1]	2 [1-4]	0.000[c]
Incidence of redirection of the needle	14,3%	68,6%	0.000[b]
Number of redirections[a]	0 [0-0]	2 [0-5]	0.000[c]
Access time [a]	19 [14-40]	48 [15,75-70,25]	0.028[c]
Complications rate	5,7%	37,1%	0.001[b]
Arterial puncture	0	14,3%	0.54[b]
Hematoma	0	25,7%	0.002[b]
Pneumothorax	0	5,7%	0.493[b]
Malposition	5,7%	2,9%	1.00[b]

[a]Mean±SD ; NS : not significant ; [b] Student t-test ; [c] Fisher exact test

DISCUSSION

Our prospective and randomized study demonstrated that USG of SCV catheterization permitted a significantly higher success rate from the first attempt and a significant reduction in complications.

The overall success rate was higher in the UG group compared to LM group but the difference was statistically not significant. Our data confirms the results of the few previous studies concerning SCV cannulation (13,14). This result is in line with recent meta-analysis and systematic review that clearly shows the advantage of the USG compared to anatomic LM guidance techniques cannulation, including fewer complications and higher success rate (15).

In addition, the use of real-time USG for CVC insertion has repeatedly

demonstrated better outcomes compared to other techniques (static USG or Doppler) especially in terms of success rate and has been recommended to be used routinely for CVC (6,16).

Our study showed that USG in case of difficult catheterization (obesity in the mean example in our study) would be particularly beneficial. These findings are supported by the study of Hatefield (17) in which he assesses the usefulness of USG in 33 patients presenting various risk factors of difficult catheterization.

From a technical point of view, we adopted the longitudinal approach to US guided SCV catheterization. We should notice the great contribution of this approach to have such results. Compared to the short-axis approach, this technique enables the operator to visualize the whole needle, including its tip, from entry into the skin until vessel puncture. So, the long-axis approach would be associated with greater first-attempt success, fewer needle redirections (18) and lower complications rate mainly less arterial puncture and posterior wall penetration (which could cause pneumothorax) (19).

In this study, the VSC catheterizations were performed by inexperienced residents in training.

The evolution of the access time according to the rank of the patient shows a learning effect in the USG group but not in the LM group because the slope of the curve is very low so we cannot predict the difficulty of the method even among experienced operators.

This finding is confirmed by Galtieri (20) who concluded that USG for catheterization of the SCV improves the success rate for less experienced operators.

Our study had some limitations. First, there was a lack of follow-up of long-term complications especially thrombotic and infections complications. Second, the cannulation was performed by tow residents in training in US-guided CVC placement.

CONCLUSION

According to our study, US guidance for SCV catheter seems to be a safe and effective method to performing CVC insertion in ICU adult patient and provides a interest alternative technique for catheterization. This technique is easy to learn allowing the intensivist attending to have a quick improvement of his practice.

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