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Effectiveness of Ultrasonography Guided Subclavian Catheterization

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Abstract

Background: Central venous catheterization (CVC) insertion is a prevalent invasive procedure performed in critical care patients. Although this procedure is considered to provide better patient comfort and a lower infection risk compared to other methods, it has a higher risk of complications, such as pneumothorax, arterial puncture, nerve injury, and bleeding. Ultrasonography (USG)-guided subclavian catheterization has recently become a popular technique. This study retrospectively analyzed 50 patients in the intensive care unit (ICU) who underwent infraclavicular subclavian catheterization with the out-of-plane technique under USG guidance.

Objectives: This study aimed to evaluate the effectiveness of subclavian catheterization applied with the out-of-plane technique in the ICU.

Methods: This retrospective study included 50 patients who underwent subclavian CVC insertion via the out-of-plane technique under USG guidance in the ICU between March and December 2020. Age, gender, height, weight, body mass index, admission to the ICU, use of anticoagulant and/or anti-aggregant medicine, and coagulation parameters were recorded for each patient. The success of the procedure, the number of attempts, and the duration of the procedure were scanned retrospectively from the records. Malposition and complications were monitored using USG throughout the procedure and chest radiographs after the procedure.

Results: The 50 patients comprised 27 (54%) men and 23 (46%) women, with a mean age of 72.8±11.8 years. In all patients, subclavian CVC insertion was successfully performed under USG guidance via the out-of-plane technique. The mean procedural time was 220.90±60.20 sec. The procedure was completed in a single session for 27 (54%), two sessions for 22 (44%), and three sessions for 1 (2%) patient. Only one complication (pneumothorax) developed in one patient, who underwent tube thoracostomy. No catheter malposition was observed in other patients.

Conclusion: USG-guided subclavian catheterization is a safe technique to be performed by experienced practitioners.

Keywords: Landmark, Out-of-plane technique, Subclavian vein, Ultrasonography

1. Background

Central venous catheterization (CVC) insertion is a common invasive procedure performed on critical care patients. Common indications for CVC insertion include intravenous fluid therapy, total parenteral nutrition, central venous and pulmonary artery pressure monitoring, and the requirement of hemodialysis (1,2).

While internal jugular vein (IJV) cannulation is preferred more frequently in critical care patients, subclavian CVC insertion is avoided due to the high risk of complications, particularly mechanical ones (1,3).

Despite the lack of substantial evidence, subclavian catheterization is considered to reduce the infection rate and thrombosis risk in critical care patients. Additionally, long-term use of this catheter is more useful for patient comfort due to its localization (1,4).

Ultrasonography (USG) is used for various processes on critical care patients, predominantly for CVC insertion. The use of USG for IJV and femoral catheterization procedures has become a routine practice. It is mostly performed to reduce complications, such as pneumothorax, arterial puncture, hemothorax, and nerve injury. In addition, CVC insertion can be safely performed after detecting anatomical variants and vascular anomalies (1,5, 6). However, USG is rarely used for subclavian catheterization, compared to IJV cannulation, due to the difficulty of obtaining images and the need for greater experience in subclavian catheterization (7). On the other hand, real-time USG-guided subclavian catheterization insertion has recently become a popular procedure (8, 9).

The classical landmark technique for subclavian CVC insertion is not preferred by many clinicians due to the risk of pneumothorax, which is a critical complication, and also not administered in clinical practice very often (10). This disadvantage further limits its use in patients with a diagnosis of emphysema, chronic obstructive pulmonary disease (COPD), and respiratory failure (1,10). However, its complications can be reduced, and it can become a more viable technique when performed under USG guidance. Moreover, studies have shown that USG-guided catheterization reduces pneumothorax, arterial puncture, and hematoma (8,11).

To date, numerous techniques have been described for USG-guided subclavian CVC insertion. Among these, the infraclavicular approach is commonly used, either with longitudinal (in-plane) or short (out-of-plane) ultrasound axis. Additionally,

USG-guided subclavian CVC insertion has been shown to have higher success when administered by both experienced and less experienced practitioners and to have fewer mechanical complications, compared to the classical landmark technique for subclavian CVC insertion (1,8-11).

This study retrospectively analyzed 50 patients who underwent infraclavicular subclavian catheterization with the out-of-plane technique under USG guidance.

2. Objectives

The aim was to evaluate the effectiveness of subclavian catheterization applied with the out-of-plane technique in the intensive care unit (ICU).

3. Methods

This retrospective study reviewed the medical records of 112 patients followed up in the ICU between March and July 2020. Among these, 50 patients that underwent subclavian CVC insertion via the out-of-plane technique under USG guidance were included in the study. Age, gender, height, weight, body mass index (BMI), admission to the ICU, use of anticoagulant and/or anti-aggregant medicine, and coagulation parameters were recorded for each patient. The study was approved by the local Ethics Committee (Date: July 2, 2020; No: 680).

The success of the procedure, the number of attempts, and the duration of the procedure (time from skin puncture to the insertion of the catheter into the vein) were scanned from the records. Malposition and complications were monitored using USG throughout the procedure and via chest radiographs after the procedure.

Inclusion criteria were all patients that underwent subclavian CVC insertion via the out-of-plane technique under USG guidance in the ICU. On the other hand, patients that underwent subclavian CVC insertion via other techniques or IJV and femoral cannulation were excluded from the study.

3.1. Catheterization technique

Subclavian CVC insertion was performed via the out-of-plane technique on each patient. The patient was placed in the supine position, and the right and left subclavian veins, as well as arteries, were visualized on USG to determine the most appropriate side for operation (Figure 1A). Following the sterilization procedures, 3 ml of 2% prilocaine was diluted with 3 ml of 0.9% sodium chloride solution (1% concentration) and then applied to the targeted infraclavicular area (Figure 1B). The pleura and the subclavian vein, as well as the artery, were identified using the USG probe via the out-of-plane technique. Following the skin sterilization, and the USG probe, a 12 MHz linear USG probe (Esaote Mylabsix SpA, Genoa, Italy) was inserted in the infraclavicular area. The subclavian vein and artery, pleura, and lung were visualized in the transverse short-axis view (Figure 1A). The subclavian vein was viewed obliquely by rotating the probe 45° (clockwise for the right CVC and anticlockwise for the left CVC). Skin puncture was performed in the middle of the probe using an 18G 6.5 cm introducer needle (by inserting the guidewire through the needle). The needle was advanced under USG guidance using the out-of-plane technique, and then the localization of the needle was confirmed using the in-plane technique (Figure 2). Subsequently, a three-port central catheter (Arrow International, Reading, PA, USA) was inserted according to the Seldinger technique. Throughout the procedure, the IJV was monitored by USG for catheter malposition. After the procedure, the location of the catheter was confirmed by chest radiography.

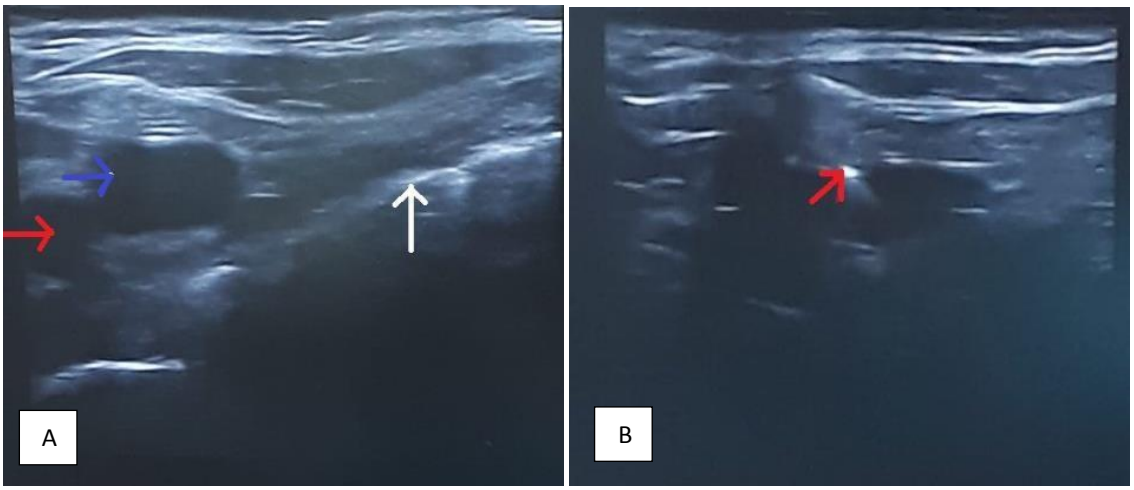

Figure 1. A: Ultrasound image showing the administration of the out-of-plane technique (blue arrow: subclavian vein, red arrow: subclavian artery, white arrow: pleura), **B:** The out-of-plane technique (the white area pointed by the red arrow shows the needle insertion point)

Figure 2. Ultrasound image showing the advancement of the needle into the catheter in the subclavian vein via the in-plane technique (red arrow: the subclavian vein, blue arrow: the subclavian artery, white line in the blue circle: the projection of the catheter)

At the end of the procedure, procedural time (time from skin puncture to the insertion of the catheter into the vein), the number of attempts, catheterization duration, malposition, and complications were recorded for each patient.

3.2. Statistical analysis

Data were analyzed using the SPSS software for Windows (version 22; SPSS Inc., Chicago, IL, United States). Whether the distribution of continuous variables was normal or not was determined by the Kolmogorov-Smirnov test. The Levene test was also used for the evaluation of the homogeneity of variances. Continuous data were described as mean±SD for skewed distributions. Categorical data were presented as the number of cases (%). Statistical differences in not normally distributed variables between two independent groups were compared by the Mann-Whitney U test. The degree of the relationship between variables was assessed with Spearman correlation analysis. A P-value of <0.05 was considered significant in all statistical analyses.

4. Results

The 50 patients comprised 27 (54%) men and 23 (46%) women with a mean age of 72.8±11.8 years. The mean body height was 168±10 cm, the mean body weight was 76.5±11.8 kg, and the mean BMI was 32.6±15 kg/m^2. Pneumonia was the most common indication for ICU hospitalization (n=22), followed by COPD (n=13), lung carcinoma (n=8), acute kidney failure (n=4), and cardiopulmonary resuscitation (n=3) (Table 1).

Out of all patients, 45 (90%) were receiving low-molecular-weight heparin treatment, 2 (4%) were using acetylsalicylic acid, 2 (4%) were using clopidogrel, and 1 (2%) patient was using a new generation of oral anticoagulant (Table 1).

The mean prothrombin time was 13.09±1.02, the mean activated partial thromboplastin time was 28.3±2.5, and the mean international normalized ratio was 1.5±0.2. The mean platelet (PLT) count was 212±100 x109/L, and the minimum PLT count was 90x109/L.

The mean procedural time was 220.90±60.20 sec. In all patients, subclavian CVC insertion was successfully performed under USG guidance via the out-of-plane technique. The procedure was not terminated due to failure in any patient, and it was completed in a single session for 27 (54%), two sessions for 22 (44%), and three sessions for 1 (2%) patient.

The malposition of the catheter was monitored using USG throughout the procedure and via posteroanterior chest X-rays after the procedure. Following the insertion of the catheter, no failure or malposition was observed in any patient. Only one complication (pneumothorax) developed in one patient, who underwent tube thoracostomy. No arterial injury, bleeding, or nerve injury occurred in any patient. The mean catheterization duration was 17.4±8 days in all patients.

There is no significant difference in the duration of the procedure and the number of attempts according to the admission cause to the ICU (Table 2). No significant relationship was found between the procedural time, as well as the number of attempts, and age, weight, and BMI (P>0.05). (Table 3).

Table 1. Patients' characteristics

	Variables	n	%
Gender	Male	27	54
	Female	23	46
ICU Admission cause	Pneumonia	22	44
	Chronic Obstructive Pulmonary Disease	13	26
	Lung Carcinoma	8	16
	Acute Kidney Failure	4	8
	Cardiopulmonary Resuscitation	3	6
Anticoagulant use	Low-Molecular-Weight Heparin	45	90
	Acetylsalicylic Acid	2	4
	Clopidogrel	2	4
	New Generation Oral Anticoagulant	1	2

ICU: Intensive Care Unit

Table 2. Comparison of procedural time and number of attempts in various causes of ICU admission

		Duration of procedure (second)	P-value*	Number of attempts	P-value*
		Mean±SD		Mean±SD	
COPD	Yes	199.17±57.40	0.138	1.25±0.45	0.125
	No	227.82±60.25		1.53±0.56	
Pneumonia	Yes	229.60±59.84	0.209	1.56±0.51	0.128
	No	212.28±60.66		1.36±0.57	
Acute Kidney Failure	Yes	220.85±57.77	0.959	1.46±0.55	0.877
	No	222.00±96.35		1.50±0.58	
Post Cardiac Arrest	Yes	221.85±59.51	0.728	1.45±0.54	0-533
	No	206.67±85.05		1.67±0.58	
Lung Carcinoma	Yes	217.49±60.33	0.335	1.42±0.54	0.213
	No	210.31±58.13		1.31±0.31	

* Mann Whitney U test
ICU: Intensive Care Unit
COPD: Chronic Obstructive Pulmonary Disease

Table 3. Relationship between procedural time, as well as the number of attempts, and age, weight, and BMI

		Duration of procedure (second)	Number of attempts
Age	Spearman's ρ	-0,115	-0,139
	P-value	0,427	0,337
Weight	Spearman's ρ	0,189	0,185
	P-value	0,188	0,200
BMI	Spearman's ρ	0,095	0,056
	P-value	0,512	0,701

BMI: Body Mass Index

5. Discussion

In the present study, the administration of subclavian CVC insertion via the out-of-plane technique under real-time USG guidance led to a remarkably low complication rate, with pneumothorax being developed in only one patient. Additionally, no catheter malposition was observed in any patient, and the displacement of the catheter into the internal jugular vein, which is a common malposition, was prevented by USG.

The use of USG significantly facilitates CVC catheterization. USG-guided CVC catheterization was first described in the 1990s and has grown more popular year by year. Moreover, the landmark technique is still used actively, particularly in subclavian CVC (1,2,5).

Real-time USG has become a routine technique in IJV and femoral vein catheterization and has been shown to reduce complications caused by CVC applications and the number of attempts (1). Although the use of USG for subclavian CVC is recommended, it has not entered clinical practice as much as IJV cannulation and other methods due to the difficulty in obtaining UGG images and the requirement for greater experience (7,9,10).

The infraclavicular approach is commonly used for CVC insertion under real-time USG guidance, either with the longitudinal (in-plane) or short (out-of-plane) ultrasound axis. In the out-of-plane technique, the ultrasound beam is orientated in a transverse plane perpendicular to the target vessel such that the vessel appears as a circular structure. The advantages of this approach include better visualization of proximal structures and relative ease for less experienced operators. However, it can be disadvantageous as it produces a cross-sectional image, on which the tip of the needle appears similar to any other structure and thus can lead to inadvertent posterior wall puncture of the target vessel.

By contrast, the in-plane technique is performed with the USG beam aligned parallel to the target vessel, and the needle is maintained within the plane of the USG beam. The advantage of this technique is that the entire needle can be visualized while it is inserted into the vessel, although it requires greater

experience (11).

In this study, subclavian CVC insertion was performed via the out-of-plane technique under real-time USG guidance on each patient. Moreover, no arterial injury, bleeding, or nerve injury occurred in any patient. Based on these findings, real-time IJV catheterization, which is widely used all over the world and has become a routine practice in our clinic, can be safely used in subclavian catheterization as well. It is also considered that monitoring vascular and neural structures with USG will increase the confidence of physicians, particularly in patients with emphysematous lungs and a high risk of bleeding and pneumothorax. The reported rate of pneumothorax in subclavian interventions performed with the landmark technique is approximately 1%-6.6%, which is likely to increase with the number of unsuccessful attempts (12-15). Although the prevalence of mechanical complications, such as pneumothorax, has decreased in real-time USG, these complications still exist (16,17). Additionally, mechanical complications caused by catheterization can be higher in patients with an increased number of attempts and a BMI of below 20 kg/m^2 or above 30 kg/m^2, even when the procedure is performed by an experienced operator (14,17). In our study, the only complication was pneumothorax in only one patient. A chest tube was inserted in the patient, and there was no complication in the follow-up. Additionally, in line with the literature, the patient had a BMI of <20 kg/m^2. Except for pneumothorax, no malposition or other mechanical complications occurred in any patient.

Fragou et al. (10) compared real-time USG-guided subclavian catheterization with the in-plane technique versus the landmark technique and reported that mechanical complications were observed in a limited number of patients and no pneumothorax developed in any patient. However, catheter malposition was observed in almost 10% of the patients. In the present study, USG monitoring provides the opportunity to reposition the catheter in the superior vena cava in case of malpositioning.

Previous findings indicate that USG-guided subclavian catheterization provides higher success rates with lower complication rates (10-12,16,17). Nevertheless, studies comparing the in-plane and out-of-plane techniques are limited. A previous meta-analysis (18) indicated that success rates in both applications were similar, while larger controlled studies were required. In the present study, the success rates were also similar.

In previous studies, the number of repetitive attempts is limited to three, and studies have reported that the rate of failure and complications increases as the number of attempts increases (10,11,18). In the clinic under study, the number of attempts was limited to three, and the technique or the needle insertion point was changed in case of failure. Moreover, although the number of patients that underwent two attempts in the present study was higher than those reported in previous studies, the present complication rate was remarkably low.

In this study, after performing sterilization and surgical cleaning during the procedure, the mean procedural time (i.e. time from the insertion of the needle to reach the superior vena cava) was measured at 220 sec (range: 110-350 sec). It is considered that this period is an indication of a successful procedure and that further studies are needed to compare the technique used in this study to the landmark technique and other techniques. Tammam et al. compared the out-of-plane, in-plane, and landmark techniques in USG-guided IJV cannulation in 90 ICU patients and reported the mean procedural times as 52.30, 52.70, and 116.57 sec, respectively. The authors also found a significant difference between the landmark technique and the other two techniques(15).

The present study was limited due to its retrospective nature and the limited number of patients. One of its limitations is that it cannot be a comparative study regarding other techniques.

6. Conclusion

It is considered that subclavian catheterization performed with the out-of-plane technique under USG guidance will decrease complications and increase the success rate of the procedure, as well as patient comfort. Nevertheless, studies are needed to compare this technique to other techniques concerning the success rate. Central venous catheterization can be performed more easily under USG guidance, and its complications can be reduced. Many studies have shown that USG-guided catheterization reduces the incidence of arterial puncture, hematoma, and pneumothorax (8,11).

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Footnotes

Conflicts of Interest: The authors declared no conflicts of interest regarding the authorship and/or publication of this article.

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