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Comparing the Complications in Central Venous Catheterization by Ultrasound Guidance vs Anatomical Landmark Technique in Critical Ill ICU Patients

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Author`s Contribution

[1,2]Provided concept/research design, data collection and statistical analysis, [3]Critical revision of the manuscript for important intellectual content. [4]Edit of manuscript and project management, [5,6]critical revision of the manuscript for important intellectual content.

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ABSTRACT

Objective: To compare the complication rates during central venous catheterization using ultrasound guidance versus the anatomical landmark technique in critical ill ICU patients.

Methodology: A prospective comparative study was conducted in intensive care unit (ICU) of Farooq Teaching Hospital, Rawalpindi from December 2023 to June 2024. Total 127 critically ill ICU patients with acute surgical or medical conditions requiring central venous catheterization (CVC), such as hypotension, dehydration, or required blood resuscitation, where periphery approach was not feasible, underwent CVC insertion. Patients were randomly divided into two groups: one group underwent ultrasound-guided CVC insertion, while the other group used anatomical landmark technique. The rate of complications was measured between the groups.

Results: Mean age of the patients was 46.5±11.2 years. The mean time from skin puncture to blood flashback was 104±172 sec in ultrasound group compared to 401±587 sec in landmark group. Among 127 patients, 61 underwent catheterization using ultrasound guidance, while 66 underwent catheterization using the anatomical landmark technique. The complication rates between the two groups were compared. The complications experienced by patients included multiple attempts (>1 puncture), pneumothorax, improper cannulation, hematoma, arterial punctures, incisional bleeding, and ecchymosis. In ultrasound group, 11.5% of patients experienced complications, compared to 28.8% in anatomical landmark group (p = 0.016).

Conclusion: Ultrasound-guided central venous catheterization was associated with fewer complications and a higher success rate (correct placement of the CVC), making it easier to perform. This procedure simplicity is linked to enhanced safety and patient comfort.

Keywords: Anatomical landmark; Catheterization, Central Venous; Ultrasonography, Interventional.

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Introduction

Central venous catheterization (CVC) is crucial and lifesaving treatment of critically ill patients.[1] Indications for CVC include administering medication, monitoring central venous pressure (to assess volume status), fluid resuscitation (in large volumes), delivering hyperosmotic fluids, blood sampling, and parenteral nutrition.[2] Another reason for the usage of CVC in critical ill patients is that peripheral lines can quickly become exhausted, especially when hyperosmolar fluids are administered. Recent technological advancements have led to the increased use

of ultrasonography for CVC, enhancing efficiency, reducing complications, and improving patient safety.[3]

Until 1984, when doppler ultrasound was first introduced to assist with CVC. In early years, when anatomical landmark technique was standard, the complication rate was 5.4% for experienced staff and a notable 11% for residents under supervisors and inexperienced interns.[4] In comparison to modern era, where ultrasound-guided CVC is rapidly becoming the gold standard, the complication rate is 7.7%, with a notable decrease to only 0.4% for major complications.[5] Complications associated with anatomical landmark can include pneumothorax, arterial puncture, hemothorax, thrombosis, nerve injury, placement failure, hematoma, and even mortality.[6] Even in modern era, the incidence of mechanical complications is reported to be 17%. The number of CVCs performed in ICU can vary, but the overall frequency of CVCs in hospitals is high. The higher frequency of CVCs, the greater the potential for complications. Additionally, complications tend to be more common in teaching hospitals, often due to insufficient supervision, training, and adherence to proper guidelines.[7] Every healthcare provider should strive to enhance the quality of patient care by actively working to minimize and prevent complications associated with medical procedures.

The study objective was to compare the complication rates during central venous catheterization using ultrasound guidance versus the anatomical landmark technique in critical ill ICU patients. Additionally, it was to evaluate if ultrasound guidance could enhance the success rate, reduce the time to completion, and decrease the number of attempts required for CVC in the ICU.

Methodology

A prospective comparative study was conducted to assess the effectiveness of ultrasound guidance in the placement of CVC in ICU patients at Farooq Teaching Hospital/Akhtar Saeed Medical College, Rawalpindi from December 2023 to June 2024. Approval from the institutional review board was secured before the study commenced. A consecutive sample of 127 patients requiring CVC were randomly assigned to underwent CVC either with ultrasound assistance or through the anatomical landmark technique. WHO calculator was used for sample size, by using 95% confidence interval and 5% alpha error, and a 9% complication rate for CVC.[4] The study included all ICU patients presenting with acute surgical or medical condition requiring CVC, such as hypotension, dehydration, or required blood resuscitation, where periphery approach was not feasible. The study excluded patients under 18 years old and pregnant women.

Patients were randomly divided into two groups; one group underwent ultrasound-guided CVC insertion, while the other group used anatomical landmark technique. "Time" was measured from the moment the needle made contact with the skin until blood flashback was observed in syringe. The time required to set up ultrasound machine was not recorded. The number of attempts needed to obtain blood during CVC, the occurrence of complications, and other relevant parameters were documented on data collection form.

The patients were classified as a "difficult stick" if they had a history of intravenous drug abuse, coagulopathy, abnormal anatomy, obesity, or severe peripheral vascular disease. "Coagulopathy" was determined as bleeding disorder caused by liver disease or in patients underwent treatment with Coumadin. “Complications” experienced by patients included pneumothorax, improper cannulation, hematoma, arterial punctures, incisional bleeding, and ecchymosis. The "user experience" was determined by number of CVC lines using landmark technique that they had successfully performed prior to study, as recorded by preceptor on data collection form. "Experienced user" was determined as those who had performed ≥ 25 CVC insertions. Before study, none of the user had experience with obtaining CVC using ultrasound guidance.

Real-time ultrasound-guided technique was utilized by a Canon Toshiba Xario 100 ultrasound machine equipped with an 8 MHz linear probe. To ensure sterility, probe was encased in sterile cover, and sterile gel was applied. The probe was held in operator left hand and identified the vein and artery on ultrasound image. Whereas, positioning a needle of large-bore beneath the center of probe, operator confirmed the trajectory of needle and attempted cannulation. After encountering blood flash, ultrasound probe was removed, and standard Seldinger technique was employed. The investigators, referred to as "users," were residents in their first through third postgraduate years. The "preceptors" included ICU faculty and senior registrars with a special interest in ultrasonography. The preceptors were tasked for acquiring the ultrasound machine and recorded the outcomes. The user conducted the procedure, and

preceptor documented the following outcomes: "time," starting from when needle touched the skin until blood flashback was observed in syringe; number of attempts needed to obtain blood during CVC; occurrence of complications; and other relevant parameters.

The "user" training on ultrasound machine included a 1 hr didactic lecture as part of their postgraduate training, along with an additional 1 hr lecture by consultant radiologist. The "preceptor" underwent same training and developed their skills through additional studies.

Data were analyzed using SPSS v 23. The abovementioned three variables were measured included data collected exclusively from ultrasound-guided group. Independent t test was employed to compare ages, time and number of CVC attempts between groups. Categorical variables were analyzed using chi square test. To account multiple comparisons, the post hoc analysis was done and alpha level was adjusted to 0.05.

Results

Ultrasound use led to a quicker blood flash in ultrasound group compared to landmark group. Mean age of the patients was 46.5±11.2 years. The mean time from skin puncture to blood flashback was 104±172 sec in ultrasound group compared to 401±587 sec in landmark group. The ultrasound group required fewer CVC attempts compared to the landmark group (1.5±0.9 vs 3.4±1.6 attempts). The users noted multiple subjective factors, such as improved anatomy with ultrasound image (85.3%), avoidance of complications with the ultrasound image (88.5%), and enhanced procedure efficiency with ultrasound guidance (80.3%) (Table I). Complications during CVC attempts were recorded in two groups and compared (Table II). The characteristics and users

Table II: Complications in both groups.

Complications	Ultrasound group (n=61)	Landmark group (n=66)	p value
Pneumothorax	0	2	.206
Improper cannulation	0	2	.206
Hematoma	5 (8.2%)	12 (18.2%)	.001
Arterial puncture	0	18 (27.3%)	.0001
Incisional bleeding	2 (3.3%)	0	.195
Ecchymosis	0	1 (1.5%)	.184

Table III: User experience and characteristics.

Variable		Ultrasound group (n=61)	Landmark group (n=66)	p value
Experience of user in landmark technique	Little	36 (59%)	42 (63.5%)	.614
	Moderate	21 (34.4%)	19 (28.8%)	
	Quite	4 (6.6%)	5 (7.7%)	
Experience of user in ultrasound	None	46 (75.4%)	58 (87.9%)	.051
	Some	15 (24.6%)	8 (12.1%)	
ICU resident	No	15 (24.6%)	32 (48.5%)	.011
	Yes	46 (75.4%)	34 (51.5%)	
Postgraduate year	1	18 (29.5%)	26 (39.4%)	.591
	2	28 (46%)	28 (42.4%)	
	≥ 3	15 (24.5%)	12 (18.2%)	

Table I: Demographic and clinical characteristics of patients in each group.

Variable		Ultrasound group (n=61)	Landmark group (n=66)	p-value
Age (years)	Mean ± SD	48.0±11.2	44.9±11.2	.018
Time (sec)	Mean ± SD	104±172	401±587	.0001
No. CVC attempts	Mean ± SD	1.5±0.9	3.4±1.6	.0001
Gender	Male	25 (41%)	40 (60.6%)	.032
	Female	36 (59%)	26 (39.4%)	
Difficult stick	No	6 (9.8%)	25 (37.9%)	.073
	Yes	55 (90.2%)	41 (62.1%)	
IV drug abuse	No	54 (88.5%)	58 (87.9%)	.987
	Yes	7 (11.5%)	8 (12.1%)	
Anatomy detection improved	Yes	54 (88.5%)	-	
Avoid complications	Yes	55 (90.2%)	-	
Increased efficiency	Yes	49 (80.3%)	-	
Coagulopathy	No	49 (80.3%)	54 (81.8%)	.632
	Yes	12 (19.7%)	12 (18.2%)	
Approach	Internal jugular	35 (57.4%)	10 (15.2%)	.0001
	Subclavian	1 (1.6%)	10 (15.2%)	
	Femoral	24 (39.4%)	46 (69.6%)	
	Peripheral	1 (1.6%)	0	
Venous cutdown	No	49 (80.3%)	64 (97%)	.003
	Yes	12 (19.7%)	2 (3%)	
Procedural complications	No	54 (88.5%)	47 (71.2%)	.016
	Yes	7 (11.5%)	19 (28.8%)	

experience are detailed in Table III.

Table IV presents the post hoc analysis comparing results between inexperienced physicians (those who have done 20 or less CVCs) and experienced physicians (those who have done > 20 CVCs) on patients classified as "difficult sticks." Regardless of physicians' experience level, the ultrasound guidance led to significant reductions in both the time to blood flashback and number of CVC attempts. As expected, inexperienced physicians needed more time and a higher number of attempts in both landmark and ultrasound groups.

Table IV: Difficult stick procedures done by inexperienced and experienced physicians.

Variable	Group	N	Mean ± SD
Inexperienced; Time (sec)	Ultrasound	17	104.6±11.8
	Landmark	23	403.5±66.4
No. of attempts	Ultrasound	17	1.3±0.7
	Landmark	23	3.1±1.6
Experienced; Time (sec)	Ultrasound	9	55.7±71.0
	Landmark	3	170±110
No. of attempts	Ultrasound	9	1.2±0.5
	Landmark	3	2.5±1.9

Discussion

Ultrasound-guided CVC is documented previously.[8] Ultrasound is used to describe the anatomy of internal jugular vein and to assess different techniques for percutaneous cannulation.[9] However, these studies offer limited experience and do not provide a prospective comparison between ultrasound guidance and landmark technique.

This study results revealed that the complication rate was 11.5% for ultrasound-guided and 28.8% for anatomical landmark technique. The results of this study are consistent with those of Munir et al which also compared the successful rate of ultrasound-guided to anatomical landmark technique. The successful rate was 43.3% for ultrasound-guided and 26.7% for anatomical landmark technique. Thus, indicating a better safety and fewer complications for ultrasound-guided of insertion, although the successful rate in this study is higher than that reported by Munir et al.[10] Reusz et al study reported that ultrasound-guided CVC was found to be superior, similar to the results of this study. However, their study included different methods of venous approach, such as femoral, subclavian, and peripheral veins, as well as arterial approach.[11] Whereas, this study results are aligned with Reusz et al study. Additionally, a meta-analysis conducted by Lau et al highlighted enhanced successful rate of CVC, though their population was children, whereas this study focused on adults aged 18 years and older.[12] Also, Calvache et al emphasized the mechanical complications associated with the anatomical landmark technique and advocated for safer techniques, such as ultrasound-guided, for CVC placement. However, their study did not include a comparison of the results from ultrasound-guided procedures.[13] The complication rate of 11.5% in this study's ultrasound-guided group is comparable to that reported by Adrain et al and other studies rates.[14,15] Arterial puncture was the most common complication, which was effectively managed with vessel compression and did not require additional treatment. The complication rate was less with ultrasound guidance compared to the landmark method in Lazaar et al study.[16] In this study, the complication rate might be attributed to limited experience of the young operators with ultrasound guidance technique.

Conclusion

The study concluded that the comparison of both techniques determined that ultrasound-guided technique is significantly superior. Ultrasound guidance led to a reduced number of CVC attempts. This study suggests that only minimal instruction in basic physiology of ultrasound and hands-on training is required for successful use of ultrasound-guided CVC. This approach can be particularly beneficial for patients in whom landmarks are neither visible nor palpable.

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