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Original Article

The Success Rate and Complications of Central Venous Catheterization for General Surgery Patients in a Tertiary Hospital

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Abstract

Objective: Central venous catheterization (CVC) is one of the essential surgical procedures. It can lead to life-threatening complications. This prospective study aimed to evaluate the success rate and complications of central venous catheterization.

Methods: This prospective observational cohort study collected data from patients undergoing central venous catheterization at the General Surgery Department, Rajavithi Hospital, from October 2020 to September 2022. Demographic information, the number of insertion attempts, operator details, success rates, the method used (ultrasound (US)-guided or anatomical landmark), and complications were recorded. Data analysis employed descriptive statistics, chi-square tests, student's *t*-tests, and binary logistic regression.

Result: 310 patients were enrolled. The overall success rate for central venous catheter (CVC) insertion was 95.2%. The US-guided method showed a significantly higher success rate compared to the anatomical landmark method (99.3% vs. 91.2%, $P = 0.001$), with 82.1% catheterized successfully on the first attempt using the US-guidance versus 50.9% with the landmark method ($P < 0.001$). The overall mechanical complication rate was 4.2%, including arterial puncture (1.6%), hematoma (0.3%), pneumothorax (0.3%), self-limiting arrhythmias (0.6%), and improper catheter placement (1.3%). The CRBSI rate was 7.7%, higher when occurring more than 15 days post-insertion ($P < 0.001$). Complication rates were significantly lower with the US-guided method compared to the landmark method (0.7% vs. 7.5%, $P = 0.003$). Procedures performed by 3rd to 4th-year residents also had lower complication rates compared to 1st to 2nd-year residents (0.3% vs. 3.9%, $P = 0.023$).

Conclusion: The US-guided catheterization demonstrates a high success rate, fewer attempts, and reduced complication rates. Therefore, its regular use in catheterization procedures is strongly recommended.

Keywords: Success rate, Complications, Central venous catheterization (CVC)

Introduction

Central venous catheterization (CVC) is an essential procedure in the surgical department for hemodynamic monitoring and long-term administration of fluids, antibiotics, total parenteral nutrition (TPN), hemodialysis, and chemotherapy. The common sites for catheterization are the internal jugular, subclavian, and occasionally femoral veins.[1] CVCs have been associated with immediate complications such as pneumothorax, hemothorax, hematoma, catheter misplacement, arterial puncture (10% - 20%)[2] and/or unsuccessful insertion (7%-14%).[3] Late complications include thrombosis and infection. The rate

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of complications varies, depending on operator experience and patient comorbidities such as coagulopathy and hemodynamic instability.

In contemporary practice, ultrasound (US) guidance has substantially reduced mechanical complications associated with central venous catheterization (CVC), minimized cannulation attempts, and increased success rates, thereby prompting its inclusion in several national guidelines.[4-6] The traditional method of catheterization using anatomical landmarks is gradually being replaced by ultrasound (US) guidance. However, Rajavithi Hospital does not routinely employ US-guided catheterization due to various factors such as limited access to ultrasound machines, inexperienced operators, and the need for equipment preparation. Consequently, the Department of Surgery organizes an annual workshop simulation to train general surgery residents in CVC, mainly focusing on those who lack experience with ultrasound-guided techniques before they perform procedures on actual patients. This initiative aims to prevent complications and improve success rates.

Currently, our hospital lacks specific data regarding the success rates and complication rates associated with central venous catheterization. Therefore, this study aimed to evaluate the success rate and complications of central venous catheterization in surgical patients at Rajavithi Hospital.

Methods

This prospective observational cohort study enrolled 310 inpatients treated at the General Surgery Department of Rajavithi Hospital from October 2020 to September 2022. Approval for the study was obtained from the Ethics Committee of Rajavithi Hospital (EC No. 234/2563), and all patients provided written informed consent following a detailed explanation of the study protocol. No exclusion criteria were considered except for patient refusal. All patients undergoing central venous catheterization were monitored and documented until they were no longer indicated for the catheter or until catheter-related bloodstream infection (CRBSI) occurred, at which point the catheter was removed.

Central venous catheterization methods are mainly classified into two methods[7]: the anatomical landmark method, which uses gross anatomical landmarks on the body surface, and the ultrasound (US)-guided method, which uses ultrasound images. All general surgery residents received training through a workshop simulation using both the US-guided and anatomical landmark techniques and successfully completed this training for central venous catheterization (CVC) before performing procedures on actual patients. All catheterizations were performed by general surgery residents and attending physicians. The residents selected either the US-guided or anatomical landmark technique based on their preference.

A triple-lumen catheter set (Certofix®) for catheterization was employed according to indications. The indications for CVC were hemodynamic monitoring, volume resuscitation and assessment, infusion of irritant medication, infusion of TPN, and difficult peripheral venous access.

Patients were positioned supine or in Trendelenburg's position with their heads rotated towards the opposite side. Central venous catheters (CVCs) were typically inserted on the right side; however, if conditions were unfavorable, such as infection at the puncture site or surgical wounds, or if insertion on the right side was not feasible, the CVC was placed on the left side. All procedures adhered to standard aseptic techniques and utilized local anesthesia with a small, 24-gauge needle for venipuncture.

The US-guided method uses a real-time approach, performed with a linear transducer probe 4-12 MHz, with a sterile cover. The central veins were identified along their larger longitudinal axis and their relationship to other anatomical structures. Under the US-guided method, an 18-gauge needle is introduced into the inferior portion of the internal jugular or another vein. This vein is accessed through a transducer placed at the insertion point; the correct introduction of the needle was always confirmed by ultrasound guidance and the easy aspiration of venous blood. The Seldinger technique[8] was used to place the catheter, which was advanced into the superior vena cava until insertion into the right atrium. In the anatomical landmark method, after local anesthesia, the internal jugular vein was located with a 24-gauze needle connected to a 3-ml syringe as the needle advanced through the skin at an angle of 45° toward the ipsilateral nipple. The return of venous blood into the syringe confirmed entry into the vessel; a 24-gauze needle was then used to guide the 18-gauge needle and place the catheter using the Seldinger technique.

A successful catheterization was defined by the following criteria: the catheter tip was visible and parallel to the wall of the superior vena cava on chest radiography, indicating proper placement; the catheter could be used for its intended purpose, and no complications occurred. Conversely, an unsuccessful technique was characterized by the inability to cannulate the central vein after three attempts, failure to locate or puncture the central vein, or the inability to advance the guidewire or catheter. If the initial method failed after three attempts, the operator either sought assistance from an experienced operator or chose an alternative insertion site. The number of attempts was defined as each insertion and withdrawal of the introducer needle from the skin. Following the procedure, all patients underwent chest radiography to assess catheter tip placement and identify any complications.

Demographic data, including age, gender, body mass index (BMI), site of catheterization (jugular, subclavian, or femoral vein), side of catheterization (right or left), indications for CVC insertion, level training of operator, method of insertion, existing of risk factor (such as diabetes mellitus, hypertension, ischemic heart disease, chronic renal disease, malignancy, coagulopathies, and respiratory distress) were evaluated and recorded in checklist. Moreover, the number of attempts, success rate, catheter-related complications (arterial puncture, hematoma, pneumothorax, self-limiting arrhythmias, catheter misplacement, and CRBSI), and follow-up 30 days until catheter removal were also documented in the checklist.

Demographic data and clinical features were analyzed using descriptive statistics. Quantitative variables were summarized using mean and standard deviation. Two methods of study were compared by student's *t*-test. Categorical variables were compared with the chi-square test and summarized as counts and percentages. The *P*-value of less than 0.05 was considered significant. All statistical analysis was performed with a statistical package for social sciences (SPSS) version 17.

Results

In this study, 310 patients were enrolled. Patient demographic and baseline characteristics are shown in Table 1. The mean age was 60.51 ± 14.96 years, with 166 male patients. The mean lifespan of the CVC was 8.9 ± 7.7 days (range 1-39). The US-guided method was used in 151 patients, and the anatomical landmark method was used in 159 patients. The most common location for catheterization was the right internal jugular vein, with 278 patients (89.7%) receiving catheters there.

Table 1 Baseline patient demographic data of the study patient

	Overall populations (n = 310)	US-guide method (n = 151)	Landmark method (n = 159)
Age (year): mean ± SD	60.51 ± 14.96	60.88 ± 15.10	60.16 ± 14.87
Gender: number (%)			
Male	166 (53.5)	81 (53.6)	85 (53.5)
BMI (kg/m^2): mean ± SD	22.23 ± 4.36	23.14 ± 11.78	22.23 ± 4.43
Underlying Disease: number (%)	242 (78.1)	113 (74.8)	32 (20.1)
Diabetes	72	40	32
Hypertension	99	57	42
Chronic kidney disease	35	20	15
Coronary artery disease	21	14	7
Cerebrovascular accident	12	7	5
COPD/Asthma	10	5	5
Malignancy (Breast, Stomach, Colorectal, Esophagus, Thyroid, HPB, Cervix, Brain)	169	71	98
Coagulation profile: number (%)			
INR < 1.5	258 (83.2)	115 (76.2)	143 (89.9)
INR ≥ 1.5	52 (16.8)	36 (23.8)	16 (10.1)

Table 1 (cont.) Baseline patient demographic data of the study patient

	Overall populations (n = 310)	US-guide method (n = 151)	Landmark method (n = 159)
Platelet count (cell/mm^3)			
≥ 100,000	282 (91.0)	128 (84.8)	154 (96.9)
< 100,000	28 (9.0)	23 (15.2)	5 (3.1)
Operator: number (%)			
Resident 1	38 (12.3)	22 (14.6)	16 (10.1)
Resident 2	129 (41.6)	72 (47.7)	57 (35.8)
Resident 3	85 (27.4)	39 (25.8)	46 (28.9)
Resident 4	13 (4.2)	8 (5.3)	5 (3.1)
Staff	45 (14.5)	10 (6.6)	35 (22.1)
Location of catheter: number (%)			
Right internal jugular vein	278 (89.7)	132 (87.4)	146 (91.8)
Left internal jugular vein	12 (3.9)	10 (6.6)	2 (1.3)
Right subclavian vein	10 (3.2)	2 (1.3)	8 (5.0)
Left subclavian vein	2 (0.6)	0 (0.0)	2 (1.3)
Right femoral vein	6 (1.9)	6 (4.0)	0 (0.0)
Left femoral vein	2 (0.6)	1 (0.7)	1 (0.6)

Data are presented as mean ± SD or %

The overall success rate was 95.2%, with the success rate of the US-guided CVC insertion significantly higher than that of the anatomical landmark method [150 (99.3%) vs. 145 (91.2%), $P = 0.001$], as shown in Table 2. In the US-guided method, 82.1% of catheters were successfully placed on the first attempt, compared to 50.9% in the anatomical landmark method ($P < 0.001$), as shown in Table 3. There was no significant difference in success rate between 3rd to 4th-year residents (experienced operators) and 1st to 2nd-year residents ($P = 0.265$).

Table 2 Overall success rate and complications of central venous catheterization

Result (n = 310)	n (%)
Overall successful: number (%)	295 (95.2)
US-guided method	150 (99.3)
Anatomical Landmarks method	145 (91.2)
Mechanical complications: number (%)	13 (4.2)
Arterial puncture	5 (1.6)
Hematoma	1 (0.3)
Pneumothorax	1 (0.3)
Self-limited arrhythmia	2 (0.6)
Improper catheter placement	4 (1.3)
Catheter-related infection (CRBSI): number (%)	24 (7.7)

*Data are presented as No. (%)

Table 3 Comparison of the catheterization outcomes in two methods

Variables	The study Methods		
	US-guided, n (%)	Landmarks, n (%)	*P*-value
Success rate: number (%)			0.001
Successful	150 (99.3)	145 (91.2)	
Unsuccessful	1 (0.7)	14 (8.8)	
Number of attempts: number (%)			
One attempt	124 (82.1)	81 (50.9)	< 0.001
More than one attempts	27 (17.9)	78 (49.1)	
Mechanical complications: number (%)	1 (0.7)	12 (7.5)	0.003
Types of mechanical complications: number (%)			
Arterial puncture	0 (0)	5 (3.1)	
Hematoma	1 (0.7)	0 (0)	
Pneumothorax	0 (0)	1 (0.6)	
Self-limited arrhythmia	0 (0)	2 (1.3)	
Improper catheter placement	0 (0)	4 (2.5)	
Catheter-related bloodstream infection (CRBSI): number (%)	20 (13.2)	4 (2.5)	< 0.001

*Data are presented as No. (%)

The overall mechanical complication rate was 13 (4.2%) [including arterial puncture 5 (1.6%), hematoma 1 (0.3%), pneumothorax 1 (0.3%), self-limiting arrhythmias 2 (0.6%), and improper catheter placement 4 (1.3%)] as shown in Table 2. No major bleeding, life-threatening conditions, or symptomatic venous thrombosis were reported. There was no significant correlation observed between the mean BMI and complications ($P = 0.079$).

Moreover, the rate of complications was significantly lower in the US-guided method than in the anatomical landmark method (0.7% vs. 7.5%, $P = 0.003$). Additionally, the rate of complications in procedures performed by 3rd to 4th-year residents also had lower complication rates compared to 1st to 2nd-year residents (0.3% vs. 3.9%, $P = 0.023$).

The catheter-related bloodstream infection (CRBSI) rate was found to be 24 (7.7%), and the associated incidence on the day of insertion was more than 15 days ($P < 0.001$). In addition, we found that US-guided catheterization was associated with an increased risk of CRBSI compared to anatomical landmarks [20 (13.34%) VS 4 (2.76%), $P < 0.001$].

Discussion

In this study, the overall success rate was 95.2%. The success rate of the US-guided method for CVC insertion was 99.3%, whereas the anatomical landmark method had a success rate of 91.2% ($P = 0.001$). Consistent with previous research, these findings highlight the notably high success rate associated with the use of the US-guided method.[1,9-11] Verghese et al.'s study demonstrated a 100% success rate for catheterization using the US-guided method, compared to a 77% success rate for patients using the anatomical landmark method.[12] Despite the significantly higher success rate of the US-guided method, the efficacy of both approaches relies heavily on the skills and experience of the operator.[13,14] Therefore, the implementation of a CVC simulation workshop training program is warranted to promote the routine adoption of US-guided methods for CVC insertion.

The number of attempts for catheter insertion, especially on the first attempt ($P < 0.001$) in the central vein, was significantly lower with the US-guided method compared to the anatomical landmark method. This is a critical concern for critically ill patients, where saving time is of paramount importance.[15] Mansfield et al. noted that the complication rate after three or more attempts was six times higher compared to the first attempt when comparing anatomical landmarks with the US-guided method.[16] Another critical finding is the markedly lower complication rate associated with the US-guided method. These results are consistent with prior studies investigating the

frequency of catheter insertion attempts. The central issue here underscores the direct correlation between shorter access times and fewer attempts, thereby mitigating the risk of complications.[1,17,18]

The incidence of overall complications was significantly higher ($P = 0.003$) in catheterizations utilizing anatomical landmarks, especially among 1st- to 2nd-year general surgery residents. Karakitsos et al. found no cases of hematoma or pneumothorax with the US-guided method, whereas eight patients experienced these complications when anatomical landmarks were used.[19] Similar results were reported by Rando et al.[20] Randolph et al.'s meta-analysis demonstrated the advantages of US-guided techniques across operators of varying experience levels in central venous catheterization[21] Miller et al. observed that skilled operators using ultrasound achieved a notable reduction in time to blood flash and fewer attempts compared to inexperienced operators who struggled with both methods. Additionally, lower complication rates associated with US guidance enhance its cost-effectiveness, as highlighted by Calvert et al.'s systematic review and economic evaluation of US-guided CVC.[22] Therefore, proficiency in US-guided catheterization is crucial for physicians. Recognizing this need, Feller et al. emphasized the importance of training surgeons and nurses in US-guided techniques due to their simplicity, applicability, and economic benefits.[23] This necessity led to the introduction of CVC simulation workshops at Rajavithi Hospital's Department of Surgery, aimed at improving trainees' procedural skills in real-world scenarios.[24]

As outlined above, US-guided central venous catheterization has been endorsed and adopted by junior resident operators. However, there remains debate regarding the continued teaching of anatomical landmark methods. Operators exclusively trained in US-guided techniques may lack proficiency in anatomical landmark cannulation when ultrasound is unavailable.[25]

A meta-analysis by Jun Takeshita et al. suggests that US-guided central venous catheterization potentially reduces the incidence of catheter-related bloodstream infections (CRBSI).[26] In contrast, our study revealed a different outcome: US-guided catheterization showed a higher risk of CRBSI compared to anatomical landmarks [20 cases (6.4%) vs. 4 cases (1.3%), $P < 0.001$]. This finding aligns with research by Buetti et al., who conducted a post hoc analysis of three randomized controlled trials and found an increased risk of CRBSI associated with the US-guided insertion (HR, 2.21; 95% CI, 1.17 - 4.16; $P = 0.014$)[27] A limitation noted in Buetti's study was uncertainty surrounding ultrasound techniques, including adherence to hygiene protocols. Furthermore, since patient randomization in these trials considered factors such as catheter insertion site, skin asepsis, and dressings rather than insertion technique, various confounders may have influenced the results, particularly given that ultrasound guidance is typically employed in challenging or severe cases.

Limitation

The primary limitations of the study include the absence of a control group and its single-institution design. Despite these constraints, this prospective observational cohort study was conducted within a representative population, which is particularly relevant for physicians undergoing residency training and helps mitigate potential selection bias. It is important to note that recording bias may have influenced the reported complications due to the lack of standardized monitoring datasets and specific charting tools for these outcomes. Additionally, the lack of statistical significance in our cohort could be attributed to an insufficient sample size for certain complications with very low incidences, such as pneumothorax and thrombosis. Furthermore, it is crucial to acknowledge that this study was conducted during the COVID-19 pandemic, which may impact the generalizability of its findings.

Conclusion

Ultrasound-guided catheterization presents several advantages, such as high success rates, fewer attempts needed, and decreased complication rates. Therefore, its regular use in catheterization procedures is strongly recommended. Training in procedural ultrasound techniques and the integration of ultrasound guidance for central venous catheterization should be considered the standard of care.

Conflict of interest

No authors have any potential conflict of interest to disclosure.

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