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Evaluation and Analysis of Outcomes Resulting from Internal Jugular Vein Catheterization Using In-Plane and Out-of-Plane Ultrasound-Guided Techniques in Oncology Patients at Shariati Hospital

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Abstract

Background: Central venous catheters (CVCs) are primarily used in oncology to protect peripheral veins and provide effective access to chemotherapy. The authors investigated the results of in-plane ultrasound-guided imaging compared to out-of-plane imaging in patients with oncology-related CVC placement in the oncology department of Shariati Hospital in Tehran.

Methods: This cross-sectional analytical study was conducted on 50 eligible oncology patients over 6 months in 1400 at Shariati Hospital in Tehran. The patients were randomly divided into two groups: in-plane and out-of-plane, and the internal jugular venous catheter was inserted by using one of the methods above by an anesthesiologist. The necessary variables for statistical analysis were collected using predetermined questionnaires.

Results: The mean age of the patients was 73.42 years, with 25 female participants. The catheter insertion was successfully performed in all patients. The mean duration of catheter insertion in the study population was 2.289 seconds, the mean number of skin punctures was 1.7, and catheter placement was successful in 62% of patients on the first attempt. A total of 23 complications occurred, with carotid artery puncture being the most common. The catheterization method, whether in-plane or out-of-plane, did not affect the initial success of catheter insertion.

Conclusions: According to the findings of this study, internal jugular vein catheterization was successfully performed using both in-plane and out-of-plane methods with similar results.

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Introduction

Central Venous Catheters (CVCs) are long, thin, and flexible tubes that are commonly used in clinical settings to administer medications, fluids, nutrients, or blood products for treatment. Various types of CVCs are available, and depending on the patient's condition, healthcare providers can choose short-term or long-term CVCs to facilitate the treatment process. Some types of CVCs can remain in patients for weeks, months, or even years. Additionally, the catheter can remain in the body as long as the patient is undergoing treatment, eliminating the need for multiple needle insertions.

CVCs are vital for the care of hospitalized and critically ill patients as they provide extensive venous access for various clinical procedures such as medication administration, blood sampling, and hemoglobin level measurement. They are particularly useful in oncology departments where CVCs are extensively

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used. The use of CVCs protects peripheral veins and provides efficient access to chemotherapy. Especially for long-term infusion chemotherapy regimens, CVCs offer clear advantages over peripheral venous catheters [1].

Various techniques are employed for the placement of a catheter in the internal jugular vein. The traditional approach to catheterization is based on anatomical landmarks, generally using techniques that measure specific points on the patient's body.

However, based on current evidence-based recommendations, it is advised to use an ultrasound-guided approach whenever possible for catheter placement in the internal jugular vein. By using ultrasound, the precise position of the internal jugular vein can be identified, and the catheter can be directly guided. This method is more accurate and safer, reducing the risk of complications such as blood leakage and injury to surrounding structures [2].

Therefore, if possible, ultrasound guidance should be utilized for the placement of an internal jugular vein catheter.

The conventional methods of catheter placement involve using surface anatomy knowledge and touch to locate the target veins before attempting catheterization (referred to as the "landmark technique"). This technique relies on identifying superficial anatomical landmarks or skin indicators and blindly inserting a needle until blood is aspirated. [3] However, these techniques cannot account for anatomical variations at the site of catheter insertion, which have been reported for the internal jugular vein (IJV), subclavian vein (SV), and femoral vein (FV) in some patients. [4,5] Therefore, it is challenging to identify these described anatomical variations using conventional methods. Additionally, this approach carries a high risk of mechanical complications such as pneumothorax, hemothorax, and accidental arterial puncture. [6] Hence, there is a need for a new approach that is safer and more efficient for catheterization.

Methods

After consultation with the esteemed oncology service and coordination with the head nurse of the oncology department, the patients were transferred to a dedicated room for central venous catheterization. Following the transfer, the surgical procedure and its associated complications were fully explained to the patients by the anesthesia specialist, and informed consent was obtained from all patients. After proper patient positioning and standard monitoring, a peripheral venous line that had been implanted during the patient's hospital stay in the oncology department was utilized for sedation during the procedure. The procedure was performed under anesthesia using propofol 100-20 milligrams and fentanyl 100-50 micrograms.

Subsequently, the upper chest area on both the left and right sides was thoroughly cleansed with povidone-iodine solution, and the corresponding areas were draped on the patient, initiating catheterization under sterile conditions. The patients were randomly divided into two groups, the in-plane and out-of-plane groups, and the jugular vein catheterization was performed using one of the mentioned methods by the anesthesia specialist (preferably an anesthesia specialist or senior resident).

Standard monitoring, including electrocardiography, pulse oximetry, and blood pressure measurement, was carried out by the anesthesia specialist and senior resident. All patient characteristics, including weight, body mass index, age, gender, diagnosis, platelet count, hemoglobin level, vital signs, and emergency or elective catheter insertion, were recorded on a sheet by the anesthesia technician.

After selecting the type of procedural method, the following variables were recorded on a designated form:

• Catheter insertion time (in seconds)
• Access site (left side, right side)
• Number of skin punctures
• Number of vein cannulations
• Number of needle redirections
• Number of guide wire passages
• Number of incorrect guide wire insertions
• Operator's skill level
• Success and failure rates

Complications

The following events were recorded during the procedure and within 48 hours after catheter insertion in the hospital:

• Arrhythmia resolving upon catheter withdrawal
• Guidewire displacement
• Arterial puncture
• Problematic bleeding (site bleeding)
• Catheter malpositioning or migration requiring reinsertion
• Infections
• Thrombosis
• Pneumothorax
• Hematoma formation
• Posterior internal jugular vein wall puncture

Infections were described based on positive blood cultures or obvious contamination at the site requiring catheter removal. Thrombosis was diagnosed based on superficial or deep thrombosis at the site. After completing the procedure, all patients were transferred to the radiology department for chest X-rays and were evaluated by the anesthesia specialist.

Result

Baseline Characteristics

Table 1 presents the baseline characteristics of the participants in this prospective cross-sectional study. Fifty cancer patients visiting Shariati Hospital in Tehran during the year 2021, who required a central venous catheter, were enrolled in the study using a census method. The average age of the patients was 73.10 ± 32.42, with 25 of them being female. Subsequently, the patients were equally divided into two groups: the in-plane group and the out-of-plane group. All initial characteristics of the patients, including body mass index, blood pressure, heart rate, body temperature, and laboratory indices, were within the normal range.

Diagnostic Cancer Types

The results showed that 12 patients (24%) had ALL, 26 patients (52%) had AML, 1 patient (2%) had GCT, and 11 patients (22%) had MM. (Table 2 and Figure 1)

Catheter Insertion Reasons

The distribution of the sample population based on the reasons for catheter insertion showed that 42 patients (84%) underwent catheterization due to chemotherapy, and 8 patients (16%) underwent catheterization for transplantation. (Table 3 and Figure 2)

Results of the Study Outcomes in the Two Study Groups

As shown in Table 4, the average catheter insertion duration in the study population was 82.4 seconds, the average number of skin punctures was 7.1, and catheter insertion was successful in the first attempt in 62% of patients. In 80% of patients, catheter insertion was performed from the right side. Among the patients, 23 complications occurred, with carotid artery puncture being the most common. Arrhythmia was resolved by removing the needle in 9 patients. The interaction between the in-plane and out-of-plane methods did not have a significant effect on variables such as catheter insertion duration, successful first attempt, number of skin punctures, catheter insertion site, occurrence of complications, and average needle redirection (Table 4).

It was observed that the catheter insertion site, whether on the right or left side, had no significant effect on the initial success of the procedure (Figure 3).

Table 1: Baseline Characteristics of the Participants

Variable	Total Population	Inplane Group (25 patients)	Out of Plane Group (25 patients)
Age, years (SD)	42/32 (10/73)	43/40 (10/51)	41/24 (11/13)
Gender, n (%)			
Male	25 (50)	15(60)	10(40)
Female	25(50)	10(40)	15 (60)
Weight, kg (SD)	69/50 (5/65)	70/04 (6/01)	68/9 (5/34)
Height, m (SD)	168/28 (6/60)	167/44 (5/50)	169/12 (7/56)
Body Mass Index, kg/m2 (SD)	24/20 (2/11)	24/6 (2/35)	23/80 (1/82)
Systolic Blood Pressure, mmHg (SD)	130/34 (15/81)	131/08 (15/31)	129/60 (16/58)
Diastolic Blood Pressure, mmHg (SD)	68/40 (11/73)	69/72 (11/95)	67/08 (11/60)
Heart Rate (SD)	88/74 (11/28)	84/84 (8/99)	92/64 (12/14)
Body Temperature (SD)	37/21 (0/15)	37/24 (0/12)	37/18 (0/18)
Platelet Count (SD)	164/26 (40/13)	161/44 (44/69)	167/08 (35/68)
Hemoglobin Level (SD)	12/39 (1/08)	12/55 (1/11)	12/23 (1/05)
PTT Value (SD)	32/40 (1/90)	32/40 (1/47)	32/40 (2/29)
INR Value (SD)	1/07 (0/18)	1/05 (0/02)	1/09 (0/26)

Table 2: Diagnostic Cancer Types in the Study Population

Cancer Type	Frequency	Percentage
ALL	12	24
AML	26	52
GCT	1	2
MM	11	22
Total	50	100

ALL: Acute lymphoid leukemia; AML: Acute myeloid leukemia; GCT: Giant Cell Tumor; MM: Multiple Myeloma

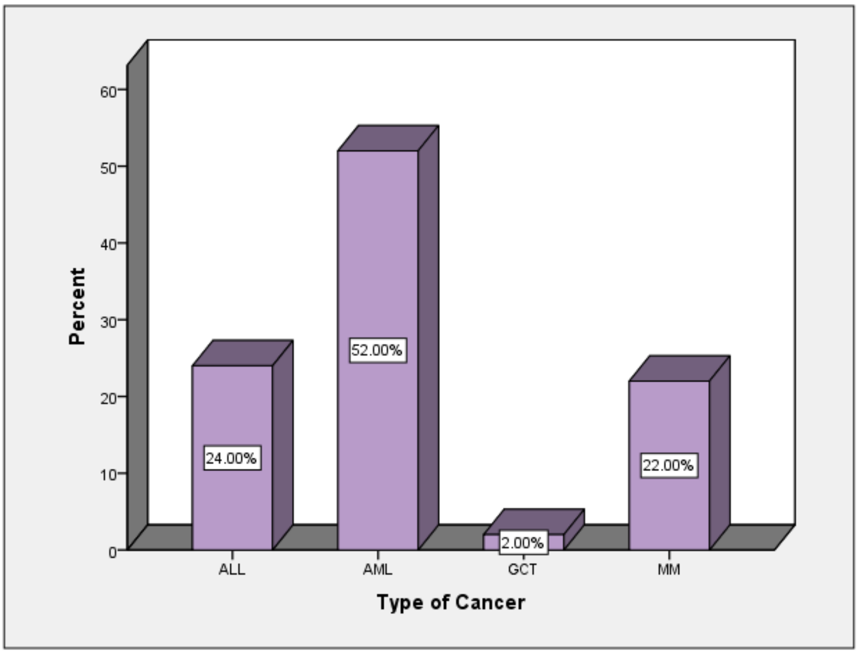

Fig. 1: Bar chart of diagnostic cancer types in the study population

Table 3: Catheter Insertion Reasons in the Study Population

Insertion Reason	Frequency	Percentage
Chemotherapy	42	84
Transplantation	8	16
Total	50	100

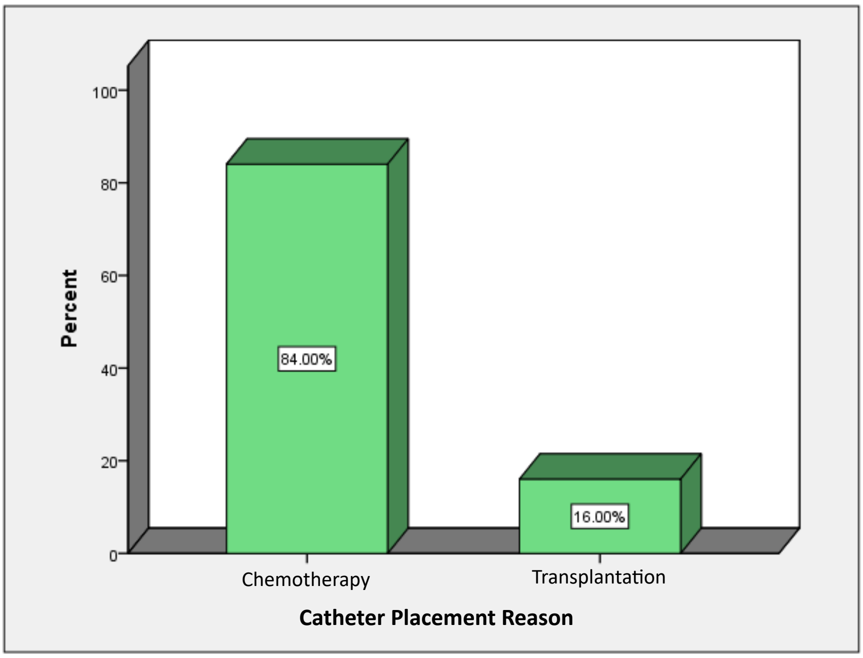

Fig. 2: Bar chart of catheter insertion reasons in the study population

Table 4: Results of the Study Outcomes in the In-plane and Out-of-plane Groups

Characteristics	Total Patients	In-plane Group	Out-of-plane Group
Catheter Insertion Duration (in seconds)	(135/6) 289/2	324 (136/2)	255 (129)
Successful First Attempt (frequency, percentage)	31 (62)	15 (60)	16(64)
Average Number of Skin Punctures	1/7 (0/88)	1/6(0/86)	1/8 (0/91)
Catheter Insertion Site (frequency, percentage)			
Right	40 (80)	21 (84)	19 (76)
Left	10 (20)	4 (16)	6(24)
Complications (frequency, percentage)	23 (4/6)	14 (2/8)	9(1/8)
Hematoma	3 (6)	2 (8)	1(4)
Carotid Artery Puncture	10 (20)	6 (24)	4 (16)
Posterior Wall Puncture	7 (14)	4 (16)	3 (12)
Extravasation	3 (6)	2 (8)	1 (2)
Average Needle Redirection for Vein Entry	0/98 (0/92)	1/08 (1/07)	0/87 (0/76)
Resolution of Arrhythmia by Catheter Removal (frequency, percentage)	9 (18)	3(12)	6(24)

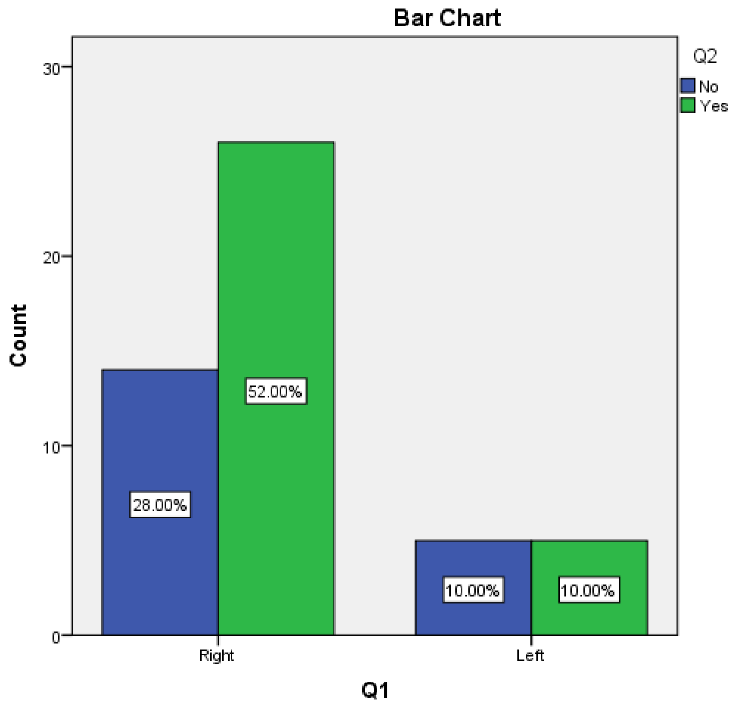

Fig. 3: Interaction plot of the catheter insertion site and initial success

Furthermore, the catheterization method, whether in-plane or out-of-plane, did not affect the initial success of catheter insertion (Figure 4).
Finally, the catheterization method did not have a significant interaction with resolving cardiac arrhythmia (Figure 5).

Discussion and conclusion

Ultrasound-guided central venous catheterization was introduced into clinical practice in the early 1970s and is now used for various clinical activities. With advances in computer and technology, ultrasound devices have become capable of high-resolution imaging of tissues and blood flow. As mentioned earlier, the traditional method of catheter insertion is associated with complications. The use of ultrasound imaging before or during vascular catheterization improves the success of the initial attempt and reduces complications. [2] Real-time ultrasound guidance is currently recommended to prevent complications in the placement of a catheter in the

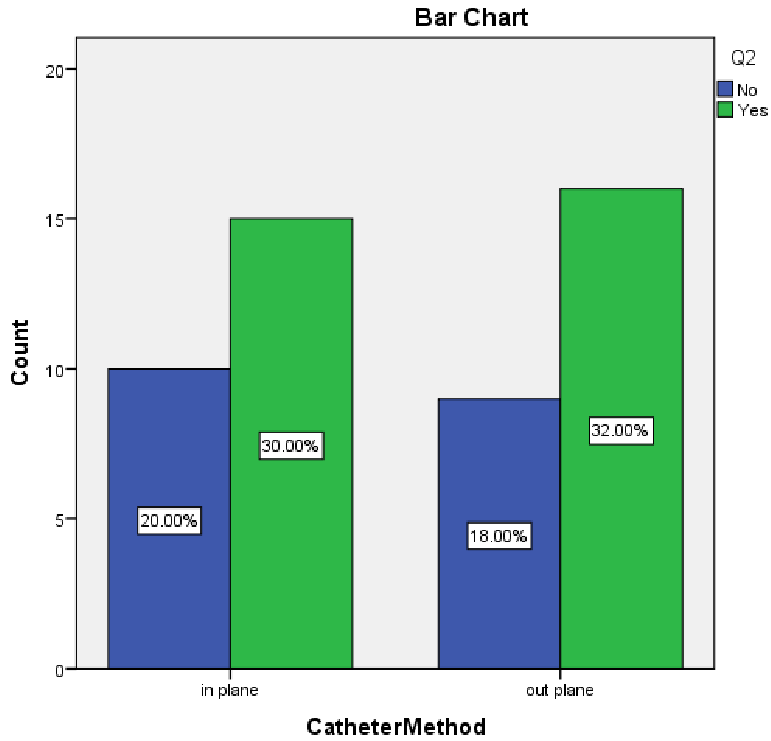

Fig. 4: Interaction plot of the catheterization method and initial success

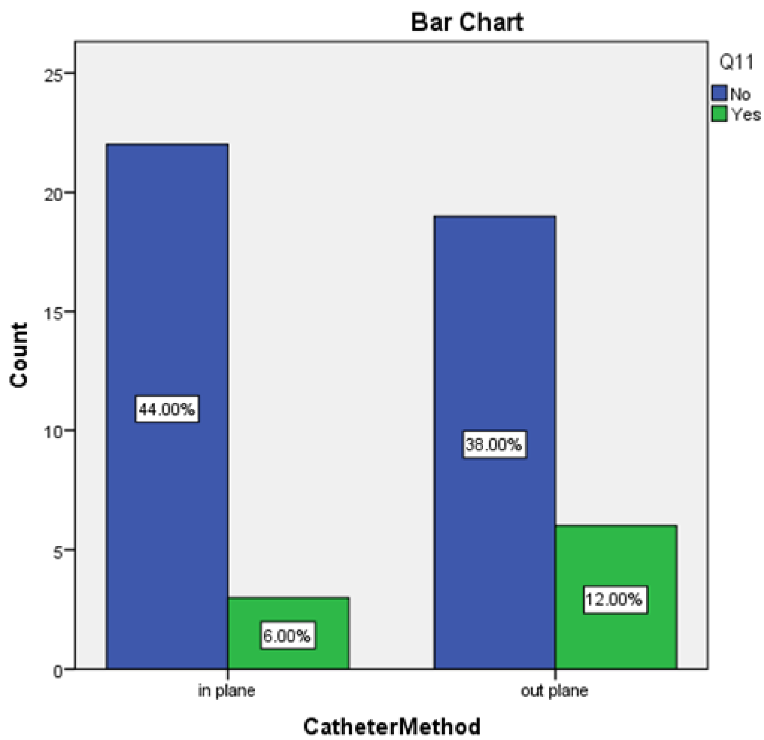

Fig. 5: Interaction plot of the catheterization method and resolution of cardiac arrhythmia

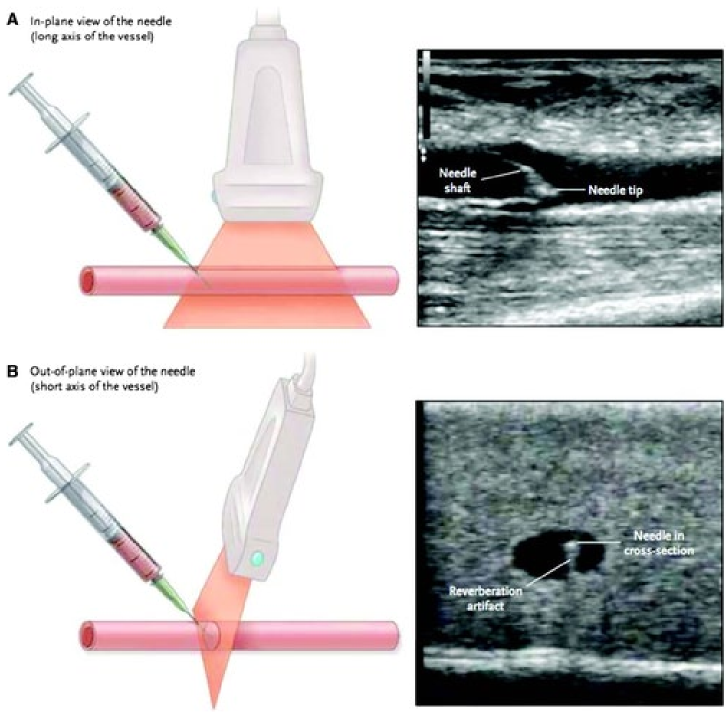

Fig. 6: (A) Catheter insertion using the long-axis/in-plane approach compared to (B) the short-axis/out-of-plane approach under ultrasound guidance

internal jugular vein. The most common imaging techniques used in ultrasound-guided CVC placement are short-axis/out-of-plane and long-axis/in-plane approaches. Imaging of veins in short-axis and long-axis is defined by the spatial relationship between the veins and the ultrasound probe. The needle visualization in ultrasound is defined as in-plane or out-of-plane based on the position of the needle tip and the ultrasound beam. In clinical practice, out-of-plane needle insertion is performed when the veins are oriented on the short axis, and in-plane needle insertion is performed when the veins are oriented on the long axis. Additionally, a combination of these imaging techniques, such as oblique imaging of the veins while keeping the needle in place, can facilitate catheter placement in challenging situations. [7]

Catheter insertion with an out-of-plane view is easier for two reasons. Firstly, distinguishing veins from arteries in this view is easier with the compression technique. Secondly, the transverse approach allows the operator to easily track the needle trajectory through the tissues until it reaches the vein. The time to successful catheter placement may be shorter in the transverse view compared to the longitudinal view. Before proceeding with the longitudinal view, the physician should identify the vein location using the transverse view. Then, the probe should be rotated 90 degrees so that its longitudinal axis aligns with the vein. This view allows direct visualization of the needle penetration into the vein. [7,8] An interventional radiologist can use imaging as a tool for venous access. The physician can choose either the transverse or longitudinal views to select the vein and determine the site of catheter insertion. No definitive studies show the superiority of one view over the other, and it likely depends on the chosen vein for catheter placement and the patient's surface anatomy. [9]

Complications Related to Central Venous Catheterization

Like all procedures, the physician should obtain an adequate medical history and perform a physical examination of the patient to determine the appropriate method and anatomical site for catheter insertion. Understanding anatomical variations and being aware of potential complications (especially the presence of an underlying coagulopathy) should be evaluated. There is clear evidence that ultrasound guidance for central venous catheterization leads to improved catheter insertion success on the first attempt and overall success rate, reducing the risk of associated complications. It has been particularly beneficial in patients with challenging conditions such as obesity, short neck, and non-cooperative individuals [10]. However, some meta-analyses have found that carotid artery puncture may occur in 4% of catheter insertions

under ultrasound guidance [11].
In general, after CVC placement, complications such as infection, pneumothorax, hemothorax, subcutaneous bleeding, or arterial puncture in the spinal and neck regions, catheter fracture, incorrect catheter placement, thrombus formation, and infection may occur. Successful catheter placement depends on the anatomical situation and the proficiency of the person inserting the catheter [2].
Mechanical complications often occur during or immediately after catheter placement. Thrombosis is frequently observed in cases where the intervention is difficult or the inserter lacks experience. The incidence of thrombotic complications ranges from 5% to 50% [12]. The mortality rate increases when a thrombus dislodges and enters the bloodstream. Additionally, thrombus formation is associated with increased infection rates. Embolism is also a life-threatening complication of catheter insertion [13].
Ventricular arrhythmias and bundle branch blocks may manifest if the catheter reaches the right atrium. Inserting a catheter with a length shorter than 16 centimeters may help prevent these complications [14,15]. Pneumothorax and hemothorax, which are more commonly observed when catheters are inserted via the subclavian vein, may occur when the physician is inexperienced or the patient is in the wrong position [2]. Infection is the most common complication following catheter insertion. According to reports from the Centers for Disease Control and Prevention, approximately 250,000 infections related to catheter insertion occur annually, with a mortality rate of 20% [16].
In the studies mentioned in this text, the use of ultrasound guidance techniques for the placement of internal jugular vein catheters has been investigated. These studies show that pre-procedural ultrasound can improve the success rate of catheter placement and reduce complications.
The results of these studies demonstrate that ultrasound guidance, regardless of the technique used (short-axis or long-axis view), increases the success rate of catheter placement on the first attempt, and there is no significant difference between the different ultrasound guidance techniques. Furthermore, the number of skin punctures, needle redirection, and catheter insertion time do not significantly differ between the two ultrasound guidance methods.
In another study, a comparison was made between the short-axis/out-of-plane and long-axis/in-plane techniques for internal jugular vein catheter placement, and the results showed no significant difference in the success rate on the first attempt between these two techniques. Similar findings have been reported in other studies as well.
However, it should be noted that there is heterogeneity in some of the studies, and there is insufficient evidence to demonstrate a significant difference between the two ultrasound guidance techniques in terms of success rate on the first attempt and overall success rate.
Therefore, based on the available studies, it appears that both ultrasound guidance techniques (short-axis and long-axis view) are equally effective for the placement of internal jugular vein catheters, and there is no significant difference between these two methods. However, further studies with larger sample sizes and more operator experience are needed to obtain more definitive results in this area.
In the current study, a total of 23 complications were reported, with 14 cases in the in-plane/LAX group and 10 cases in the out-of-plane/SAX group. The most common complication was carotid artery puncture (10 cases), followed by posterior wall puncture (7 cases). In a recently published study, 210 patients undergoing elective cardiac surgery were randomly assigned to three groups: SAX (70 patients), LAX (70 patients), and oblique-axis (OAX) view (70 patients). The quality of needle visualization was significantly better in the OAX and LAX views compared to the SAX view. Only 2 patients in the LAX group experienced carotid artery puncture, while no such complications were observed in the other groups. Additionally, posterior wall vein puncture was only observed in the SAX group (14.3%). This higher incidence may be because, in the SAX approach, the needle is more visualized as an echogenic point, which may not necessarily reflect the needle tip. In our study, there were 7 cases of posterior wall puncture (4 cases in the LAX group and 3 cases in the SAX group).
The SAX view provides better visualization of surrounding structures and their positions relative to the needle (especially the carotid artery), making it easier to guide the needle away from the carotid artery. However, the SAX view does not depict the entire needle path or show the depth of insertion. Currently, the SAX approach does not fully protect patients against inadvertent carotid artery puncture. Although meta-analyses have shown that the use of ultrasound has higher success rates on the first attempt and requires fewer attempts overall, carotid puncture still occurs in some studies, with an incidence of up to 4%. The overlapping of the two vessels is a significant risk factor for carotid artery puncture during internal jugular vein catheterization. Troiano and colleagues found that in 54% of patients, the internal jugular vein overlapped more than 75% of the carotid artery on ultrasound imaging when the needle cannulation was oriented towards the carotid artery. This significant overlap of the internal jugular vein on the carotid artery, in addition to the anterior needle advancement

out of the plane used in the short-axis view (SAX), predisposes patients to carotid puncture, unlike the middle-oblique view, which reduces the average overlap of the two vessels to 36%.
Compared to the LAX view, the SAX view provides better visualization of the needle along its path and depth of insertion, thus preventing the needle from going outside the target vessel. However, since the surrounding structures are not visualized in the LAX view, it becomes difficult to determine whether the needle is in the artery or vein [36]. In another clinical trial, a significant posterior wall puncture was observed in the SAX group (1.15%) compared to the LAX group (0%). No carotid artery puncture was observed in this study [17].
In a meta-analysis conducted by Zhang et al. (2019), they analyzed the results of 9 clinical trials involving 993 patients undergoing internal jugular vein catheterization. The researchers found no statistically significant difference between the SAX and LAX groups regarding carotid artery puncture (RR 1.39, 95% CI 0.73-2.38). They concluded that there is still insufficient evidence to demonstrate a difference between the two methods in terms of carotid artery puncture and suggested that future studies focus on a combined approach using both SAX and LAX [18].
Both in-plane and out-of-plane techniques have been successful in placing internal jugular vein catheters. However, due to the lack of sufficient evidence regarding the superiority of one method over the other, well-designed and robust trials are necessary for further evaluation of the outcomes.

Conflict of Interests

This study does not have any conflict of interest.

Ethical Approval

The institutional review board approved the study.

Funding/Support

Any institutions have not funded this study.

Abbreviation

IJV (Internal Jugular Vein), SV (Subclavian), FV (Femoral Vein), ALL (Acute Lymphoid Leukemia), AML (Acute Myeloid Leukemia), GCT (Giant Cell Tumor), MM (Multiple Myeloma)

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