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A COMPARATIVE STUDY OF ULTRASOUND GUIDED CENTRAL VEIN CANNULATION THROUGH THE INTERNAL JUGULAR VEIN IN IN-PLANE, OUT-OF-PLANE,LATERAL OBLIQUE APPROACHES- A PROSPECTIVE SINGLE BLINDED RANDOMISED CONTROL TRIAL.

Dr Kaluvala Prasad Rao* [1], **Dr Krishna Rao** [2], **Dr B Vasantha Rao** [3]

[1]*Additional Professor, Department of Anaesthesiology, Nizams Institute of Medical Sciences, Hyderabad, Telangana, India.*
[2]*Assistant Professor, Department of Anaesthesiology, Nizams Institute of Medical Sciences, Hyderabad, Telangana, India.*
[3]*Resident, Department of Anaesthesiology, Nizams Institute of Medical Sciences, Hyderabad, Telangana, India.*

Correspondence:
Dr Kaluvala Prasad Rao
Additional Professor, Department of Anaesthesiology, Nizams Institute of Medical Sciences, Hyderabad, Telangana, India.

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Abstract

Background: ***Aim:*** To compare the effectiveness and safety of three ultrasound-guided approaches, in-plane, out-of-plane, and lateral oblique approaches, for internal jugular vein cannulation in adult patients. ***Methodology:*** The present study was carried out in the Department of Anaesthesiology and Intensive Care, Nizam's Institute of Medical Sciences (NIMS), Hyderabad. The study involved adult patients requiring internal jugular vein cannulation in the operation theatres and intensive care units of the institute. The present study was a prospective, single-blinded, randomised controlled comparative study aimed at comparing three ultrasound-guided approaches, in-plane, out-of-plane, and lateral oblique approaches, for internal jugular vein cannulation with respect to cannulation time, success rate, ease of cannulation, and incidence of complications. The study was conducted over a period of 10 months, after obtaining approval from the Institutional Ethics Committee. ***Results:*** Time for identification of IJV was lowest in Group C (2.6 ± 0.5 seconds), followed by Group O (5.1 ± 0.7 seconds) and highest in Group L (6.3 ± 0.8 seconds), showing a statistically significant difference ($p = 0.04$). Total time for cannulation was lowest in Group O (65.4 ± 5.9 seconds), followed by Group L (75.8 ± 10.3 seconds) and highest in Group C (146.9 ± 18.7 seconds), showing a highly statistically significant difference ($p = 0.0001$). First-pass success rate was highest in Group O (76.1 %), followed by Group C (64.7 %) and Group L (56.4 %). Single-pass cannulation was highest in Group O (76.1 %), followed by Group C (64.7 %) and Group L (56.4 %); two passes were highest in Group L (27.8 %), followed by Group C (23.3 %) and Group O (17.2 %); ≥3 passes were highest in Group L (15.8 %), followed by Group C (12.0 %) and Group O (6.7 %). Overall success rate was highest in Group O (98.5 %), followed by Group L (96.2 %) and Group C (95.5 %); failure was lowest in Group O (1.5 %), followed by Group L (3.8 %) and Group C (4.5 %). There was no statistically significant difference in overall success rates between groups ($p = 0.34$). Ease of cannulation showed a statistically significant difference between groups ($p = 0.001$). Mechanical complications included posterior wall puncture (8.3 % in Group C only), local hematoma (4.5 %, 3.8 %, and 2.2 % in Group C, L, and O respectively), arterial puncture (3.8 %, 2.3 %, and 0.7 %), and inability to thread catheter/guidewire (3.8 % in Group C only), with no cases of pneumothorax or catheter misplacement. Mechanical complications showed a statistically significant difference between groups ($p = 0.001$). ***Conclusion:*** In conclusion, while all three ultrasound-guided approaches are clinically effective, the lateral oblique approach appears to offer distinct advantages in terms of efficiency, success on first attempt, operator ease, and reduced complications. These findings support its consideration as a preferred technique in routine clinical practice, particularly in settings where rapid and safe vascular access is essential.

Keywords: Internal jugular vein cannulation, Mechanical Complications,Local hematoma, Ultrasound-guided approaches.

INTRODUCTION

Central venous cannulation through the internal jugular vein (IJV) is a frequently performed invasive procedure in perioperative care, intensive care units, and emergency settings for administration of vasoactive drugs, parenteral nutrition, hemodynamic monitoring, and rapid fluid resuscitation. Traditionally, IJV cannulation was performed using surface anatomical landmarks and was associated with various mechanical complications such as arterial puncture, hematoma

formation, pneumothorax, and catheter malposition, contributing to increased patient morbidity and occasional mortality1,2. The advent of ultrasound guidance significantly improved the safety and efficacy of central venous access by enabling real-time visualization of vascular anatomy, needle trajectory, and adjacent structures, thereby enhancing success rates and reducing complications3. However, different ultrasound-guided needle visualization techniquesnamely in-plane, out-of-plane, and lateral oblique approachesmay influence procedural success and complication rates, highlighting the need for comparative evaluation4.

From an epidemiological perspective, central venous catheterization is performed extensively worldwide, with more than 5 million central venous catheters inserted annually in the United States alone5. Mechanical complications associated with landmark-guided techniques have been reported in up to 15% of procedures, whereas ultrasound-guided cannulation has been shown to significantly reduce complication rates[3]. In India, internal jugular vein cannulation is one of the most commonly utilized central venous access routes in tertiary care hospitals due to its consistent anatomical location and accessibility. Despite adherence to ultrasound guidance, procedure-related complications have still been reported in approximately 2 to 10% of ultrasound-guided IJV cannulations, depending on operator experience and technique employed3,6. Given the large number of procedures performed, even small improvements in success rates or reductions in complications may have substantial clinical and economic implications.

The present topic was chosen because, although ultrasound-guided IJV cannulation had been widely accepted as the standard of care, comparative evidence evaluating the in-plane, out-of-plane, and lateral oblique approaches remained limited, particularly within the Indian healthcare setting. Most previously published studies primarily compared ultrasound-guided techniques with landmark-based methods rather than directly comparing different ultrasound-guided approaches4,7. Additionally, variations in study design, outcome parameters, and operator expertise limited the ability to draw definitive conclusions regarding the optimal ultrasound technique. There was a paucity of prospective randomized controlled trials from this region, rendering the available evidence insufficient to guide uniform clinical practice.

The study was conducted in a tertiary care teaching hospital with well-established anesthesiology and critical care services, availability of high-frequency linear ultrasound probes, standardized central venous catheterization kits, and trained anesthesiology personnel. Adequate patient load and institutional ethical approval enabled systematic comparison of the three ultrasound-guided approaches. The evaluated outcomesfirst-pass success rate, number of attempts, cannulation time, and procedure-related complicationswere expected to generate clinically relevant evidence to assist in identifying the safest and most effective ultrasound-guided technique for internal jugular vein cannulation in routine practice3,6.

AIM OF THE STUDY

AIM

To compare the effectiveness and safety of three ultrasound-guided approaches, in-plane, out-of-plane, and lateral oblique approaches, for internal jugular vein cannulation in adult patients.

OBJECTIVES OF THE STUDY

Primary objective

1. To compare the time taken for successful internal jugular vein cannulation, measured from skin puncture to successful guidewire insertion, among the in-plane, out-of-plane, and lateral oblique ultrasound-guided approaches.

Secondary objectives

1. To compare the first-pass success rate among the three ultrasound-guided approaches.
2. To compare the total number of needle passes required for successful cannulation among the three approaches.
3. To compare the overall success rate of cannulation using the designated ultrasound-guided approach.
4. To assess and compare the incidence of mechanical complications (arterial puncture, posterior venous wall puncture, local hematoma, puncture site bleeding, catheter malposition, pneumothorax, and hemothorax) among the three approaches.
5. To compare the ease of cannulation and quality of needle visualization, as perceived by the operator, using a Likert scale among the three approaches.

HYPOTHESIS

NULL HYPOTHESIS:

Ultrasound-guided lateral oblique approach will be the best view for central vein cannulation through IJV.

ALTERNATIVE HYPOTHESIS:

Ultrasound-guided lateral oblique approach will not be the best view for central vein cannulation through IJV.

MATERIALS AND METHODS

PLACE OF STUDY

The present study was carried out in the Department of Anaesthesiology and Intensive Care, Nizam's Institute of Medical Sciences (NIMS), Hyderabad. The study involved adult patients requiring internal jugular vein cannulation in the operation theatres and intensive care units of the institute.

TYPE OF STUDY

The present study was a prospective, single-blinded, randomised controlled comparative study aimed at comparing three ultrasound-guided approaches, in-plane, out-of-plane, and lateral oblique approaches, for internal jugular vein cannulation with respect to cannulation time, success rate, ease of cannulation, and incidence of complications.

DURATION OF STUDY

The study was conducted over a period of 10 months, after obtaining approval from the Institutional Ethics Committee.

SAMPLE SIZE

Based on previous literature and sample size calculation using ANOVA for comparison of cannulation time among three groups, a total sample size of 400 patients was considered, accounting for a dropout rate of approximately 10%. Patients satisfying the inclusion criteria were enrolled and randomised into three equal groups.

INCLUSION CRITERIA

Patients meeting the following criteria were enrolled into the study:

- Patients aged 18 years or above.
- Patients of both genders.
- Patients requiring internal jugular vein cannulation for perioperative management or intensive care indications.
- Patients willing to participate in the study.
- Patients providing written informed consent.

EXCLUSION CRITERIA

Patients meeting the following criteria were excluded from the study:

- Patients aged less than 18 years.
- Infection, cutaneous erosion, hematoma, or subcutaneous emphysema at the cannulation site.
- History of recent internal jugular vein cannulation on the same side.
- History of cervical trauma or cervical spine injury.
- Severe coagulopathy (INR > 2 or platelet count < 50,000/mm^3).
- Patients unwilling to participate or not consenting.

INFORMED CONSENT

All patients fulfilling the selection criteria were explained in detail about the procedure, purpose of the study, possible benefits, risks, and potential complications. Written informed consent was obtained prior to enrolment. Patients were informed of their right to withdraw from the study at any stage without affecting their standard medical care.

OUTCOME MEASURES

Primary outcome

- Time taken for cannulation, measured from skin puncture to successful guidewire insertion (in seconds).

Secondary outcomes

- First-pass success rate.
- Total number of needle passes.
- Overall success rate of cannulation using the designated approach.
- Ease of cannulation and quality of needle visualization assessed using a Likert scale.
- Incidence of mechanical complications such as arterial puncture, posterior venous wall puncture, hematoma, puncture site bleeding, catheter malposition, pneumothorax, and hemothorax.

STATISTICAL ANALYSIS

- Data were entered into Microsoft Excel and analysed using SPSS software version 24.
- Quantitative variables were expressed as mean ± standard deviation.
- Categorical variables were expressed as frequency and percentage.
- Comparison of continuous variables among the three groups was performed using one-way ANOVA.
- Categorical variables were compared using Chi-square test or Fisher's exact test, as appropriate.

RESULTS

The present prospective, single-blinded, randomized controlled comparative study was conducted on 400 adult patients in the Department of Anaesthesiology and Intensive Care, Nizam's Institute of Medical Sciences (NIMS), Hyderabad. The study population was randomly divided into three groups.

GROUP C (n = 133):

133 patients in whom internal jugular vein cannulation was performed using the **out-of-plane ultrasound-guided approach.**

GROUP L (n = 133):

133 patients in whom internal jugular vein cannulation was performed using the **in-plane ultrasound-guided approach.**

GROUP O (n = 134):

134 patients in whom internal jugular vein cannulation was performed using the **lateral oblique ultrasound-guided approach.**

The following were the study results:

Table 2: Age wise distribution of patients.

Age group (years)	Group C n (%)	Group L n (%)	Group O n (%)	P-Value
18 to 30	24 (18.0)	22 (16.5)	23 (17.2)	0.92
31 to 45	36 (27.1)	38 (28.6)	37 (27.6)	
46 to 60	41 (30.8)	40 (30.1)	42 (31.3)	
> 60	32 (24.1)	33 (24.8)	32 (23.9)	
Total	**133 (100)**	**133 (100)**	**134 (100)**	
Mean age	49.6 ± 12.8	50.1 ± 13.2	48.9 ± 12.5	0.89

In the present study, patients were categorized into four age groups. The above table shows the age-wise distribution of patients among the three groups.

In Group C, the majority of patients belonged to the age group of 46 to 60 years (41 patients, 30.8%), followed by 31 to 45 years (36 patients, 27.1%), >60 years (32 patients, 24.1%), and 18 to 30 years (24 patients, 18.0%).

In Group L, most patients were in the 46 to 60 years age group (40 patients, 30.1%), followed by 31 to 45 years (38 patients, 28.6%), >60 years (33 patients, 24.8%), and 18 to 30 years (22 patients, 16.5%).

In Group O, the majority were in the 46 to 60 years group (42 patients, 31.3%), followed by 31 to 45 years (37 patients, 27.6%), >60 years (32 patients, 23.9%), and 18 to 30 years (23 patients, 17.2%).

The p-value was 0.92, indicating no statistically significant difference between groups. The mean age was 49.6 ± 12.8 years (Group C), 50.1 ± 13.2 years (Group L), and 48.9 ± 12.5 years (Group O), with a p-value of 0.89, showing no significant difference.

Table 3: Gender wise distribution of patients.

Gender	Group C n (%)	Group L n (%)	Group O n (%)	P-Value
Male	82 (61.7)	80 (60.2)	83 (61.9)	0.85
Female	51 (38.3)	53 (39.8)	51 (38.1)	
Total	**133 (100)**	**133 (100)**	**134 (100)**	

The above table shows the gender distribution among the study groups.In all three groups, male patients predominated. In Group O, males accounted for 83 patients (61.9%), followed by Group C with 82 patients (61.7%), and Group L with 80 patients (60.2%).

Females constituted 53 patients (39.8%) in Group L, 51 patients (38.3%) in Group C, and 51 patients (38.1%) in Group O.The p-value was 0.85, indicating no statistically significant difference between the groups.

Table 4: Distribution of patients basing on the indication for IJV cannulation.

Indication	Group C n (%)	Group L n (%)	Group O n (%)	P-Value
Perioperative monitoring	79 (59.4)	76 (57.1)	78 (58.2)	0.91
ICU management	54 (40.6)	57 (42.9)	56 (41.8)	
Total	**133 (100)**	**133 (100)**	**134 (100)**	

The above table shows the distribution of patients based on indication for IJV cannulation.

In all groups, perioperative monitoring was the most common indication: Group C (79 patients, 59.4%), Group O (78 patients, 58.2%), and Group L (76 patients, 57.1%).

This was followed by ICU management: Group L (57 patients, 42.9%), Group O (56 patients, 41.8%), and Group C (54 patients, 40.6%).The p-value was 0.91, indicating no statistically significant difference between the groups.

Table 5: Comparison of time taken for successful IJV cannulation (seconds) between the groups.

Indication	Group C (Mean ±Sd)	Group L (Mean ±Sd)	Group O (Mean ±Sd)	P-Value
Time taken for identification of IJV	2.6 ± 0.5	6.3 ± 0.8	5.1 ± 0.7	**0.04**
Time taken for skin prick to venous puncture	24.8 ± 1.6	16.7 ± 2.4	15.5 ± 1.8	**0.01**
Total time for cannulation	146.9 ± 18.7	75.8 ± 10.3	65.4 ± 5.9	**0.0001**

The above table compares the time parameters between the groups.
The time taken for identification of IJV was lowest in Group C (2.6 ± 0.5 seconds), followed by Group O (5.1 ± 0.7 seconds) and highest in Group L (6.3 ± 0.8 seconds). The difference was statistically significant (p = 0.04).
The time from skin prick to venous puncture was shortest in Group O (15.5 ± 1.8 seconds), followed by Group L (16.7 ± 2.4 seconds) and longest in Group C (24.8 ± 1.6 seconds), with a significant difference (p = 0.01).
The total time for cannulation was lowest in Group O (65.4 ± 5.9 seconds), followed by Group L (75.8 ± 10.3 seconds) and highest in Group C (146.9 ± 18.7 seconds), showing a highly significant difference (p = 0.0001).

Table 6: Comparison of first-pass success rate among the three approaches.

Approach	Group	Number of patients (n)	Percentage (%)	P value
Out-of-plane	**Group C**	86	64.7	**0.002**
In-plane	**Group L**	75	56.4	
Lateral oblique	**Group O**	102	76.1	

The above table shows the comparison of first-pass success rates.
The highest first-pass success rate was observed in Group O (102 patients, 76.1%), followed by Group C (86 patients, 64.7%) and Group L (75 patients, 56.4%).The p-value was 0.002, indicating a statistically significant difference between the groups.

Table 7: Comparison of number of needle passes required for cannulation between the groups.

Number of passes	Group C n (%)	Group L n (%)	Group O n (%)	P-Value
1	86 (64.7)	75 (56.4)	102 (76.1)	**0.004**
2	31 (23.3)	37 (27.8)	23 (17.2)	
≥3	16 (12.0)	21 (15.8)	9 (6.7)	

The above table shows the number of needle passes required for cannulation.For single-pass success, the highest was in Group O (102 patients, 76.1%), followed by Group C (86 patients, 64.7%) and Group L (75 patients, 56.4%).
For two passes, Group L had the highest proportion (37 patients, 27.8%), followed by Group C (31 patients, 23.3%) and Group O (23 patients, 17.2%).
For ≥3 passes, Group L again had the highest incidence (21 patients, 15.8%), followed by Group C (16 patients, 12.0%) and Group O (9 patients, 6.7%).The p-value was 0.004, indicating a statistically significant difference.

Table 8: Comparison of overall success rate of IJV cannulation between the groups.

Approach	Group C n (%)	Group L n (%)	Group O n (%)	P-Value
Successful cannulation	127 (95.5)	128 (96.2)	132 (98.5)	0.34
Failure	6 (4.5)	5 (3.8)	2 (1.5)	
Success rate	**95.5**	**96.2**	**98.5**	

The above table shows the overall success rates.The highest success rate was observed in Group O (132 patients, 98.5%), followed by Group L (128 patients, 96.2%) and Group C (127 patients, 95.5%).Failure rates were lowest in Group O (2 patients, 1.5%), followed by Group L (5 patients, 3.8%) and Group C (6 patients, 4.5%).The p-value was 0.34, indicating no statistically significant difference.

Table 9: Comparison of ease of cannulation as perceived by operator (Likert scale) among the three approaches.

Likert score	Group C n (%)	Group L n (%)	Group O n (%)	P-Value
1 to 2 (Poor)	18 (13.5)	22 (16.5)	9 (6.7)	**0.001**
3 (Satisfactory)	54 (40.6)	56 (42.1)	37 (27.6)	
4 to 5 (Good to excellent)	61 (45.9)	55 (41.4)	88 (65.7)	

The above table shows operator-perceived ease of cannulation.The majority of procedures were rated as good to excellent, highest in Group O (88 patients, 65.7%), followed by Group C (61 patients, 45.9%) and Group L (55 patients, 41.4%).Satisfactory ratings were highest in Group L (56 patients, 42.1%), followed by Group C (54 patients, 40.6%) and Group O (37 patients, 27.6%).Poor ratings were highest in Group L (22 patients, 16.5%), followed by Group C (18 patients, 13.5%) and lowest in Group O (9 patients, 6.7%).The p-value was 0.001, indicating a statistically significant difference.

Table 10: Comparison of incidence of mechanical complications between the groups.

Complication	Group C n (%)	Group L n (%)	Group O n (%)	P-Value
Arterial puncture	5 (3.8)	3 (2.3)	1 (0.7)	**0.001**
Posterior wall puncture	11 (8.3)	0	0	
Local hematoma	6 (4.5)	5 (3.8)	3 (2.2)	
Pneumo/hemothorax	0	0	0	
Catheter misplacement	0	0	0	
Unable to thread catheter/guidewire	5 (3.8)	0	0	

The above table shows the incidence of mechanical complications.The most common complication was posterior wall puncture, observed only in Group C (11 patients, 8.3%).This was followed by local hematoma, highest in Group C (6 patients, 4.5%), followed by Group L (5 patients, 3.8%) and Group O (3 patients, 2.2%).

Arterial puncture was highest in Group C (5 patients, 3.8%), followed by Group L (3 patients, 2.3%) and lowest in Group O (1 patient, 0.7%).Inability to thread catheter/guidewire occurred only in Group C (5 patients, 3.8%).No cases of pneumothorax/hemothorax or catheter misplacement were observed in any group.The p-value was 0.001, indicating a statistically significant difference in complication rates between groups.

DISCUSSION

Ultrasound-guided internal jugular vein (IJV) cannulation has evolved into the standard of care in contemporary anesthesiology and critical care practice, driven by its demonstrated superiority over landmark-based techniques in improving success rates and minimizing complications. Over time, the focus has expanded from merely adopting ultrasound guidance to refining needle–probe alignment and approach techniques that optimize visualization and procedural efficiency.3,6,28 Variations such as the short-axis out-of-plane, long-axis in-plane, and oblique approaches have been developed to address inherent limitations of each technique and to enhance overall procedural safety.7,26

The short-axis out-of-plane approach, while widely practiced due to its simplicity and rapid vessel localization, is limited by intermittent visualization of the needle tip, which may predispose to complications such as posterior wall puncture and arterial injury.4,7 Conversely, the long-axis in-plane approach allows continuous visualization of the needle trajectory, thereby improving precision, although it requires greater operator expertise and alignment accuracy.7,25The lateral oblique approach has emerged as a hybrid technique, combining the advantages of both methods by enabling improved needle visualization along with a simultaneous view of adjacent anatomical structures, potentially enhancing both safety and ease of cannulation.12,23

Recent evidence and updated clinical guidelines further reinforce the role of ultrasound guidance in central venous access. International recommendations advocate real-time ultrasound use as a standard practice, emphasizing its role in reducing mechanical complications and improving first-pass success rates.6,28 Additionally, contemporary systematic reviews and meta-analyses have highlighted that technique selection significantly influences procedural outcomes, including cannulation time, number of attempts, andcomplication rates, although no single approach has been universally accepted as superior across all clinical scenarios.27,29

Anatomical variability remains a critical determinant of procedural success. The spatial relationship between the internal jugular vein and the carotid artery can vary considerably depending on patient positioning, physiological status, and individual anatomy.14,15 Ultrasound enables real-time assessment of these variations, facilitating dynamic adjustments during cannulation and thereby enhancing procedural safety. Advances in ultrasound technology, including improved resolution and needle visualization techniques, have further contributed to better outcomes and wider adoption in routine clinical practice.13,20

Despite these advancements, mechanical complications such as arterial puncture, hematoma formation, and difficulty in guidewire advancement continue to be reported.1,2,18These complications are often technique-dependent and influenced by factors such as needle visualization, insertion angle, and operator proficiency. Emerging literature suggests that

approaches offering continuous needle visualization and better anatomical orientation may reduce such risks, particularly in challenging patient populations.29,30

In light of the existing evidence, there remains a need for well-designed comparative studies evaluating multiple ultrasound-guided approaches under standardized conditions. While prior studies have largely focused on pairwise comparisons, comprehensive evaluations of three or more techniques within the same clinical framework are limited.24,26 Such comparisons are essential to identify the most efficient, safe, and user-friendly technique, particularly for routine clinical use and training purposes.

In this context, the present study was designed to provide a structured comparison of three commonly employed ultrasound-guided approaches for IJV cannulation. By systematically assessing procedural time, success rates, number of attempts, operator-perceived ease, and complication profiles, this study aims to bridge existing gaps in the literature and contribute to evidence-based optimization of central venous access techniques. The findings are expected to have important implications for clinical practice, particularly in enhancing procedural safety, improving efficiency, and guiding training strategies in anesthesiology and critical care settings.

AGE-WISE DISTRIBUTION

The present study demonstrated that the majority of patients across all three groups belonged to the 46 to 60 years age category, followed by the 31 to 45 years group, while comparatively fewer patients were observed in the younger (18 to 30 years) and elderly (>60 years) categories. Importantly, the distribution of patients across age groups was nearly identical among the three study arms, and statistical analysis confirmed that there was no significant difference. Furthermore, the mean age values were comparable across all groups, indicating effective randomization and homogeneity of baseline characteristics. This uniformity ensures that age did not act as a confounding variable influencing procedural outcomes such as success rates, time taken, or complication profiles, thereby strengthening the internal validity of the study.

From a clinical and pathophysiological perspective, the predominance of middle-aged patients undergoing internal jugular vein cannulation can be attributed to the higher burden of systemic diseases and surgical interventions in this age group. Individuals in the 4th to 6th decades of life are more likely to present with chronic conditions such as hypertension, diabetes mellitus, ischemic heart disease, and malignancies, all of which frequently necessitate invasive monitoring, administration of vasoactive agents, or long-term venous access. Additionally, perioperative requirements for major surgeries, which are more common in this age group, further increase the demand for central venous catheterization. Anatomically, vascular structures in middle-aged individuals are generally more compliant and accessible compared to elderly patients, in whom vessel tortuosity, calcification, and reduced elasticity may complicate cannulation. Conversely, younger patients often require central access less frequently, contributing to their lower representation in such studies.

The findings of the present study are consistent with previously published literature. Karakitsos et al.3, in their study on ultrasound-guided IJV cannulation, reported a similar predominance of middle-aged patients, reflecting the demographic profile of patients requiring invasive monitoring and critical care. Lal et al.26, in a randomized comparative study of different ultrasound-guided approaches, also observed that the majority of patients belonged to the middle-aged group. Furthermore, Baidya et al.24 reported comparable age distribution across study groups, indicating that age-related trends are more reflective of clinical necessity than procedural preference. Saugel et al.30, in a structured review, also noted that most studies on central venous access predominantly involve adult populations with mean ages in the fifth decade, supporting the findings of the present study.

Variations in age distribution across different studies may be attributed to several factors, including study design, patient selection criteria, and the clinical setting in which the study is conducted. For instance, studies conducted in pediatric populations or neonatal intensive care units will naturally demonstrate a younger age distribution, whereas studies focusing on geriatric patients or chronic care settings may show a higher proportion of elderly individuals. Additionally, regional differences in disease prevalence, life expectancy, and healthcare access can influence the demographic profile of patients requiring central venous catheterization. Tertiary care centers dealing with complex surgical and critical care cases may have a higher representation of middle-aged patients, whereas community hospitals may exhibit a broader age distribution. These factors collectively contribute to the variability observed in age-related findings across different studies.

GENDER-WISE DISTRIBUTION

The present study demonstrated a clear predominance of male patients across all three groups, with consistent proportions and no statistically significant difference between them. Female patients constituted a smaller proportion but were evenly distributed, indicating appropriate randomization and absence of gender-related bias in group allocation. This uniformity ensures that gender did not influence procedural outcomes, thereby allowing a fair comparison of the different ultrasound-guided approaches.

The higher proportion of male patients can be explained by epidemiological and socioclinical factors. Males have been shown to have a higher prevalence of cardiovascular diseases, trauma, and certain malignancies, all of which frequently necessitate central venous access for monitoring and therapeutic purposes. Lifestyle-related risk factors such as smoking, alcohol consumption, and occupational hazards are more prevalent among males in many populations, contributing to increased morbidity and hospitalization rates. Furthermore, in certain socio-cultural contexts, males may have greater access to healthcare facilities, leading to higher representation in hospital-based studies. These factors collectively explain the observed male predominance in the present study.

Similar findings have been reported in previous studies evaluating central venous catheterization. Eisen et al.2 observed a higher proportion of male patients in their analysis of complications associated with central venous catheters. Lee and Kim19 also reported male predominance in their comparative study of ultrasound-guided versus landmark techniques for IJV cannulation. Baidya et al.24 demonstrated a similar gender distribution in their randomized study, reinforcing that male predominance is commonly observed in populations requiring critical care and surgical interventions. Parienti et al.31, in a large observational study, also reported a higher proportion of male patients undergoing central venous catheterization, supporting the findings of the present study.

Variations in gender distribution across studies may be influenced by differences in study populations, clinical specialties, and geographic regions. Studies conducted in obstetric and gynecological settings will naturally demonstrate female predominance, whereas studies focusing on trauma, cardiac surgery, or intensive care may show a higher proportion of male patients. Additionally, cultural and socioeconomic factors influencing healthcare-seeking behavior can significantly affect gender representation in different regions. Variability in inclusion criteria, such as the exclusion of certain patient groups, may also contribute to differences in gender distribution across studies.

INDICATION FOR IJV CANNULATION

The present study demonstrated that perioperative monitoring was the most common indication for internal jugular vein cannulation across all three groups, followed by ICU management. The distribution of indications was comparable between the groups, and statistical analysis revealed no significant difference, indicating uniformity in clinical requirements among the study population. This homogeneity ensures that the observed differences in procedural outcomes are attributable to the techniques employed rather than variations in underlying clinical indications. The predominance of perioperative cases also reflects the nature of the study setting, where a substantial proportion of patients required central venous access for intraoperative and immediate postoperative management.

Central venous catheterization is an essential component of perioperative care, particularly in major surgeries requiring precise hemodynamic monitoring, administration of vasoactive drugs, rapid fluid resuscitation, and blood transfusion. In ICU settings, central venous access is indispensable for long-term infusion of medications, parenteral nutrition, and monitoring of central venous pressure. The slightly lower proportion of ICU cases in the present study may be reflective of elective surgical workload, whereas critically ill patients represent a subset requiring more prolonged and complex management. Additionally, advancements in peripheral access techniques may have reduced the need for central venous access in certain ICU scenarios, thereby influencing the distribution.

These findings are consistent with those reported in the literature. Lamperti et al.6 emphasized that perioperative and critical care settings remain the primary indications for central venous catheterization and strongly recommended ultrasound guidance to enhance safety and success. McGee and Gould1 also highlighted that central venous access is most frequently required in surgical and critically ill patientsfor hemodynamic monitoring andadministration of medications. Clark and Young21, in a randomized controlled trial, reported a similar predominance of perioperative indications.Saugel et al.30further confirmed that the majority of central venous catheter placements occur in operative and ICU settings, aligning with the present findings.

Variations in the distribution of indications across different studies may be attributed to differences in institutional practices, patient populations, and healthcare infrastructure. Studies conducted in high-dependency or intensive care units may demonstrate a higher proportion of critically ill patients, whereas those in surgical centers may show a predominance of perioperative indications. Furthermore, the availability of alternative vascular access techniques, such as peripherally inserted central catheters (PICCs), may influence the frequency of IJV cannulation in certain settings. Regional variations in disease burden and referral patterns also contribute to heterogeneity in indication profiles across studies.

TIME TAKEN FOR SUCCESSFUL CANNULATION

The present study demonstrated significant differences in various time parameters among the three ultrasound-guided approaches. The out-of-plane approach showed the shortest time for identification of the internal jugular vein, whereas the

lateral oblique approach was associated with the shortest total cannulation time. The in-plane approach required comparatively more time for vessel identification but demonstrated moderate efficiency in overall cannulation. These differences were statistically significant, indicating that the choice of technique plays a crucial role in procedural efficiency. The findings suggest that while certain techniques may offer rapid initial localization, others may provide greater overall efficiency by facilitating smoother completion of the procedure.

The observed differences can be explained by the inherent technical characteristics of each approach. The out-of-plane technique provides a cross-sectional view of the vessel, allowing rapid identification; however, it does not permit continuous visualization of the needle tip, which may prolong subsequent steps due to the need for repeated adjustments. The in-plane approach, on the other hand, allows continuous visualization of the needle shaft and tip but requires precise alignment between the probe and needle, increasing the time required for initial positioning. The lateral oblique approach combines elements of both techniques, offering improved needle visualization along with a broader anatomical perspective, thereby facilitating quicker completion of the procedure. This balance between visualization and orientation likely contributes to its superior performance in terms of total cannulation time.

These findings are supported by existing literature. Stone et al.4 demonstrated that improved needle tip visualization significantly enhances procedural efficiency and reduces time to successful cannulation. Blaivas et al.7 reported that long-axis approaches improveneedle visualization but may require greater technical expertise. Maitra et al.27, in a network meta-analysis, concluded that oblique approaches may offer improved efficiency by combining the advantages of both short- and long-axis techniques. Kalina et al.23also reported reduced cannulation time with oblique approaches compared to conventional techniques. A systematic review by Brass et al.29, in a Cochrane review, further highlighted that ultrasound-guided techniques significantly reduce procedural time compared to landmark methods.

Differences in time-related outcomes across studies may be influenced by several factors, including operator experience, patient characteristics, and methodological variations. Studies involving experienced clinicians may demonstrate shorter procedural times irrespective of the technique used, whereas novice operators may show greater variability. Differences in defining and measuring time intervals, such as inclusion of preparation time or only needle insertion time, can also contribute to discrepancies. Additionally, patient-related factors such as obesity, anatomical variations, and hemodynamic instability may affect procedural duration, leading to variability in reported results.

FIRST-PASS SUCCESS RATE

The present study demonstrated that the lateral oblique approach had the highest first-pass success rate, followed by the out-of-plane approach, while the in-plane approach showed comparatively lower first-pass success. The difference between the groups was statistically significant, indicating that the choice of ultrasound-guided technique has a direct impact on the likelihood of successful cannulation on the first attempt. A higher first-pass success rate is clinically important as it reduces patient discomfort, minimizes complications, and improves overall procedural efficiency.

First-pass success is primarily influenced by accurate needle visualization, optimal alignment with the target vessel, and real-time anatomical assessment. The lateral oblique approach allows simultaneous visualization of both the vessel and the advancing needle, thereby reducing the risk of misalignment and improving accuracy. In contrast, the out-of-plane approach may suffer from limited needle tip visualization, increasing the likelihood of multiple attempts. The in-plane approach, although providing continuous visualization, requires precise alignment, which can be technically challenging, particularly for less experienced operators. These technical differences explain the variation in first-pass success rates observed in the present study.

The findings are consistent with previous studies in the literature. Karakitsos et al.3 demonstrated that ultrasound guidance significantly improves first-pass success compared to landmark techniques. Lal et al.26 reported higher first-pass success rates with oblique approaches compared to traditional short-axis techniques. Baidya et al.24 observed that in-plane approaches, while precise, may be associated with a learning curve that affects first-pass success.A meta-analysis by Saugel et al.30 also highlighted that approaches providing better needle visualization are associated with higher first-pass success rates.

Variations in first-pass success rates across studies may be attributed to differences in operator expertise, training, and familiarity with specific techniques. Studies involving highly experienced clinicians may demonstrate uniformly high success rates across all approaches, whereas those involving trainees may show significant differences between techniques. Patient-related factors such as difficult anatomy, obesity, or vessel collapse can also influence success rates. Additionally, differences in study design, including definitions of first-pass success and inclusion criteria, may contribute to variability in reported outcomes.

NUMBER OF NEEDLE PASSES REQUIRED

The present study demonstrated that single-pass success was highest with the lateral oblique approach, followed by the out-of-plane approach, while the in-plane approach required a greater proportion of two or more attempts. Additionally, the incidence of multiple needle passes (≥3) was highest in the in-plane group and lowest in the lateral oblique group. The difference between the groups was statistically significant, indicating that the choice of ultrasound-guided technique has a direct influence on procedural ease and efficiency. Fewer needle passes reflect improved precision and better needle control, which are important indicators of procedural success.

The number of needle passes required is closely related to the degree of needle tip visualization and the ability to maintain alignment with the target vessel. The lateral oblique approach provides a combined view of vascular anatomy and needle trajectory, allowing better spatial orientation and reducing the need for repeated attempts. In contrast, the out-of-plane approach may result in loss of needle tip visualization, leading to uncertainty regarding needle position and necessitating multiple redirections. The in-plane approach, although offering continuous visualization, requires precise alignment of the probe and needle, which can be technically demanding and may contribute to increased attempts, especially in less experienced hands.

These findings are supported by recent studies in the literature. Parienti et al.31 reported that increased number of needle passes is associated with a higher risk of complications and emphasized the importance of techniques that improve first-pass success. Saugel et al.30 highlighted that approaches with better needle visualization are associated with fewer attempts and improved procedural safety. Troianos et al.32, in their guidelines on central venous access, emphasized minimizing needle passes as a key factor in reducing complications. Additionally, Lamperti et al.33further emphasized that optimized ultrasound-guided techniques and proper probe–needle coordination improve procedural efficiency and reduce the need for multiple attempts.

Variability in the number of needle passes across different studies may be influenced by operator experience, patient anatomy, and the clinical environment. Studies involving experienced anesthesiologists may demonstrate fewer attempts regardless of the technique used, whereas studies including trainees may show greater variability. Patient-related factors such as obesity, short neck, or altered anatomy can also increase procedural difficulty. Furthermore, differences in study design, including how attempts are defined and recorded, can contribute to inconsistencies in reported results.

OVERALL SUCCESS RATE OF CANNULATION

The present study demonstrated high overall success rates across all three approaches, with the lateral oblique approach showing the highest success, followed by the in-plane and out-of-plane approaches. However, the differences were not statistically significant, indicating that all three ultrasound-guided techniques are effective in achieving successful cannulation when performed under appropriate conditions.

The high overall success rates observed in all groups can be attributed to the use of real-time ultrasound guidance, which significantly enhances visualization of vascular structures and reduces reliance on anatomical landmarks. Ultrasound allows dynamic assessment of vessel patency, size, and position, enabling precise needle placement. Even when initial attempts are unsuccessful, real-time imaging facilitates immediate correction, thereby maintaining high overall success rates. This highlights that while technique influences efficiency and complication rates, ultrasound guidance itself is the most critical determinant of success.

These findings are consistent with existing literature. Karakitsos et al.3demonstrated significantly higher success rates with ultrasound-guided cannulation compared to landmark techniques.Brass et al.29, in a Cochrane review, reported significantly higher success rates and reduced failurewith ultrasound guidance. Troianos et al.32 also emphasized that ultrasound guidance improves overall success irrespective of the specific approach used. A recent study by Gibson et al.34highlighted that accurate anatomical visualization contributes to consistently high success rates across different techniques.

Differences in overall success rates across studies may arise due to variations in operator skill, patient population, and study design. Studies involving inexperienced operators or difficult patient populations may report lower success rates. Additionally, differences in defining “successful cannulation” and inclusion of failed attempts may influence reported outcomes. Institutional protocols and availability of advanced ultrasound equipment may also contribute to variability.

EASE OF CANNULATION (OPERATOR PERCEPTION)

The present study demonstrated that the lateral oblique approach was most frequently rated as “good to excellent” by operators, followed by the out-of-plane approach, while the in-plane approach had a higher proportion of “poor” and

"satisfactory" ratings. The differences were statistically significant, indicating that operator comfort and perceived ease vary considerably between techniques.

Ease of cannulation is influenced by factors such as clarity of needle visualization, ergonomics, hand–eye coordination, and the learning curve associated with each technique. The lateral oblique approach provides a more intuitive visualization of both the vessel and needle, reducing cognitive load and facilitating smoother execution. In contrast, the in-plane approach requires precise alignment and coordination, which may be challenging, particularly for less experienced operators. The out-of-plane approach, while simpler, may cause uncertainty due to intermittent needle visualization.

These findings are supported by previous studies. Moore and Taylor13 emphasized that operator comfort and familiarity with ultrasound techniques significantly influence procedural performance. Troianos et al.32 highlighted that ease of use is an important factor in technique selection, particularly in emergency settings. A study by Hind et al.35 demonstrated that techniques providing better visualization are associated with higher operator satisfaction. Additionally, Lamperti et al.33also emphasized that structured ultrasound-guided approaches improve operator confidence and procedural efficiency. Variations in perceived ease across studies may be due to differences in operator experience, training, and familiarity with specific techniques. Operators trained predominantly in one technique may perceive it as easier, introducing subjective bias. Differences in equipment, such as probe type and image quality, may also influence ease of use. Furthermore, institutional training protocols and exposure to different techniques can significantly affect operator perception.

MECHANICAL COMPLICATIONS

The present study demonstrated that mechanical complications were highest in the out-of-plane approach, with notable occurrences of posterior wall puncture, arterial puncture, local hematoma, and difficulty in guidewire threading. The in-plane and lateral oblique approaches showed significantly lower complication rates, with the lateral oblique approach demonstrating the safest profile. The difference between groups was statistically significant, indicating that technique selection plays a crucial role in minimizing complications.

The higher complication rate observed with the out-of-plane approach can be attributed to poor needle tip visualization, which increases the risk of overshooting the vessel and causing posterior wall puncture or arterial injury. In contrast, the in-plane approach allows continuous visualization of the needle, reducing such risks. The lateral oblique approach further enhances safety by providing both needle visualization and anatomical context, allowing better control during needle advancement. These factors collectively contribute to lower complication rates with techniques that offer superior visualization.

These findings are consistent with previous literature. McGee and Gould1 and Eisen et al.2 reported that mechanical complications are closely related to needle visualization and operator technique. Parienti et al.31 demonstrated that multiple attempts and poor technique significantly increase complication rates. Troianos et al.32strongly recommended ultrasound guidance to reduce complications associated with central venous access. A recent study by Schmidt et al.36 showed that approaches with improved needle visualization significantly reduce arterial puncture and hematoma formation. Similarly, Saugel et al.30 emphasized that real-time ultrasound guidance is critical in minimizing procedural complications.

Variations in complication rates across studies may be influenced by operator experience, patient characteristics, and study methodology. Studies involving high-risk patients, such as those with coagulopathy or difficult anatomy, may report higher complication rates. Differences in definitions and reporting of complications can also contribute to variability. Additionally, advancements in ultrasound technology and improved training may lead to lower complication rates in more recent studies compared to earlier ones.

STRENGTHS

- The study design was prospective, randomized, and comparative, which improves the validity and reliability of the findings.
- A large sample size was included, enhancing the statistical power and generalizability of the results.
- Equal distribution of patients among groups ensured balanced comparison between techniques.
- Use of ultrasound guidance in all groups minimized procedural bias and allowed fair evaluation of different approaches.
- Multiple clinically relevant outcomes were assessed, including time parameters, success rates, number of attempts, ease of cannulation, and complications.
- Objective measurements such as time taken and success rates reduced subjectivity in outcome assessment.
- Inclusion of operator-perceived ease (Likert scale) added practical clinical relevance.
- Statistical analysis was appropriately performed, with clear reporting of p-values for all comparisons.

- The study evaluated both efficacy and safety parameters, providing a comprehensive understanding of each technique.
- Real-world clinical setting increases applicability of results in routine anesthetic and critical care practice.
- Comparison of three different ultrasound-guided approaches in a single study adds novelty and broader insight.

LIMITATIONS

- The study was single-blinded, which may introduce observer or performance bias.
- Operator experience and skill level were not standardized or stratified, which could influence outcomes.
- Conducted at a single center, limiting external generalizability.
- Long-term complications or follow-up outcomes were not assessed.
- Patient-related factors such as BMI, anatomical variations, or comorbidities were not analyzed in detail.

FUTURE RECOMMENDATIONS

- Multicentric studies should be conducted to improve generalizability across different clinical settings.
- Studies including operators with varying levels of experience can help assess learning curves and reproducibility.
- Future research should evaluate long-term outcomes and late complications.
- Inclusion of specific patient subgroups (e.g., obese, critically ill, or anatomically difficult cases) may provide deeper insights.
- Cost-effectiveness and training requirements of each technique should be explored.

CONCLUSION

The present study demonstrates that ultrasound-guided internal jugular vein cannulation is a highly effective and safe procedure across all three approaches evaluated. Baseline characteristics, including age, gender distribution, and indications for cannulation, were comparable among the groups, indicating that the observed differences in outcomes are attributable to the techniques themselves rather than patient-related factors.

In conclusion, while all three ultrasound-guided approaches are clinically effective, the lateral oblique approach appears to offer distinct advantages in terms of efficiency, success on first attempt, operator ease, and reduced complications. These findings support its consideration as a preferred technique in routine clinical practice, particularly in settings where rapid and safe vascular access is essential.

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