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COMPARATIVE EVALUATION OF REAL-TIME ULTRASONOGRAPHY GUIDED VERSUS CONVENTIONAL ANATOMICAL LANDMARK GUIDED TECHNIQUE FOR CENTRAL VENOUS CANNULATION IN ELECTIVE CARDIAC SURGERY PATIENTS

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ABSTRACT

Central venous catheterization is a critical procedure in cardiac and intensive care practice, with both conventional anatomical landmark technique and real-time ultrasonography guidance being used for internal jugular venous cannulation. This prospective randomized study compared the efficacy, safety, and procedural characteristics of ultrasound-guided cannulation with the landmark technique in 76 adult patients undergoing elective cardiac surgery. All procedures were performed by an experienced anesthesiologist, and outcomes included number of attempts, access time, total cannulation time, overall success rate, and procedure-related complications. The ultrasound group demonstrated significantly shorter access time (39 vs 118 seconds, $p = 0.001$) and total cannulation time (225.84 vs 438.95 seconds, $p < 0.001$). Although overall success rates were comparable (76.32% vs 78.95%, $p = 1.00$), complications such as carotid artery puncture and hematoma occurred only in the landmark group. No cases of pneumothorax, hemothorax, or catheter malposition were observed in either group. The findings indicate that ultrasound guidance facilitates faster venous access with fewer complications, supporting its routine use in central venous cannulation, particularly in cardiac surgical patients.

KEYWORDS: *Ultrasound-guided cannulation, Central venous catheterization, Internal jugular vein, Landmark technique & Cardiac surgery patients*

INTRODUCTION

With advanced knowledge in medical monitoring, ever increasing value has been placed on the establishment of a central venous catheter. During past few years, central venous cannulation has been used for various indications [1]. It is of vital importance in many surgeries and postoperative care of patients. It has become an integral part in the management of critically ill patients in ICU setup and monitoring central venous pressure (CVP) became an important aid [1].

It was not until 1950's and 1960's that the application of principles governing the adequacy of cardiac function led to the monitoring of central venous pressure as an indicator of intravascular volume, preload and cardiac performance [2]. Before this period considerable attention was directed towards the importance of radial artery pressure monitoring [3]. The Seldinger technique and J-tipped guidewire made central venous cannulation through internal jugular vein practical. Thereafter balloon tipped pulmonary artery catheter was introduced and accepted.

The introduction of these techniques has allowed optimal adjustment of circulatory variables by hemodynamic measurements and volume replacement, infusion of a wide variety of pharmacologically active agents which cannot be satisfactorily infused via peripheral lines and provision of intravenous nutrition for prolonged period [1].

Vascular cannulation is the cornerstone of monitoring and therapy for the most serious illness [4] particularly in those patients where major changes in intravascular volume, afterload or contractility occur [5,6]. The filling pressure measurements afforded by monitoring CVP allow differentiation between hypovolemia and myocardial infarction [7,8]. The differentiation between hypovolemia and ventricular failure is difficult under anesthesia; consequently, the measurement of intracardiac pressure or volume is necessary to make accurate diagnosis [9]. The CVP is the pressure in the right atrium and most accurately reflects alteration in volume or compliance of right atrium or ventricle, tricuspid or pulmonary valvular dysfunction and the effects of increased right ventricular afterload. Central venous pressure also correlates with changes in pulmonary and left ventricular end diastolic pressure therefore it reflects left ventricular function [10]. Central venous pressure monitoring is carried out during perioperative period on a patient who is undergoing a surgical or cardiac procedure [11].

Cannulation by percutaneous route became the urgent, elective and emergency central venous catheterization approach most preferred by anesthesiologists and many intensivists [12].

In 1952, Aubaniac described infraclavicular subclavian technique for central venous catheterization (CVC). Later in 1962, Wilson and associates popularized central venous catheterization through subclavian routes [13]. In 1966, Hermosura et al, described a method for placement of polyethylene catheter in internal jugular vein [14]. Craig et al, described the use of internal jugular vein for catheterization of central venous system but considered it undesirable because of dislodgement and obstruction due to neck movements [15].

Various positions were used to access cannulation but they were frequently associated with complications such as arterial puncture, pneumothorax, neurological damage, infection, dysrrhythmias, atrial thrombus, cardiac rupture [16,17]. The femoral vein has been universally abandoned as a route to the central venous system because of high incidence of thromboembolism and thrombophlebitis in the lower extremities [18]. Though Wilson and associates popularized subclavian vein catheterization, ten years later Shapira et al recommended discontinuation of the technique due to serious complications of pneumothorax and hemothorax [19]. Later, English et al described two methods of internal jugular vein percutaneous cannulation. One method was based on palpation of internal jugular vein, while the other was related to the medial border of the clavicular attachment of sternocleidomastoid muscle [20]. Several alternative anatomic landmark techniques are proposed for central venous cannulation [21,22,23,24] but percutaneous right internal jugular cannulation is favoured for various reasons [25]. Cannulation is influenced by patient factors such as body mass index (BMI), site of attempted access, and operator experience [26,27,28]. Inability to cannulate the IJV may occur in up to 19.4% of cases [27] and complication rate can be as high as 12.3% even with experienced operators [29].

Ultrasonography provides 'real-time' imaging, i.e., the needle can be visualised entering the vein. The use of ultrasound and Doppler to assist cannulation of the internal jugular vein was reported as early as 1984 [30]. USG guidance also decreases number of attempts [28] per cannulation increasing success rate [28,29,31], makes the procedure faster [28] and lessens complications [29,31,32] as USG provides 'real-time' imaging. The Agency for healthcare research and quality (AHRQ) in USA [31] and the National institute for clinical excellence (NICE) in UK [33] recommends CVC placement under USG guidance to improve patient care. Success rate with USG guidance can be as high as 100% with less complication [34].

So, an endeavour has been created to assess whether the USG guided central venous cannulation has a better success rate than the conventional landmark guided technique. This study was designed to compare the USG guided technique with landmark guided technique with respect to success rate and complications.

The objective of this study was to compare the efficacy, safety, and procedural characteristics of real-time ultrasonography guided central venous cannulation with the conventional anatomical landmark technique. The study aimed to assess and analyse the number of attempts required for successful venous access, overall success rate, access time, total cannulation time, and procedure-related complications in adult patients undergoing elective cardiac surgery. By evaluating these parameters, the thesis sought to determine whether ultrasound guidance offered a measurable advantage in terms of

precision, speed, and complication reduction when compared with the traditional landmark approach, thereby contributing to improved patient care and safer venous access practices in clinical settings.

MATERIAL AND METHODS

STUDY DESIGN AND SETTING

This prospective, single-blinded, randomized controlled study was conducted in the Cardiothoracic and Vascular Surgery (CTVS) operation theatre and post-operative recovery unit of IPGME&R Hospital, Kolkata. The study was carried out over a period of twelve months, from February 2013 to January 2014, with the primary objective of comparing real-time ultrasonography guided internal jugular venous cannulation with the conventional anatomical landmark guided technique in patients undergoing elective cardiac surgery.

STUDY POPULATION AND ETHICAL APPROVAL

A total of seventy-six adult patients requiring central venous access for cardiac surgery were included after obtaining approval from the Institutional Ethics Committee. All eligible patients provided informed written consent. The study population consisted of both male and female patients between 20 and 60 years of age, and only those scheduled for elective cardiac surgery were enrolled.

INCLUSION AND EXCLUSION CRITERIA

Patients were included if they were adults aged between 20 and 60 years, belonged to either sex, and were posted for elective cardiac surgery. Exclusion criteria comprised patient refusal, anatomical deformities of the neck, local infection at the insertion site, proven coagulopathy, known vascular abnormalities, and poor pulmonary function where pneumothorax might be poorly tolerated. Patients outside the defined age limits were also excluded.

SAMPLE SIZE AND RANDOMIZATION

Sample size was calculated using n Master 2.0 software, assuming a 20% improvement in first-attempt success rate in the ultrasonography group, with 80% power and a 5% level of significance. The estimated requirement was 38 subjects per group, giving a total sample size of 76. Patients were randomly allocated to one of two groups using a computer-generated sequence, with 38 patients assigned to anatomical landmark technique (Group I) and 38 to ultrasonography guided technique (Group II). The operator performing the procedure was blinded to group allocation.

PRE-PROCEDURAL ASSESSMENT AND MONITORING

All patients underwent a complete pre-anesthetic evaluation including history, physical examination, and investigations such as complete blood count, renal and liver function tests, coagulation profile, chest radiography, echocardiography, and electrocardiography. Standard ASA monitoring—including pulse oximetry, electrocardiography, and non-invasive blood pressure—was applied in the operating room. Peripheral intravenous access was secured prior to induction, and emergency drugs and equipment were kept ready. After induction of anesthesia and intubation, patients were positioned in 10–30° Trendelenburg tilt with the head rotated to the contralateral side, and a shoulder roll was placed to optimize venous access. The right internal jugular vein was preferred for cannulation in both groups.

CANNULATION TECHNIQUE: GROUP I – ANATOMICAL LANDMARK

In the anatomical landmark technique, the triangle formed by the two heads of the sternocleidomastoid muscle was identified. Pulsation of the carotid artery was palpated and displaced slightly medially. A 22G seeker needle was introduced lateral to the pulsation toward the ipsilateral nipple at approximately 45°. After locating the vein, an 18G introducer needle was inserted parallel to this trajectory. Upon aspiration of venous blood, a guidewire was advanced using the Seldinger technique, the tract was dilated, and a central venous catheter was inserted over the guidewire. Free venous backflow confirmed correct positioning, and the catheter was secured with sutures and covered with sterile dressing.

CANNULATION TECHNIQUE: GROUP II – ULTRASOUND GUIDED

In the ultrasound-guided group, a 10.5 MHz linear vascular probe was used to visualize the neck vessels in real time. After sterile preparation, the probe was applied over the apex of the sternocleidomastoid carotid triangle. The internal jugular vein was identified as a compressible, non-pulsatile, oval structure, while the artery appeared pulsatile and non-compressible. Needle insertion was performed under real-time ultrasound guidance, allowing visualization of vessel puncture and guidewire passage. Once venous blood was aspirated, the remaining steps of dilatation and catheter insertion were completed as in Group I.

DEFINITION OF FAILURE AND OUTCOME MEASURES

Cannulation was considered a failure if more than one attempt with the 18G needle was required, if the side or site of cannulation had to be changed, or if the operator was replaced. The primary outcome measures recorded in both groups were number of attempts, access time (from skin puncture to venous aspiration), total cannulation time (from skin puncture to catheter placement), and complications including arterial puncture, hematoma, pneumothorax, hemothorax, and catheter malposition.

POST-PROCEDURAL CONFIRMATION

All patients underwent post-procedural chest X-ray (PA view) to verify catheter tip position and to rule out complications. Ideal placement was defined as the catheter tip lying parallel to the superior vena cava, below the clavicle, and above the level of the third rib or tracheal carina.

STATISTICAL ANALYSIS

Data were entered into Microsoft Excel and analysed using Statistica version 6. Continuous variables were expressed as mean ± standard deviation, and categorical variables as frequency and percentage. Intergroup comparisons were performed using appropriate statistical tests, and a p-value < 0.05 was considered statistically significant.

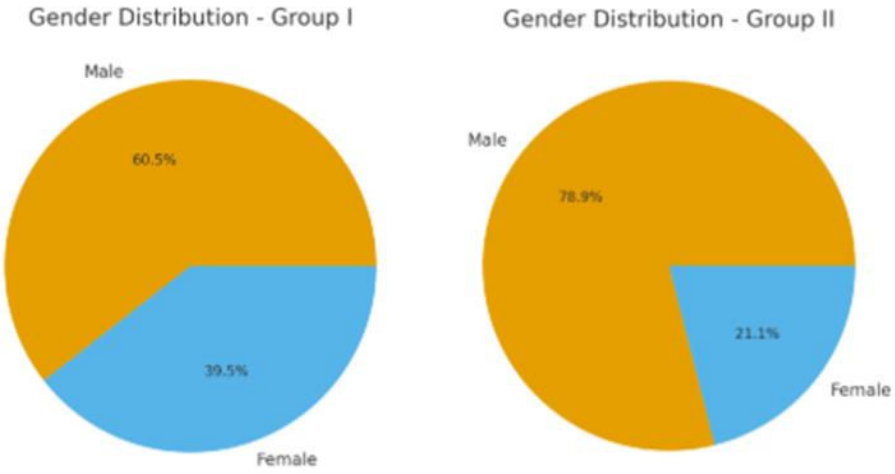
RESULTS AND OBSERVATIONS

Table 1: Age characteristics of study population

Parameter	Group I (Landmark)	Group II (USG Guided)	p value
Mean age (years)	44.97 ± 14.46	42.21 ± 13.01	0.384
Minimum age (years)	20	20	—
Maximum age (years)	71	65	—

Both groups were comparable in terms of age distribution. Group I had an age range of 20–71 years with a mean age of 44.97 years, while Group II ranged from 20–65 years with a mean age of 42.21 years. Statistical analysis showed no significant difference between the two groups (p = 0.384), indicating that age was well matched and unlikely to influence procedural outcomes.

Figure 1: Gender Distribution in study groups.



Sex distribution of patients of each group that indicates 23 (60.53%) male and 15 (39.47%) female patients were in Group I. In Group II there were 30 (78.95%) male and 8 (21.5%) female patients. Male predominance was observed in both groups, more markedly in Group II (78.95%). However, the male–female ratio between groups was not statistically significant (p = 0.133). This indicates that sex difference was not a confounding factor in the study outcomes.

Table 2: Number of attempts required

Group	Mean Attempts	Standard Deviation	p value
Group I	1.37	± 0.852	0.791
Group II	1.34	± 0.708	—

The majority of cannulations were achieved on the first attempt in both groups. Group I had 81.57% first-attempt success compared with 76.31% in Group II. The mean number of attempts was similar between groups, and no significant difference was found (p = 0.791). This indicates that operator skill and difficulty were comparable.

Table 3: Cannulation site used

Cannulation Site	Group I (n=38)	Group II (n=38)	p value
Right Internal Jugular Vein	35 (92.1%)	38 (100%)	0.209
Right Subclavian Vein	2 (5.26%)	0	—
Left Subclavian Vein	1 (2.63%)	0	—

The right IJV was the most common site of access. In Group I, a few cases required subclavian access due to cannulation difficulty. Group II used right IJV exclusively, likely due to real-time visualization. Despite this difference, p = 0.209 shows no statistical significance.

Table 5: Overall success of cannulation

Outcome	Group I n (%)	Group II n (%)	p value
Successful	30 (78.95%)	29 (76.32%)	1.00
Failed	8 (21.05%)	9 (23.68%)	—

Success rates were high and comparable in both groups. Failures occurred when more than one attempt was required or when an alternative site/operator was needed. The procedure success difference was not significant (p = 1.00), indicating similar feasibility of both techniques.

Table 6: Time from skin puncture to venous aspiration

Group	Mean (seconds)	Median (seconds)	SD	Range	p value
Group I	118.03	35	± 252.628	15–1200	0.001
Group II	39	20	± 56.26	4–300	—

The average access time was significantly shorter in Group II. Ultrasound guidance enabled faster localization of the vein, with nearly three-fold reduction in mean access time. The statistical test confirmed this superiority (p = 0.001).

Table 7: Time from skin puncture to catheter placement

Group	Mean (seconds)	Median (seconds)	SD	Range	p value
Group I	438.95	300	± 396.49	120–1920	<0.001
Group II	225.84	150	± 209.096	40–1200	—

Total cannulation time was significantly shorter in the ultrasound group. The reduction reflects both faster access and controlled guidewire passage. The difference was highly significant (p < 0.001).

Table 8: Complications observed

Complication	Group I (n=38)	Group II (n=38)	p value
Carotid artery puncture	3 (7.89%)	0	0.240
Hematoma	3 (7.89%)	0	—
Pneumothorax	0	0	—
Hemothorax	0	0	—
Catheter malposition	0	0	—

Complications occurred only in the landmark group. Three patients sustained carotid puncture with subsequent hematoma formation. No major complications such as pneumothorax, hemothorax, or catheter malposition were reported in either group. Although numerically favorable, the difference was not statistically significant (p = 0.240).

Table 9: Objective parameters reported in results

Objective Parameter	Reported?	Evidence from Results
Number of attempts required	✓ Yes	Mean attempts for both groups (1.37 vs 1.34), no statistical difference
Overall success rate	✓ Yes	Success rate 78.95% vs 76.32%, p = 1.00
Access time	✓ Yes	118.03 sec vs 39 sec, statistically significant (p = 0.001)
Total cannulation time	✓ Yes	438.95 sec vs 225.84 sec, p < 0.001
Complications	✓ Yes	Carotid puncture + hematoma only in landmark group (3 cases), none in USG group

DISCUSSION

In this prospective study, real-time ultrasonography guided internal jugular venous cannulation was compared with the conventional anatomical landmark technique in adult cardiac surgical patients. Both techniques demonstrated comparable success rates; however, ultrasound guidance significantly reduced access time, total cannulation time, and procedure-

related complications. These findings agree with the progressive shift toward image-assisted vascular access in modern perioperative and critical care practice.

Our study demonstrated a first-attempt success rate above 75% in both groups, similar to Karakitsos et al., who reported significantly higher first-attempt success with ultrasound in critically ill patients [35]. The overall success rate did not differ significantly between the two groups in the present study, consistent with the findings of Denys and Uretsky [36], who noted that success rates may not vary markedly but complication rates are clearly reduced with ultrasound guidance. In our cohort, carotid artery puncture and resultant hematoma occurred exclusively in the landmark group, whereas no such adverse events were encountered with ultrasonography.

Randolph et al. demonstrated an 86% reduction in mechanical complications when ultrasound was used for central venous access [37]. The complete absence of arterial puncture and hematoma in our USG group aligns with these results, reinforcing ultrasound's role in preventing mechanical injury. Indian literature supports this pattern. Palepu et al. evaluated 130 catheter placements and found a significantly lower rate of arterial puncture with ultrasound (2.3%) compared with the landmark technique (10.7%) [38]. In our study, arterial puncture was reported in 7.89% of landmark cases, while none occurred under ultrasound guidance, showing close concordance.

Time efficiency is one of the major advantages of ultrasound. In the present study, mean access time was 39 seconds in the USG group versus 118 seconds in the landmark group, and total cannulation time was nearly half in the ultrasound group. Similar observations were reported by Fry et al., who demonstrated improved cannulation speed with ultrasound, especially in high-risk populations [39]. Palepu et al. also reported faster cannulation under ultrasound guidance in intensive care settings [38], while NICE guidelines strongly recommend ultrasound use during IJV cannulation to enhance both speed and safety [40].

A meta-analysis by Randolph et al. concluded that ultrasound increases the success of cannulation and reduces complications, particularly for the internal jugular vein [37]. The findings from our study are consistent, showing shorter procedure time, fewer complications, and equally high success rates with ultrasound. The absence of pneumothorax, hemothorax, and catheter malposition in both groups reflects the elective surgical setting and the experience of the operator. However, mechanical complications like carotid puncture were observed only in the landmark group, similar to previous reports by English et al. [41], highlighting the potential risks associated with blind techniques.

Indian experience mirrors international findings. Palepu et al. concluded that routine use of ultrasound significantly improves safety and procedural success in central venous catheterization in Indian intensive care units [38]. A recent Indian multicentric trial reported reduced complications and improved procedural ease with ultrasound, especially for trainees and in technically difficult cases [42]. Given the high prevalence of anatomical variations in the IJV [36], ultrasound helps identify vessel position, depth, and patency prior to needle insertion.

The strengths of the present study include a randomized design, adequate sample size, and standardized technique performed by a single experienced anesthesiologist. However, the single-operator model may limit generalization, as ultrasound benefits are often even greater among less experienced operators. Additionally, this study was conducted exclusively in elective cardiac surgery patients, excluding emergency situations where ultrasound guidance could potentially offer even greater advantages.

Table 10: Comparison of Findings Between Present Study and Published Literature

Parameter	Present Study Result	Comparative Study Result	Reference
First-attempt success rate	76–82%	Higher success with USG (85% vs 68% landmark)	[35]
Total success rate	76–79%	Overall success improved with USG	[35, 37]
Access time	39 sec (USG) vs 118 sec (landmark)	Faster access with USG	[38, 39]
Total cannulation time	226 sec (USG) vs 439 sec (landmark)	Procedure time reduced with USG	[35, 39]
Arterial puncture	7.89% in landmark group only	Arterial puncture significantly lower with USG	[35, 38]
Hematoma formation	Only in landmark group	Landmark: 10.7%; USG: 2.3%	[38]
Catheter malposition	None in either group	Reduced malposition with USG	[35, 37]
Pneumothorax / Hemothorax	None in both groups	Reduced with USG guidance	[37, 40]
Operator ease	Better needle visualization	Improved in difficult anatomy & trainees	[38, 42]
Recommendation	Ultrasound should be routine	Strong recommendation in guidelines	[40]

CONCLUSION

In this study, real-time ultrasound guidance for internal jugular venous cannulation significantly reduced access time and total cannulation time compared with the conventional anatomical landmark technique, while maintaining comparable overall success rates. Ultrasound guidance also eliminated arterial puncture and hematoma formation seen with the landmark approach, although the overall complication rates remained low in both groups. These findings support the routine use of ultrasound for central venous catheter insertion, particularly in high-risk cardiac surgical patients, to enhance safety, efficiency, and procedural accuracy.

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