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ORIGINAL ARTICLE

Comparison of Ultrasound Versus Non Ultrasound based Techniques for Internal Jugular Venous Cannulation in Cardiac Surgical Patients: A Prospective Randomised Controlled Trial

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Abstract

Objectives: The study aims to compare the success rate, time for cannulation and complications of ultrasound-guided internal jugular venous cannulation versus blind landmark-based technique in adult cardiac surgical patients. The primary objective is to compare the success rate between USG group and landmark group. The secondary objectives are to determine the complications, time for cannulation and compare between the two groups. **Materials and Methods**: In a prospective randomized controlled double-blinded trial, 122 adult patients undergoing elective cardiac surgery were split up into two pairs. Group U (ultrasound-guided technique) and Group N (non-ultrasound-based technique). We assessed first attempt success rate, number of attempts required, time for cannulation and complications (e.g., carotid artery puncture, hematoma, pneumothorax). **Results**: Demographics between Group U and N were similar. Ultrasound-guided technique exhibited higher first attempt success rate (91.8% vs. 75.4%, p=0.014), fewer attempts (1.10 vs. 1.61, p=0.017) and fewer complications (carotid artery puncture: 1.6% vs. 6.6%, p=0.042; hematoma: 1.6% vs. 6.6%, p=0.042) compared to the non-ultrasound-based technique. Group N had a higher failure rate (6.6% vs. 0%, p=0.042). No significant difference in cannulation time was observed (U: 217.02 seconds vs. N: 214.31 seconds, p=0.92). **Conclusion**: Ultrasound-guided internal jugular venous cannulation yields better first attempt success, fewer attempts, and fewer complications than non-ultrasound-based IJV cannulation. But there wasn't any obvious distinction in cannulation time between the two sets.

Keywords: Ultrasound, internal jugular venous cannulation, cardiac surgery, success rate, complications.

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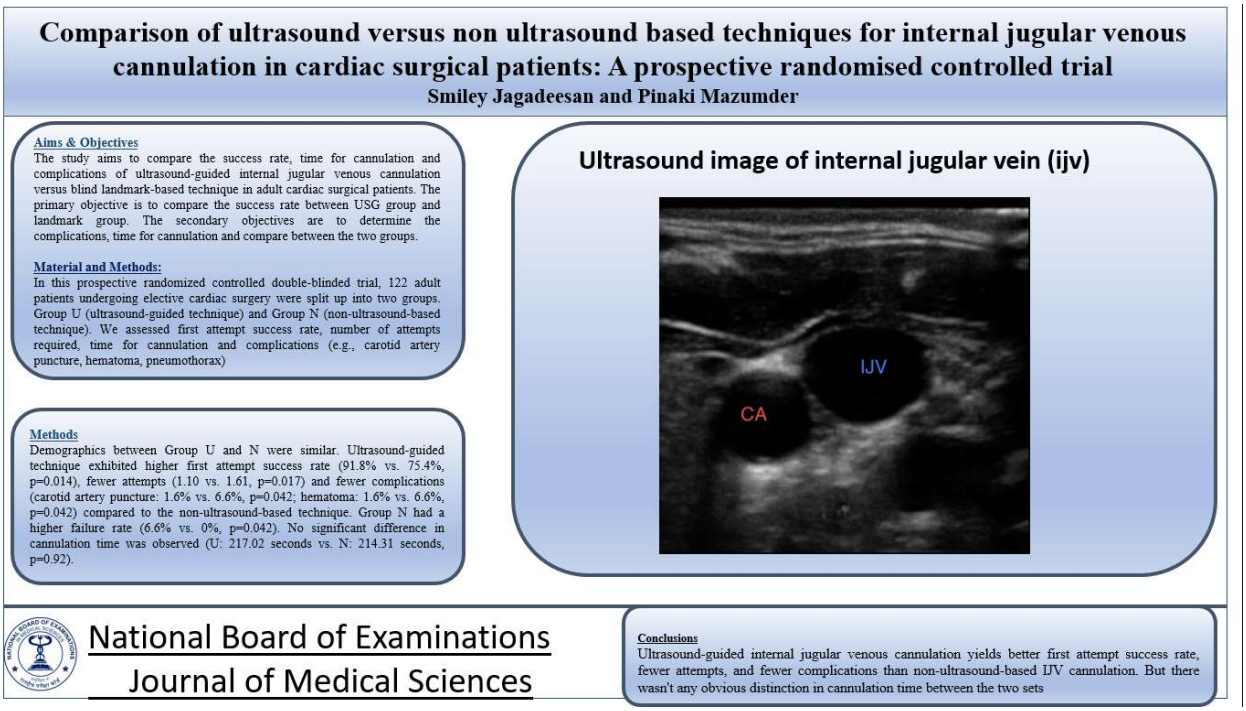
Graphical Abstract



Introduction

Central venous catheters (CVC) could help in diagnosis and treatment of critically ill patients. The catheter could be inserted into an internal jugular vein, subclavian vein, or femoral vein. In order to gain central venous access for hemodynamic monitoring (such as central venous pressure), continuous fluid administration, long-term antibiotic administration, total parenteral nutrition, chemotherapy, and hemodialysis, internal jugular vein (IJV) catheterization is frequently undertaken. Since 1966, numerous anatomic landmark-guided methods for percutaneous IJV puncture have been documented. [1-4]. Nevertheless, this procedure has concerns such as arterial puncture leading in hematoma, which can become infected or lead to carotid artery compression and other problems (thrombosis, embolism, pneumothorax, nerve damage) and should be conducted with as few attempts as possible. Complications, including mortality are influenced by patient characteristics such as BMI, location of attempted access, and operator expertise [5-7].

Despite the non-ultrasound-based technique being most commonly used for jugular venous cannulation, it is a blind procedure and carries a significant risk of accidental injury to surrounding structures (e.g., the carotid artery) and deeper penetration of the needle to underlying structures, causing pneumothorax, hemothorax, etc. The use of ultrasound aims to visualise both the jugular vein and carotid artery side by side and helps to get IJV access

under direct visualisation and reduce the risk of accidental carotid puncture. It had been proposed that central venous catheter placement would benefit from ultrasound guidance [8-12]. Ultrasound guided central venous cannulation improves success rate, reduces the number of needle passes and decreasing complications [12-16].

Though ultrasound has been effectively compared to the non-ultrasound-based technique, its widespread use has been impeded due to the impracticality of specially designed ultrasound equipment, their unavailability, the cost of the devices, and the lack of adequately trained personnel [12-16].

Ultrasound also helps to visualise the needle tip within the jugular vein and prevents deep penetration of the needle, thereby reducing puncture of the posterior wall of the IJV. It also guides the passage of a guidewire and catheter under direct vision to the IJV [10-12]. Moreover very limited number of clinical studies are available on comparison of two techniques of IJV cannulation in adult cardiac surgical patients particularly in Indian scenarios where due to vast patient population and limited resources effective utilization of available resources poses a big challenge to healthcare professionals. Therefore, this study was conducted with the objectives of comparing the success rate, time for cannulation and complications of ultrasound-guided internal jugular venous cannulation versus blind landmark-based technique in adult cardiac surgical patients.

This study distinguishes itself from previous research by specifically addressing the challenges and needs within the context of adult cardiac surgical patients in India. While conventional methods based on landmarks for internal jugular venous cannulation have been widely used, they are associated with significant risks, including arterial puncture and complications. This study's novelty lies in its focus on this specific patient population and the comparison of ultrasound-guided cannulation to the traditional technique. Additionally, it recognizes the practical limitations in terms of equipment availability and trained personnel, which are particularly pertinent in resource-constrained settings like India [10, 12]. This research intends to shed light on the effectiveness of ultrasound guidance in a unique healthcare environment, contributing valuable data to the existing body of knowledge.

Material and Methods

Study setting: This was a prospective, controlled, randomized study undertaken with 122 adult patients undergoing elective cardiac surgery at Medical College Hospital, Kolkata from October 2018 to May 2019.

Inclusion criteria: Adults more than 18 years of age who require Internal jugular venous cannulation for cardiac surgery.

Exclusion criteria: Patients with a history of CVC within 15 days, neck structural deformities from surgery or other illnesses, burns at the insertion site, bleeding disorders, local skin infection.

During enrollment 122 patients of either sex were assessed for eligibility. They were divided into two groups of sixty-one people each at random.

Control Group: The control group (Group N) in this study underwent internal jugular venous (IJV) cannulation by central approach with needle puncture at the apex of sternomastoid triangle using the traditional landmark-based technique. Patients in this group had their anatomical landmarks identified before the sterile procedure. The puncture site was determined based on these landmarks, and the IJV was accessed without the aid of ultrasound guidance. The control group served as a reference point to compare the outcomes of IJV cannulation using the traditional method against the ultrasound-guided approach.

Treatment Group: The treatment group (Group U) received IJV cannulation using the ultrasound-guided technique. In this group, ultrasound equipment was employed to visualize the IJV and carotid artery. The procedure involved precise needle placement under real-time ultrasound guidance, enhancing the accuracy of catheter insertion into the IJV. This group represented the experimental arm of the study, assessing the effectiveness of ultrasound guidance in improving the cannulation process.

Randomization Procedure: Patient allocation into either Group U or Group N was carried out through a computer-generated randomization process with software STATA 16. Eligible patients (n=122) were assessed for inclusion and they were assigned to the groups using concealed envelopes containing random numbers. This approach of allocation at random assured that each patient had an equal chance of being assigned to either group, reducing selection bias and improving the study's internal validity.

In our study, ultrasound guided IJV cannulations were done by second year junior residents posted at the cardiothoracic surgery and anesthesia unit who previously performed atleast 20 USG cannulations under the guidance of consultant anesthesiologist.

Sample size calculation: A previously completed study's formula was used to determine the sample size [11] considering an alpha error of 0.05, power 0.90 or 90%, assuming first attempt success rate of USG guided CVC insertion would be 20 % more compared to landmark technique [11]. Total 55 patients were needed to be recruited in each group for the study. Assuming a 10% dropout. A total of 122 patients, or 61 in each group, were enrolled in the study.

Procedure

A preanaesthetic check-up was performed on previous day of the surgery proper preoperative guidance was provided. After obtaining patients were moved to the preoperative room with written and informed consent, and baseline vitals were taken. On arrival in the operating room, Electrocardiographic leads, a pulse oximeter probe, and a non-invasive blood pressure cuff were connected. Nasal cannula oxygen was given at 3 liter per minute. An 18 G intravenous catheter was secured and injection morphine 2mg intravenously was given before starting the cannulation. A left-facing head position in a 10°–20° Trendelenburg angle was performed to aid the process of right IJV cannulation. Every cannulation was carried out by second year junior residents under the guidance of a consultant anaesthetist.

Ultrasound Guided Technique (Group U): In Group U, the patients underwent IJV cannulation by ultrasound technique. The neck area was prepped and draped in sterile manner with 2% chlorhexidine. The puncture site was infiltrated with 2% lignocaine. A high frequency linear probe (8-12MHz) of PHILIPS HD11XE (Philips US, Bothell, WA, USA) ultrasound machine was used. The ultrasonic probe was ready using lignocaine jelly and a sterile ultrasound A cover was put on over the probe without any bubbles. With the patient's head tilted to the left, the patient was put in a recumbent posture. The transducer was positioned above the point when the triangle made up of the sternal and clavicular heads of the sternocleidomastoid muscle, perpendicular to the vessels (out of plane technique) and parallel to the clavicle. The marker on the USG probe was directed as to face the marker on the ultrasound image corresponds to the left side of the patient. The carotid artery and IJV were located. The round, pulsing tissue that was hard to compress was found to be the common carotid artery (Fig. 1). The bigger, more readily compressible, non-pulsating structure was determined to be the IJV (Fig 2). Using the transducer while gently pressing the vein, the patency of the IJV was verified. Using the out of plane approach, an 18G the introducer needle was positioned at a 45° angle beneath the probe and had a syringe attached (Fig 1). The needle's intravascular position was confirmed by visualizing its tip on the image, and blood flow upon aspiration validated its placement. After obtaining blood flashback, after disconnecting the syringe, a steady, non-pulsatile blood flow was guaranteed. After that, a guide wire was inserted into the vein through the needle. Once the guide wire reached the needle was removed at the proper depth, leaving the guide wire visible on the screen. A minor excision was made at the wire entry point to aid dilator passage. Following dilatation, a 7Fr triple lumen was reached at the target vessel by the catheter. After removing the guide wire, each port's blood flow was examined, flushed, capped, and the line secured with sutures, concluding with the application of a sterile dressing.

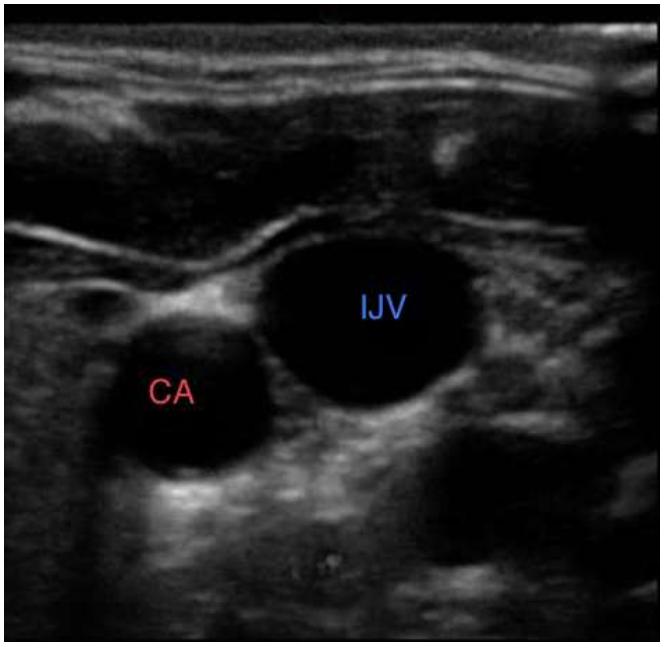


Figure 1. Ultrasound image of internal jugular vein (IJV) out of plane method- anterolateral position of IJV to carotid artery.
*IJV- Internal Jugular Vein **CA- Carotid Artery

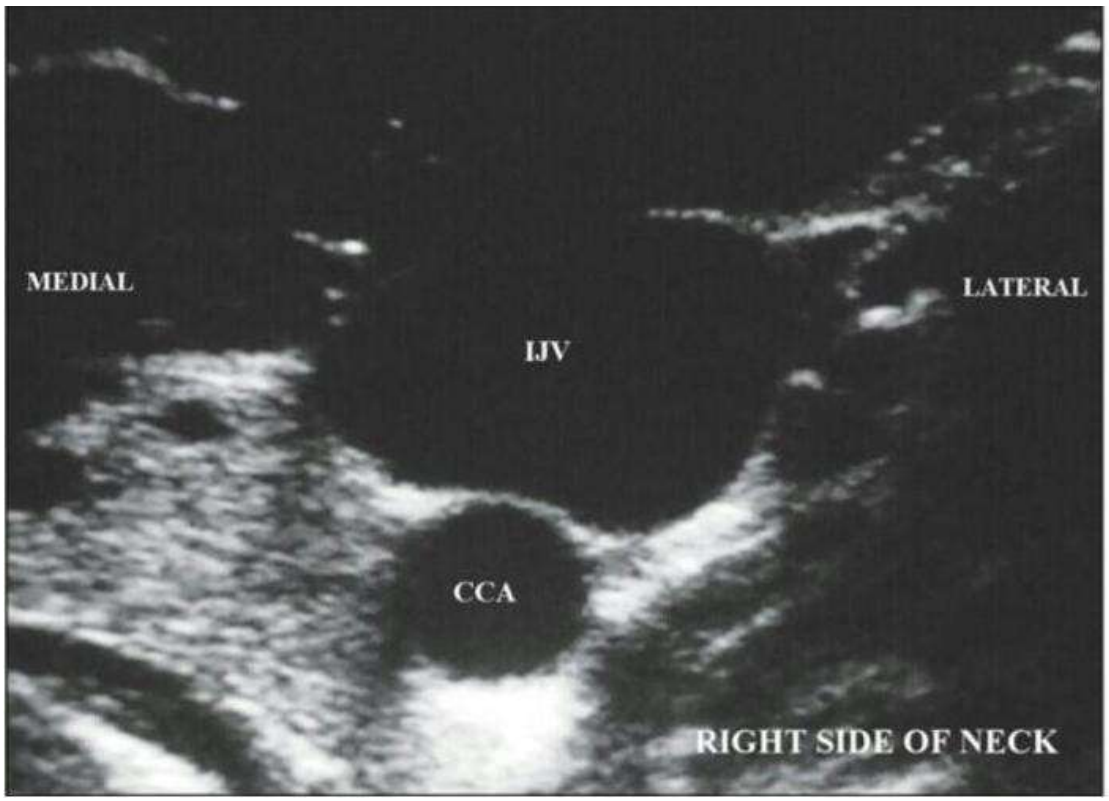


Figure 2. Anterior position of internal jugular vein to carotid artery

Non-ultrasound-based technique (Group N)

In Group N, the patients underwent IJV cannulation by traditional landmark technique through central approach on the right side. Before the sterile procedure, anatomic landmarks like the sternal notch, clavicle, and sternocleidomastoid muscle were identified. The carotid artery's course in the neck was determined through palpation. After sterile preparation and draping, landmarks were reaffirmed. Puncturing the skin at the medial border of the clavicular head of the sternocleidomastoid muscle, just lateral to the carotid pulse, was done with a seeker needle, guiding the 18G introducer needle with a syringe containing heparinized saline. Maintaining carotid palpation, the needle was inserted at a 45-degree angle from the coronal plane toward the ipsilateral nipple. The guide wire was advanced through the introducer, and after reaching the appropriate depth, the needle was withdrawn, leaving the guide wire. A small incision was made for the dilator, followed by passing the catheter over the wire. After removing the guide wire, blood return was checked at all ports, flushed, capped, sutured, and a sterile dressing applied.

The time of insertion was calculated from introducer needle skin puncture till catheter insertion over guide wire. If the puncturing needle was completely removed from the skin's surface after being pierced, the attempt was unsuccessful. When three tries at cannulation failed, the ultrasonic approach was used save the attempt, but it was still deemed a failure for both groups.

All data including patient demographics, number of attempts, first attempt success rate, failure rate, time to cannulate and complications encountered were recorded independently by junior resident. Any complications like carotid artery puncture, hematoma formation were recorded. Post procedural chest x-ray was done to ascertain the position of the catheter tip and rule out any possible complications like pneumothorax and hemothorax in both groups.

Statistical analysis

The data were collected by specifically designed proforma and entered in the Microsoft excel spreadsheet. The analysis was carried out with the help of Statistical Package for Social Sciences (SPSS), Version 25.0. After the data collection was complete, analysis was done by appropriate statistical tests. Percentage difference between two groups were expressed by Chi- square tests. Normally distributed data were expressed as mean and non-normally distributed data were expressed as median. Difference between means of two groups were expressed by unpaired student t tests. Difference between non normally distributed variables were expressed by Mann Whitney U tests. The confidence level for significance was 95% with P value lesser than 0.05 was considered as statistically significant.

Results

Of the total 122 patients recruited, 61 patients each were allocated to two groups- Ultrasound guided CVC insertion (group U) and landmark guided technique (group N). The demographic profile (Table 1) of the patients in two groups as well as for the types of cardiac surgeries performed (Table 2) were

comparable. ($p > 0.05$) Coronary artery bypass grafting was the most commonly performed cardiac surgery in both the groups.

Table 1: Characteristics of study participants.

Characteristics		Group N (n=61)	Group U (n=61)	P value
Age (years), Mean ± SD		51.03 ± 11.4	54.48 ± 8.56	0.063 ~
Gender	Females	13 (21.3%)	15 (24.6%)	0.085 ∫
	Males	48 (78.7%)	46 (75.4%)	
Weight (kg), Mean ± SD		61.67±4.3	60.34±4.5	0.810 ~
Height (cm), Mean ± SD		161.44±4.2	162.31±3.6	0.662 ~
ASA 3		37 (60.7%)	35 (57.4%)	0.136 ω
ASA 4		24 (39.3%)	26 (42.6%)	

~ Unpaired t-test was used; ∫ Chi-square test was used; ω Fisher's-exact test was used; ASA: American society of anaesthesiologist

Table 2. Number of cardiac surgeries performed in both groups.

Name of surgery	**Group N N (%)**	**Group U N (%)**
ASD* closure	2 (3.3)	0 (0)
AVR†	3 (4.9)	3 (4.9)
MVR§	11 (18.0)	9 (14.8)
CABG‖	42 (68.9)	47 (77.1)
CMC**	1 (1.6)	1 (1.6)
Others	2 (3.3)	1 (1.6)

*Atrial septal defect, † Aortic valve replacement, § Mitral valve replacement, ‖ Coronary artery bypass grafting,** closed mitral commissurotomy

Table 3. Outcome variables among the study participants.

Characteristics		**Group N**	**Group U**	**P value**
Success rate (%)	First attempt success rate	**46 (75.4%)**	**56 (91.8%)**	**0.014*** (∫)
	Failure (more than 3 attempts)	**4 (6.6%)**	**0 (0%)**	**0.042 *(Ω)**
	Mean number of attempts ± SD	**1.61 ± 1.595**	**1.10 ± 351**	**0.017 *(~)**
	Mean time for cannulation in seconds ± SD	**214.31 ± 210.693**	**217.02 ± 67.914**	**0.920 (~)**
Complications (%)	Carotid artery puncture	**4(6.6%)**	**1(1.66%)**	**0.042 *** (∫)
	Hematoma	**4(6.6%)**	**1(1.66%)**	**0.042 *(∫)**

*-P(<0.05) statistically significant ∫ Chi-square test, Ω Fisher's exact test, ~ Unpaired t-test.

Ultrasound guided CVC insertion was associated with significantly better first attempt successful cannulation (91.8%) versus landmark guided CVC technique (75.4%), p=0.014. There was no incidence of failure when cannulation was done under USG guidance versus a 6.6% failure rate in landmark based approach, p=0.042. The mean number of attempts needed to cannulate IJV was significantly less when ultrasound technique was used (1.10±0.351) versus landmark guided CVC insertion (1.61±1.595) p = 0.017, p<0.05. However there was no significant difference was noticed in time for cannulation in two groups (group U=217.02±67.914 seconds versus group N =214.31±210.693 seconds), p=0.92, > 0.05). In group N, carotid artery puncture and hematoma were noticed in 4 cases out of 61 patients (6.6%)and in group U, 1 case out of 61 patients(1.6%) had carotid artery puncture and hematoma with p value=0.042. [P value <0.05 statistically significant]. There were no cases of pneumothorax and hemothorax recorded during the study.

Discussion

In this study, our findings demonstrate the superiority of ultrasound-guided (US) internal jugular vein (IJV) cannulation over the landmark-based technique. Our investigation reveals a higher first attempt success rate, a reduced number of attempts required for IJV cannulation, lower failure and complication rates, with no significant difference in the time needed for successful cannulation.

This aligns with the results of meta-analyses of randomized controlled trials (RCTs) comparing real-time ultrasound-guided venipuncture of the IJV with the anatomical landmark-based approach. These meta-analyses consistently report higher first insertion attempt success rates, higher overall success rates, lower rates of arterial puncture, and fewer insertion attempts when using US-assisted cannulation. Consequently, the revised practice guidelines by the American Society of Anesthesiologists in 2020 recommend the use of ultrasound for guiding needle, wire, and catheter placement (American Society of Anesthesiologists, 2020) [16]. Similarly, the European Society of Anaesthesiology guidelines on peri-operative use of ultrasound for vascular access (PERSEUS vascular access) recommend ultrasound guidance for IJV cannulation in adults due to its safer profile, improved success rates, and reduced puncture and cannulation time (European Society of Anaesthesiology, 2020) [17].

The success of ultrasound-guided techniques may vary depending on the type of ultrasound guidance (static vs. real-time), the ultrasound probe used, and the study population. Notably, most studies demonstrating the superiority of US techniques over landmark techniques have utilized the dynamic method for US-guided IJV cannulation [18].

In our study, we employed real-time ultrasound guidance for IJV cannulation, which yielded a higher success rate and reduced complications compared to the landmark-based technique. However, it's worth noting that some studies, such as Tempe et al. [19], failed to demonstrate the superiority of USG-guided IJV cannulation, possibly due to the use of a static ultrasound method and a low-frequency ultrasound

probe. Furthermore, they did not define the experience level of senior residents or the number of successful cannulations performed before entering the study.

Despite the established benefits and safety of ultrasound guidance, its utilization for central venous cannulation remains inconsistent. Studies investigating current practices in the Netherlands found that ultrasound guidance was used in only 68% of patients. Barriers to its use included working in non-academic, non-teaching hospitals, providing cardiac anesthesia, and greater physician experience. Reasons for not using ultrasound included a perceived lack of benefit, increased procedure time, the absence of ultrasound equipment, and concerns about losing landmark technique skills [20]. Our study challenges this notion and underscores the importance of having ultrasound machines available at all sites for potential IJV central venous catheterization needs.

Cochrane systematic reviews and meta-analyses comparing current evidence for ultrasound guidance versus anatomical landmark techniques for IJV placement in over 5100 adult and pediatric patients in operating rooms and intensive care units have consistently demonstrated the advantages of ultrasound-guided IJV catheterization. Notably, the use of ultrasound reduces the overall rate of complications, increases overall success rates, decreases arterial puncture rates, hematoma formation, and the number of attempts, while also enhancing the success of the first attempt [9].

In contrast, the anatomical landmark technique, despite being validated and time-tested, is associated with numerous complications. For instance, Karakitsos et al. [21] reported a higher incidence of carotid artery puncture, hematoma, hemothorax, pneumothorax, and central venous catheter-associated bloodstream infections with landmark-based IJV cannulation, all significantly increased compared to the ultrasound group ($p < 0.001$). In our study, the incidence of carotid puncture was significantly lower in the ultrasound group compared to the landmark-based technique ($p = 0.042$). However, our study was not adequately powered to detect differences in other complications between the two groups.

The definition of operator competence and successful cannulation varies among different studies, making it challenging to compare success rates between the two techniques. Nandi et al. [22] compared the performance and complications of US-guided right IJV cannulation by operators with different levels of experience. They defined an expert operator as one who had performed 30 or more ultrasound-guided IJV cannulations, resulting in higher successful cannulation rates and a lower percentage of patients requiring more than two attempts. In contrast, our study defined failure as requiring more than three attempts for cannulation. This definition resulted in a lower failure rate in the landmark method compared to the ultrasound-guided group.

The definition of time for successful cannulation also varies between studies. In our study, time was calculated from introducer needle skin puncture to catheter insertion over the guide wire, leading to a longer time for cannulation in our study. However, there was no significant difference

in the time for IJV cannulation between the two groups (p = 0.92). In contrast, other studies, such as Pozzoli et al. [23], found no significant difference in the time to perform cannulation using either approach.

Furthermore, our study revealed a significantly higher first attempt success rate in the ultrasound group compared to the landmark-based technique. Similar findings were reported by Denys et al. [11]. In our study, the mean number of attempts to cannulate the IJV was lower in the ultrasound group compared to the landmark group, consistent with findings by Miller et al. [13] and Agarwal et al. [12].

In summary, our study provides compelling evidence in favor of ultrasound-guided IJV cannulation, offering a safer and more effective approach with higher success rates and fewer complications compared to the landmark-based technique. These findings emphasize the need to consider the widespread adoption of ultrasound machines for potential IJV central venous catheterization requirements.

Future directions: Future studies in central venous cannulation should focus on operator proficiency and training standards, comparing different ultrasound-guided techniques, assessing the influence of patient demographics, addressing barriers to ultrasound adoption, standardizing definitions, and further evaluating time considerations. Additionally, research should explore long-term patient outcomes and satisfaction to refine best practices in this critical medical procedure.

Limitations

Both ultrasound and landmark guided technique of CVC insertion was done by second year residents with experience of at least 20 USG guided CVC cannulation. Lack of USG guided cannulation by well trained consultants might influence the study results.

Conclusion

USG guided internal jugular venous cannulation in adult elective cardiac surgical patients achieves better first attempt success rate, reduces the number of attempts during cannulation and decrease complications like carotid artery puncture and neck hematoma compared to landmark based technique. However no difference was noticed between two techniques with regards to time taken for IJV cannulation.

Conflicts of interest

Not applicable

Ethical statement

The study was conducted after obtaining approval from institutional ethical committee (Ref no: MC/KOL/IEC/NON-SPON/133/08-2018) and written informed consent from patients.

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Not applicable

References

1. Karakitsos D, Labropoulos N, De Groot E, Patrianakos AP, Kouraklis G, Poularas J, Samonis G, Tsoutsos DA, Konstadoulakis MM, Karabinis A. Real-time ultrasound-guided catheterisation of the internal jugular vein: a prospective comparison with the landmark technique in critical care patients. Crit Care. 2006;10(6):R162. doi: 10.1186/cc5101.

2. Daily PO, Griepp RB, Shumway NE. Percutaneous internal jugular vein cannulation. Arch Surg. 1970 Oct;101(4):534-6. doi: 10.1001/archsurg.1970.01340280086023.
3. Rao TL, Wong AY, Salem MR. A new approach to percutaneous catheterization of the internal jugular vein. Anesthesiology. 1977 May;46(5):362-4. doi: 10.1097/00000542-197705000-00015.
4. Hayashi H, Ootaki C, Tsuzuku M, Amano M. Respiratory jugular venodilation: a new landmark for right internal jugular vein puncture in ventilated patients. J Cardiothorac Vasc Anesth. 2000 Feb;14(1):40-4. doi: 10.1016/s1053-0770(00)90054-5.
5. Digby S. Fatal respiratory obstruction following insertion of a central venous line. Anaesthesia. 1994 Nov;49(11):1013-4. doi: 10.1111/j.1365-2044.1994.tb04340.x.
6. Sznajder JI, Zveibil FR, Bitterman H, Weiner P, Bursztein S. Central vein catheterization. Failure and complication rates by three percutaneous approaches. Arch Intern Med. 1986 Feb;146(2):259-61. doi: 10.1001/archinte.146.2.259.
7. Mansfield PF, Hohn DC, Fornage BD, Gregurich MA, Ota DM. Complications and failures of subclavian-vein catheterization. N Engl J Med. 1994 Dec 29;331(26):1735-8. doi: 10.1056/NEJM199412293312602.
8. Hind D, Calvert N, McWilliams R, Davidson A, Paisley S, Beverley C, Thomas S. Ultrasonic locating devices for central venous cannulation: meta-analysis. BMJ. 2003 Aug 16;327(7411):361. doi: 10.1136/bmj.327.7411.361.
9. Brass P, Hellmich M, Kolodziej L, Schick G, Smith AF. Ultrasound guidance versus anatomical landmarks for internal jugular vein catheterization. Cochrane Database Syst Rev. 2015 Jan 9;1(1):CD006962. doi: 10.1002/14651858.CD006962.pub2.
10. Muralidhar K. Left internal versus right internal jugular vein access to central venous circulation using the Seldinger technique. J Cardiothorac Vasc Anesth. 1995 Feb;9(1):115-6. doi: 10.1016/s1053-0770(05)80084-9.
11. Denys BG, Uretsky BF, Reddy PS. Ultrasound-assisted cannulation of the internal jugular vein. A prospective comparison to the external landmark-guided technique. Circulation. 1993 May;87(5):1557-62. doi: 10.1161/01.cir.87.5.1557.
12. Agarwal A, Singh DK, Singh AP. Ultrasonography: a novel approach to central venous cannulation. Indian J Crit Care Med. 2009 Oct;13(4):213-6. doi: 10.4103/0972-5229.60174.
13. Miller AH, Roth BA, Mills TJ, Woody JR, Longmoor CE, Foster B. Ultrasound guidance versus the landmark technique for the placement of central venous catheters in the emergency department. Acad Emerg Med. 2002 Aug;9(8):800-5. doi: 10.1111/j.1553-2712.2002.tb02168.x.
14. Turker G, Kaya FN, Gurbet A, Aksu H, Erdogan C, Atlas A. Internal jugular vein cannulation: an ultrasound-guided technique versus a landmark-guided technique. Clinics (Sao Paulo). 2009;64(10):989-92. doi: 10.1590/S1807-59322009001000009.
15. Shrestha BR, Gautam B. Ultrasound versus the landmark technique: a prospective randomized comparative study of internal jugular vein cannulation

in an intensive care unit. JNMA J Nepal Med Assoc. 2011 Apr-Jun;51(182):56-61.

16. Practice Guidelines for Central Venous Access 2020: An Updated Report by the American Society of Anesthesiologists Task Force on Central Venous Access. Anesthesiology. 2020 Jan;132(1):8-43. doi: 10.1097/ALN.0000000000002864.
17. Lamperti M, Biasucci DG, Disma N, Pittiruti M, Breschan C, Vailati D, Subert M, Traškaitė V, Macas A, Estebe JP, Fuzier R, Boselli E, Hopkins P. European Society of Anaesthesiology guidelines on peri-operative use of ultrasound-guided for vascular access (PERSEUS vascular access). Eur J Anaesthesiol. 2020 May;37(5):344-376. doi: 10.1097/EJA.0000000000001180.
18. Boulet N, Muller L, Rickard CM, Lefrant JY, Roger C. How to improve the efficiency and the safety of real-time ultrasound-guided central venous catheterization in 2023: a narrative review. Ann Intensive Care. 2023 May 25;13(1):46. doi: 10.1186/s13613-023-01141-w.
19. Tempe DK, Hasija S, Saigal D, Sanwal MK, Virmani S, Satyarthi S. Comparison of the landmark technique and the static ultrasound-guided technique for internal jugular vein cannulation in adult cardiac surgical patients MAMC J Med Sci. 2016;2:89–93.
20. Scholten HJ, Ten Bloemendal E, Botter B, Korsten HHM, Bouwman RA. Barriers to ultrasound guidance for central venous access: a survey among Dutch intensivists and anaesthesiologists. J Clin Monit Comput. 2019 Dec;33(6):1023-1031. doi: 10.1007/s10877-018-00246-z.
21. Karakitsos D, Labropoulos N, De Groot E, Patrianakos AP, Kouraklis G, Poularas J, Samonis G, Tsoutsos DA, Konstadoulakis MM, Karabinis A. Real-time ultrasound-guided catheterisation of the internal jugular vein: a prospective comparison with the landmark technique in critical care patients. Crit Care. 2006;10(6):R162. doi: 10.1186/cc5101.
22. Nandy S, Borthakur MP, Yunus M, Karim HMR, Dey S, Bhattacharyya P. Ultrasound-Guided Right Internal Jugular Vein Cannulation by Operators of Different Experience: A Randomized, Pilot Study. Cureus. 2022 Apr 22;14(4):e24381. doi: 10.7759/cureus.24381.
23. Pozzoli M, Galli F, Capomolla S, Forni G, Cibelli F, Tavazzi L. Usefulness of ultrasonographic techniques in catheterization of the internal jugular vein in patients with chronic heart failure. G Ital Cardiol. 1994;10:1211-21.