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Ultrasound Guided Internal Jugular Vein Central Venous Catheterization in Critical Care Patients: A Comparative Study with the Landmark Technique

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Abstract: ***Background: Central venous catheterization is crucial in the management of the critically ill patients. Materials and methods: 45 critical care patients who underwent ultrasound-guided catheterization of the internal jugular vein were compared with 45 critical care patients in whom the landmark technique was used. Randomization was performed by means of a computer-generated random numbers table, and all patients were stratified with regard to age, sex, and body mass index. Results: Catheterization of the internal jugular vein was successfully achieved in 95.5% patients by ultrasound-guided technique and in 82.2% by using landmark technique (p value <0.05). Access time (skin to vein) and number of attempts were also significantly reduced in the ultrasound group. Conclusion: Our study suggests that ultrasound guided internal jugular vein catheterization in critical care patients is superior to the landmark technique.***

Keywords: Central venous catheterization, internal jugular vein, USG guided technique, landmark guided technique

1. Introduction

Central venous catheterization (CVC) is an essential procedure in critically ill patients, facilitating hemodynamic monitoring, administration of vasoactive medications, parenteral nutrition, and rapid fluid resuscitation.[1] Among various central venous access sites, the internal jugular vein (IJV) is often preferred due to its relatively consistent anatomical location, ease of access, and lower risk of complications such as pneumothorax compared to subclavian access.[2,3]

Traditionally, the landmark technique has been employed for IJV cannulation, relying on surface anatomy and palpation of the carotid artery. However, this technique is associated with a variable success rate and complications, especially in patients with altered anatomy, obesity, coagulopathy, or hemodynamic instability.[4,5] Reported complication rates for landmark-guided CVC insertion include arterial puncture (up to 12%), hematoma formation, pneumothorax, and catheter malposition.[6]

The advent and widespread use of ultrasound (USG) in critical care settings have revolutionized vascular access techniques. Real-time ultrasound guidance allows direct visualization of the vein, needle, and surrounding structures, improving both the success rate and safety profile of the procedure.[7,8] Numerous studies and meta-analyses have demonstrated that ultrasound-guided IJV cannulation significantly reduces the number of attempts, time to successful cannulation, and complication rates compared to the landmark method.[9-11]

The National Institute for Health and Care Excellence (NICE) and other international guidelines strongly recommend the use of ultrasound guidance for central venous access whenever available.[12] Despite this, landmark techniques continue to be used in various clinical settings, often due to a lack of training, equipment, or awareness about the benefits of ultrasound-guided techniques.

This study aims to compare the efficacy and safety of ultrasound-guided versus landmark-guided IJV cannulation in critically ill patients, evaluating parameters such as first-attempt success rate, number of attempts, time to cannulation, and complication rates.

2. Aims and Objectives

To compare the success rates between ultrasound-guided (USG) and landmark-based techniques for internal jugular vein (IJV) central venous catheterization (CVC) and to assess the time taken for successful catheterization using both the techniques. With primary objective to compare the number of attempts required for successful catheterization between the two techniques and to evaluate the complications associated with both techniques.

3. Materials and Methodology

USG machine with linear probe, Central venous catheterization kit, Sterile gloves and drapes, Local anaesthetic, Patient monitoring equipment, Data collection sheets and study questionnaires**.** Conducted in Central ICU, Department of Anaesthesiology, Assam Medical College and Hospital for a period of 6 months. It is a prospective, randomized, comparative study. Ethical clearance was taken from the Institution Ethics Committee (Human) before the study commenced.

Study participants: The sample size was calculated based on previous studies comparing the first-attempt success rate of ultrasound-guided and landmark-guided internal jugular vein (IJV) cannulation. Prior literature reports a first-attempt success rate of approximately 90% with ultrasound guidance and 65% with the landmark technique.[13] Using these values, with a power of 80% and a significance level of 5%, the

minimum required sample size was calculated to be 41 patients per group, rounded up to 45 patients per group, resulting in a total of 90 patients.

Interventions: USG-guided technique or landmark-based technique for internal jugular vein central venous catheterization.

Inclusion criteria:
- Critically ill patients requiring IJV cannulation
- Age >18 years
- Informed consent obtained from patient or legal representative

Exclusion criteria:
- Neck mass or infection
- Coagulopathy (INR >2, Platelets <50,000)
- Previous neck surgery or radiation
- Anatomical deformities of the neck

Randomization:
Patients were randomly allocated into:
Group A: Ultrasound-guided IJV cannulation (n=45)
Group B: Landmark-guided IJV cannulation (n=45)

Procedure:
All cannulations were performed by anaesthesiologists trained in both techniques after obtaining informed consent. In the ultrasound group, a high-frequency linear probe was used to identify the IJV and guide cannulation. Pre-procedural scan: The operator performs an ultrasound scan to identify the internal jugular vein (IJV) and surrounding anatomical structures, ensuring a safe trajectory. Skin marking: IJV location is marked on the skin for better orientation during the procedure. Skin preparation and local anesthesia: skin is disinfected, and local anaesthetic is administered at the insertion site to minimize discomfort. Real-time ultrasound-guided needle insertion: Using an in-plane approach, the needle is inserted under continuous ultrasound visualization, allowing precise guidance toward the IJV. Guidewire and catheter placement: After successful venous puncture, a guidewire is introduced, followed by catheter insertion over the wire. In the landmark group, cannulation was based on the triangle formed by the sternal and clavicular heads of the sternocleidomastoid muscle and the clavicle. Identification of anatomical landmarks – The sternocleidomastoid muscle and carotid artery were identified to determine the needle insertion point. Skin preparation and local anaesthetic administration – The site was cleaned with antiseptic and local anaesthetic was administered. Needle insertion using landmark-based technique – The needle was inserted at the identified point, directed towards the ipsilateral nipple. Guidewire and catheter placement – The guidewire was passed through the needle, and the catheter was inserted and secured over it.

Parameters Recorded:
- Number of attempts
- Time to successful catheterization (from skin puncture to successful aspiration of venous blood)
- Success on first attempt
- Overall success rate
- Complications (arterial puncture, hematoma, pneumothorax, catheter misplacement)

Statistical Analysis:
Data were analyzed using MS Excel/SPSS software version 25. Continuous variables were compared using the student's t-test; categorical variables were analyzed using the chi-square test. A p-value <0.05 was considered statistically significant.

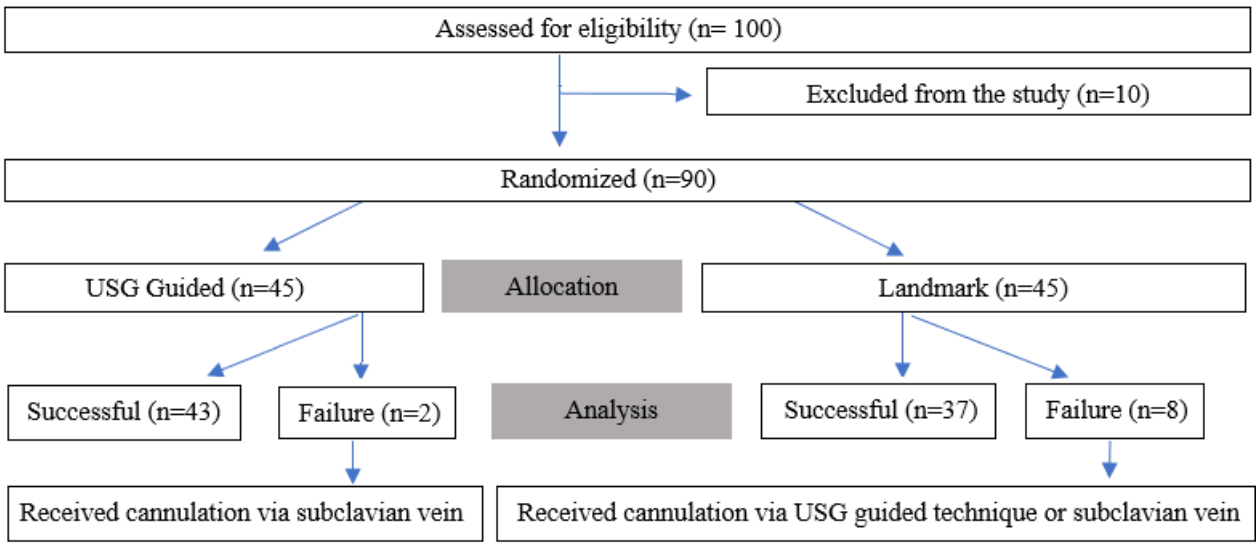

Figure 1: Consort flow diagram

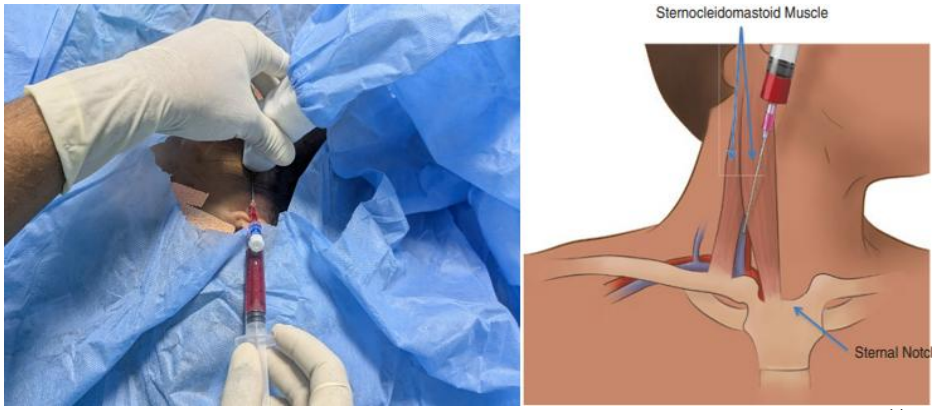

Figure 2: Showing USG guided technique(left) and landmark technique (right).[14]

4. Results

Table 1: Baseline Characteristics of the Study Population

	USG guided group (n=45)	Landmark group (n=45)	P value
Age (years)	47.8±12.31	48.1±12.31	0.85
sex ratio (M:F)	1.04	1.14	0.83
Side (R/L)	34/11	36/9	0.8
BMI (Kg/m^2)	29.1±1.53	28.8±1.53	0.78
Prior catheterization	7 (15.5%)	6 (13.3%)	0.77
Limited sites for access attempt	8 (17.7%)	9 (20%)	0.83
Previous difficulties during catheterisation	5 (11.1%)	4 (8.8%)	0.73
Untreated coagulopathy	2 (4.4%)	1 (2.2%)	0.56
Cannulation during cardiac arrest	0 (0%)	1 (2.2%)	0.31

Table 1 presents the baseline characteristics of the study population, comparing the ultrasound-guided (USG) group and the landmark group, each comprising 45 patients. The mean age was comparable between the two groups (47.8±12.31 vs. 48.1±12.31 years, p=0.85), with a similar male-to-female ratio (1.04 vs. 1.14, p=0.83). The right internal jugular vein was more commonly cannulated in both groups (USG: 34/11; Landmark: 36/9, p=0.8). Body mass index (BMI) was nearly identical (29.1±1.53 vs. 28.8±1.53 kg/m², p=0.78). Prior catheterization, limited access sites, and previous difficulties during cannulation were similarly distributed between groups, with no statistically significant differences. The incidence of untreated coagulopathy and cannulation during cardiac arrest was low and not significantly different between groups. These findings suggest that both groups were well matched in terms of baseline clinical and demographic parameters.

Table 2: Outcome Measures in Both the Group of Patients

	USG guided group (n=45)	Landmark group (n=45)	P value
Access time (sec)	63.4±15.1	91.3±22.5	<0.00001
Success rate	43 (95.5%)	37 (82.2%)	0.033
Number of attempts	1.7±0.8	2.9±1.4	<0.00001
Carotid puncture	1 (2.2%)	5 (11.1%)	0.049
Haematoma	2 (4.4%)	8 (17.7%)	0.042
Haemothorax	0	0	-
Pneumothorax	0	1 (2.2%)	0.31
Subcutaneous emphysema	0	2 (4.4%)	0.494
CVC-BSI	5 (11.1%)	5 (11.1%)	1

Table 2 summarizes the outcome measures in both study groups. The ultrasound-guided (USG) group demonstrated significantly better performance with a shorter mean access time (63.4±15.1 seconds vs. 91.3±22.5 seconds; p<0.00001), higher success rate (95.5% vs. 82.2%; p=0.033), and fewer mean number of attempts (1.7±0.8 vs. 2.9±1.4; p<0.00001) compared to the landmark group. Complication rates were also lower in the USG group. Carotid puncture occurred in only 1 patient (2.2%) in the USG group versus 5 patients (11.1%) in the landmark group (p=0.049). Similarly, hematoma formation was significantly less common in the USG group (4.4% vs. 17.7%; p=0.042). Other complications such as pneumothorax, subcutaneous emphysema, and central venous catheter-related bloodstream infections (CVC-BSI) showed no significant differences between the groups. These results indicate that ultrasound guidance significantly improves procedural efficiency and safety during internal jugular vein cannulation.

5. Discussion

This study demonstrates that ultrasound-guided internal jugular vein (IJV) cannulation significantly improves procedural efficiency and safety compared to the traditional landmark technique in critically ill patients. The ultrasound (USG)-guided group had a markedly shorter mean access time (63.4±15.1 vs. 91.3±22.5 seconds), higher success rate on first attempt (95.5% vs. 82.2%), and fewer number of attempts (1.7±0.8 vs. 2.9±1.4), all of which were statistically significant. These findings are consistent with previous studies and meta-analyses that have shown superior outcomes with ultrasound guidance (Hind et al[9]; Karakitsos et al.[10]; Brass et al.[11]).

Complication rates were also notably lower in the USG-guided group. Carotid artery puncture and hematoma formation occurred significantly less frequently in the USG group (2.2% and 4.4%, respectively) compared to the landmark group (11.1% and 17.7%). These results align with earlier reports by McGee and Gould[1] (2003), who highlighted that real-time ultrasound guidance reduces the risk of mechanical complications during central venous catheterization. Similar findings have been reported by Milling et al.[7] (2005) and Fragou et al.[8] (2011), who observed that ultrasound use not only enhances accuracy but also minimizes the incidence of complications such as arterial puncture and hematoma.

The landmark technique relies on surface anatomy and palpation, which can be challenging in obese patients, those with distorted anatomy, or in emergency situations. Anatomical variations in IJV location have been well-documented by Denys and Uretsky[5] (1991), and may contribute to increased failure and complication rates with the landmark approach. Sznajder et al.[4] (1986) and Mansfield et al.[3] (1994) also reported that the failure and complication rates were significantly higher when using anatomical landmarks alone, particularly in critically ill patients.

Importantly, although complications such as pneumothorax and subcutaneous emphysema were rare in both groups, the overall trend favored ultrasound use. Furthermore, the incidence of catheter-related bloodstream infections (CVC-BSI) was equal in both groups, suggesting that while ultrasound primarily impacts procedural success and mechanical complications, infection control remains dependent on aseptic technique and catheter care (McGee et al., 2003).[1]

Endorsed by multiple professional societies including the American Society of Echocardiography and supported by NICE guidelines, ultrasound guidance has become the recommended standard for central venous access (Troianos et al., 2011; NICE, 2002).[2] Our findings reinforce these recommendations and support the routine use of ultrasound for IJV cannulation, especially in critical care settings where patient safety and procedural efficiency are paramount.

This study had several limitations. It was a single-center study, which may limit the generalizability of the findings to other settings. The procedures were operator-dependent, introducing variability based on individual skill levels. Blinding of the operator and observer was not feasible, potentially introducing observational bias. Additionally, the sample size was relatively small, which may have reduced the statistical power to detect less common outcomes. Patients with difficult anatomy or high-risk features were excluded, limiting the applicability of results to more complex clinical scenarios. Lastly, the study did not assess long-term complications due to a short follow-up period.

6. Conclusion

Ultrasound-guided internal jugular vein cannulation significantly outperforms the landmark technique in terms of access time, success rate, and reduction of mechanical complications in critically ill patients. The use of real-time ultrasound enhances procedural accuracy, minimizes the number of attempts, and lowers the incidence of carotid puncture and hematoma formation. Given these clear benefits, ultrasound guidance should be adopted as the standard of care for central venous catheterization in critical care settings. Its routine implementation can lead to improved patient safety, better clinical outcomes, and higher procedural efficiency.

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