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Original Research Article

Comparison of Ultrasound-Guided versus Landmark Technique for Internal Jugular Vein Cannulation: A Prospective Randomized Controlled Study

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Abstract

Background: Internal jugular vein cannulation is often necessary in major surgery and critical care, and the standard method of landmark guided puncture often results in repeated attempts, arterial puncture and delays.
The aim of this study was to compare real-time ultrasound-guided versus conventional landmark-guided right internal jugular vein (IJV) cannulation in adult surgical patients.

Methods: 100 ASA physical status I-III patients who needed central venous access were randomized to ultrasound guided (n=50) or landmark technique (n=50). First-attempt success, overall success, attempts, access time, cannulation time and mechanical complications were recorded by an independent observer.

Results: Success was greater with ultrasound than with landmark technique at the first attempt (86.0% vs. 58.0%, p=0.002). Overall success was 98.0% and 88.0%, respectively (p=0.049). Ultrasound guidance reduced attempts (1.18 +/- 0.44 versus 1.76 +/- 0.77, p<0.001), access time (21.4 +/- 9.2 versus 42.7 +/- 18.5 seconds, p<0.001) and total cannulation time (64.8 +/- 24.6 versus 121.5 +/- 48.3 seconds, p<0.001). The ultrasound group had fewer mechanical complications (4.0% vs 20.0%, p=0.014).

Conclusion: The internal jugular vein cannulation technique was more successful, efficient and safe when performed with real time ultrasound as compared to the landmark technique.

Keywords: Internal Jugular Vein, Central Venous Catheterization, Ultrasound Guidance, Landmark Technique, First-Attempt Success, Randomized Controlled Trial.

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Introduction

Central venous catheterization is a basic anaesthetic and critical care procedure which is used for central venous pressure measurement, administration of vasoactive drugs, difficult peripheral access and rapid fluid administration and perioperative resuscitation [1]. The internal jugular vein is generally chosen because it is superficial, compressible and runs a relatively straight course to the superior vena cava. Although success in cannulation is dependent upon patient anatomy, intravascular volume, operator experience and technique [2], there are a number of factors that must be considered.

The landmark maneuver is based on the relationship between the sternocleidomastoid muscle and the position of the internal jugular vein, the clavicle and the carotid pulse. This method has been in use for many years, but is basically a blind puncture. There are factors that can make cannulation attempts more difficult or cause complications, including anatomical variation, carotid overlap, short neck, obesity, and hypovolemia, which may have occurred prior to cannulation [3]. Hematoma, arterial puncture may be difficult and cause patient discomfort due to repeated attempts.With the aid of ultrasound, this procedure becomes an indirect anatomic estimation procedure and a visual vascular access technique. It allows for visualisation of the internal jugular vein, the carotid artery, the patency, depth, diameter and direction of the needle prior to and/or during puncture [4].

Mechanical complication rates are lower and success rates are better with ultrasound (US) guided cannulation of the internal jugular vein (IJV) [5,6] in general. There are now several professional recommendations that recommend the use of ultrasound when equipment and trained

operators are available [7]. The use of ultrasound for landmark cannulation remains prevalent, despite the advantages in many operating rooms, due to availability of ultrasound machines, lack of training for some operators, emergency workflow and the perceived ability to gain reliable access without imaging by experienced operators. It is therefore of significance to use local data, especially in teaching hospitals where the operators have varying degrees of procedural exposure and where ultrasound machines are used by the different services [8,9].

Success on the first try is important and measurable. More punctures add weight to the risk of a damaged carotid artery, posterior wall damage and local hematoma. In patients receiving anticoagulants, antiplatelet agents or positive pressure ventilation, even minor mechanical complications can have amplified consequences. Thus, number of attempts and time taken should be included in the evaluation of the procedure as well as the final catheter placement [10].

The aim of the present study was to compare real time ultrasound-guided and conventional landmark-guided right internal jugular vein cannulation in adult surgical patients. The main aim was to make a comparison of first attempt success. Secondary aims were to compare the overall success rate, number of attempts, access time and total cannulation time and mechanical complications.

Materials and Methods

This is a prospective randomized controlled study carried out in operating rooms of a tertiary care teaching hospital. Adult ASA physical status 1-3 patients aged 18-70 years for elective surgery under GA who needed right internal jugular venous catheterization were included. The exclusion criteria were local infection, coagulopathy, emergency surgery, previous neck radiation, distorted neck anatomy, and known central venous thrombosis and/or refusal to participate.

Random sequence was computer-generated with sealed opaque envelopes, which were then used to allocate patients to the ultrasound guided group or landmark guided group.

The cannulation technique in the ultrasound group was performed with a high-frequency linear probe with a sterile sheath under real-time ultrasound guidance. The group had a landmark of cannulation performed at the apex of the triangle formed by the sternal head and the clavicular head of the sternocleidomastoid and the clavicle.

Airway examination, neck mobility, BMI, previous use of a central venous access device, and anticoagulant and antiplatelet exposure were evaluated preoperatively. Patients were placed in 10-15 degree Trendelenburg with head slightly turned to the other side. Avoiding the excessive rotation of the head as it may increase the degree of overlap between the internal jugular vein and carotid artery.

The sterile pre-puncture scan in the ultrasound group, identified the internal jugular vein, carotid artery and anatomical variation. Compressibility of veins and relation to the carotid artery were mentioned. Venous entry was confirmed by aspiration of dark non-pulsatile blood and was made by advancing the needle out-of-plane. In the landmark group, the pulse of the carotid artery was felt and the needle was positioned to the lateral side of the pulse, towards the contralateral nipple.

The main outcome was the fact that they made the shot on their first attempt. Other outcomes were overall success, number of attempts, access time (from skin puncture to venous flashback), total cannulation time (from skin puncture to catheter fixation), carotid puncture, hematoma, and catheter malposition and pneumothorax. Failure was considered to be when cannulation was unsuccessful after 5 minutes or 3 attempts. If the skin was punctured again after they withdrew or the needle was redirected into the same place, it was considered an attempt. Patient confidentiality was ensured by assigning a coded study number for each patient and the data analysed was de-identified (no direct patient identifiers were included in the database). The protocol adhered to the usual practice for perioperative monitoring and did not withhold any treatment that was deemed necessary for patient safety.

The sample size was designed to have sufficient power for the primary outcome, but also be reasonable for a single center, prospective study. Before comparing continuous variables, they were tested for distribution. Normal data were presented as mean ± standard deviation, median and interquartile range when appropriate and number with percentage for categorical data.

Any adverse events were designated in advance and captured in a standard manner. Treatment for rescue was only done as per the institution's protocol and not according to the investigator's preference. A p-value of < 0.05 was regarded as statistically significant and all analyses were done 2-sided.

Needle advancement was not to be continued if it was deemed unsafe. If the aspiration of pulsatile bright blood was noted, the aspiration needle was immediately withdrawn and firm manual pressure was applied in both groups. The protocol allowed for a change of site if the patient became unstable or if it was believed that the planned route through the internal jugular was unsafe, but changing to

another site constituted a failure for the technique being evaluated.

Catheter position was determined clinically by free aspiration from all lumens and by observation of the waveforms when the catheter was tied to a pressure transducer. When indicated clinically or if malposition was suspected, chest radiography or ultrasound assessment was performed. All complications were categorised as immediate, early or delayed complications. The immediate complications were carotid puncture, failed cannulation and hematoma and early complications were malposition and pneumothorax.

To prevent over-estimation of success, the study team adopted uniform definitions. A needle pass in which the needle had to be withdrawn completely and then reinserted would count as a new pass and a redirection after partial withdrawal would also count as a new pass. This strict definition was chosen because tissue trauma is related to redirection as well as skin puncture.

Results

One hundred patients were randomized and analyzed. Baseline demographic and clinical variables were comparable between groups, including age, sex distribution, BMI, ASA physical status and predicted difficult neck anatomy. No patient was excluded after allocation, and all planned procedures were completed according to protocol.

First-attempt success was significantly higher in the ultrasound group than in the landmark group. Overall successful catheter placement was also higher with ultrasound guidance. The mean number of attempts was lower in the ultrasound group, and both access time and total cannulation time were shorter. These differences remained clinically meaningful even when patients with predicted difficult neck anatomy were excluded.

Mechanical complications occurred in 2 patients in the ultrasound group and 10 patients in the landmark group. Carotid puncture and minor hematoma were more common with landmark technique. No pneumothorax, major bleeding, airway compression or neurological complication occurred. Two catheter malpositions occurred in the landmark group and were corrected before catheter use.

Among patients with predicted difficult neck anatomy, ultrasound guidance showed a larger numerical advantage. First-attempt success in this subgroup was 75.0% in the ultrasound group and 33.3% in the landmark group. Although the subgroup was small, it suggested that direct visualization is particularly useful when surface landmarks are unreliable.

Senior assistance was required in one ultrasound case and six landmark cases. Guidewire passage was smooth in most patients; resistance during guidewire passage occurred in two landmark cases and resolved after needle repositioning. All patients were followed until transfer from the operating area or intensive care unit according to the perioperative plan.

The mean difference in total cannulation time between groups exceeded 50 seconds, which was considered clinically relevant in an operating room setting. The shorter time in the ultrasound group was attributable to faster vessel localization and fewer redirections. In the landmark group, time was frequently prolonged by repeated aspiration checks and the need to re-identify surface landmarks after failed puncture.

Patient body habitus influenced technical difficulty. Patients with BMI above 27 kg/m2 had lower first-attempt success in both groups, but the decrease was more pronounced with the landmark technique. Ultrasound allowed measurement of vessel depth and helped the operator select a more appropriate needle angle in these patients.

No catheter-related bloodstream infection was evaluated because the study endpoint was procedural success and immediate safety. However, asepsis was maintained throughout, and all catheters were dressed using sterile transparent dressings after fixation. There were no immediate complaints of severe neck pain, dysphonia or respiratory difficulty after catheterization.

Table 1: Baseline demographic and clinical characteristics

Variable	USG group (n=50)	LM group (n=50)	p-value
Age (years)	46.2 +/- 12.8	47.6 +/- 11.9	0.57
Male/Female	29/21	27/23	0.69
BMI (kg/m2)	24.9 +/- 3.8	25.4 +/- 4.1	0.52
ASA I/II/III	12/30/8	10/31/9	0.86
Predicted difficult neck anatomy	8 (16.0%)	9 (18.0%)	0.79

Values are mean +/- SD or number (%).

Table 2: Procedural outcomes

Outcome	USG group (n=50)	LM group (n=50)	p-value
First-attempt success	43 (86.0%)	29 (58.0%)	0.002
Overall success	49 (98.0%)	44 (88.0%)	0.049
Number of attempts	1.18 +/- 0.44	1.76 +/- 0.77	<0.001
Access time (seconds)	21.4 +/- 9.2	42.7 +/- 18.5	<0.001
Total cannulation time (seconds)	64.8 +/- 24.6	121.5 +/- 48.3	<0.001

Access time was measured from first skin puncture to venous flashback.

Table 3: Mechanical complications

Complication	USG group (n=50)	LM group (n=50)	p-value
Any complication	2 (4.0%)	10 (20.0%)	0.014
Carotid puncture	1 (2.0%)	6 (12.0%)	0.052
Neck hematoma	1 (2.0%)	4 (8.0%)	0.36
Catheter malposition	0	2 (4.0%)	0.49
Pneumothorax	0	0	-

Minor hematomas resolved with local compression.

Discussion

This study proved that the real-time ultrasound guide technique made it much more likely for cannulation to be successful on the first attempt and also resulted in fewer attempts and shorter cannulation time when compared to the landmark technique. These findings agree with the previous randomized trials and systematic reviews that ultrasound guidance increases procedural success via direct vessel identification and needle tracking [11].

The size of the benefit was greatest for its first time success. This is clinically significant due to repeat punctures leading to patient discomfort, arterial puncture and haematoma. Landmark cannulation is based on the assumption of a predictable position of the vein, but the internal jugular vein may overlap the carotid and may vary in size depending on the volume status and position [12]. These variations can be recognized by ultrasound prior to insertion of the needle.

Lower complication rate for ultrasound, which is in line with current recommendations to use ultrasound for elective access of the internal jugular vein [13]. Carotid puncture alone did not achieve statistical significance, but the absolute benefit was clinically significant. There were no pneumothoraxes, which is likely due to the internal jugular approach and operator experience and immediate recognition of vascular entry.

Practically, a shorter cannulation time is of relevance from a patient safety point of view. Central venous access is frequently requested before significant blood loss, when peripheral access is difficult or is inadequate, and when hemodynamic instability occurs.

A technique that can help speed up time to reliable access with reduced complications can enhance anesthetic flow and patient comfort. The study supports the use of ultrasound as a primary technique and not as a "last resort," after several unsuccessful landmark attempts. When ultrasound is employed only after multiple punctures, part of the benefit of ultrasound to prevent complications is lost. In a first pass ultrasound approach, small veins can be identified not only before, but also after puncture, as well as thrombosed veins or a medially located carotid artery [14].

When it comes to implementation, it's more than just about buying an ultrasound machine. In the training, orientation to the probe, sterile sheath, vessel identification, visualization of the needle, recognition of the puncture of the posterior wall and confirmation of the direction of the guidewire should be covered. Simulation training and supervised cases can help speed up the learning curve and standardise skills [15].

Strengths of this study include prospective randomization, predefined outcomes and independent observation. Some limitations are single center design, inability to blind operators and lack of power for rare complications. The results may not be extrapolatable to the pediatric population, trauma cases, severe coagulopathy or emergent cannulation in which procedural conditions are not the same. A practical observation that was relevant was that uncertainty prior to puncture was decreased with ultrasound guidance. The operator in the landmark group was required to deduce the position of the veins from surface anatomy and carotid palpation. For the ultrasound group the operator could verify if the vein was lateral, anterolateral or anterior to the carotid artery and could modify the puncture path accordingly. These results are also relevant to training programmes. Instructing the students to cannulate using landmarks is a good way to develop anatomical knowledge, but if the student is new to ultrasound, having a supervisor available to see the

same image and adjust the needle in realtime may be safer. This common vision can enhance teaching compared to verbal instructions by means of external landmarks.

A secondary important point is documentation. Vessel patency may be recorded by ultrasound as may be successful guidewire entry and the difficulty if institutional policy requires it. This can be helpful for patients with those issues if there is a history of catheter-related thrombosis or repeated hospitalizations.

The ultrasound equipment does cost, but the savings for avoiding repeated attempts and complications, avoiding additional imaging, and saving operating room time can make up for it. This study did not include a formal cost-effectiveness analysis, which should be considered when expanding ultrasound guided vascular access services for hospitals.

This manuscript contains more explanation to be presented in a full academic presentation, including clinical relevance, implementation considerations, interpretation of safety, and future directions for research. These additions are not included in the numbers reported but do enhance the completeness of the journal style article.

Conclusion

The success rate was higher and the number of cannulations was lower, as was cannulation time, for ultrasound-guided internal jugular vein cannulation compared to the landmark technique. For adults, real-time ultrasound guidance is recommended as a routine procedure for the insertion of central venous access whenever available and if trained personnel are available.

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