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A comparison of internal jugular vein cannulation versus supraclavicular brachiocephalic vein cannulation using ultrasound guidance

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ABSTRACT

Background: Ultrasound has become the standard of care for the insertion of central venous catheters (CVCs) in the intensive care unit. With the introduction of ultrasonography in CVC insertion, there has been an improvement in the success rate and a dramatic decrease in the rate of complications. **Aims and Objectives:** The aim of this study was to compare the safety and ease of insertion of ultrasonically guided cannulation of the internal jugular vein (IJV) with that of the supraclavicular subclavian vein (SCV) in adult patients undergoing various surgical procedures. **Materials and Methods:** All the patients in whom central venous cannulation was planned were assigned to two groups. Group I underwent ultrasound-guided IJV while as Group II underwent cannulation ultrasound-guided SCV cannulation. A comparison was made between the two groups, of the success rates, durations of procedure, number of attempts at needle redirections, difficulties if any during insertion of guidewires, and the complications encountered. **Results:** The IJV group had a higher proportion of first-attempt success (93.2% versus 62.7%). The IJV group had a lesser incidence (3.2%) of complications such as guidewire progression and needle redirections compared with SCV (15.2%). The frequency of adverse events did not differ between the two study groups with an incidence in 3.2% in IJV group and 9.6% in the subclavian group. Higher first-attempt success rates and fewer procedural complications were seen with ultrasound-guided IJV. **Conclusion:** IJV central venous catheterization is an easier and less invasive and less risky procedure for patients.

Keywords: Central venous catheter; Complications; First-pass attempt; Intensive care unit; Ultrasound guidance

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INTRODUCTION

The insertion of a central venous catheter (CVC) is a commonly performed procedure in the management of critically ill patients.[1] The commonly used approach involves the internal jugular vein (IJV) and the subclavian vein (SCV). The placement of the CVC is associated with a high rate of serious complications.[2] Bedside ultrasonography (USG) guidance has become a popular tool for insertion of the CVCs and has decreased the incidence of complications during the procedure.[3,4] IJV cannulation has been very popular across the globe for the past few decades.[5] Both short-axis and long-axis views have been used for IJV cannulation.[6]

The infraclavicular cannulation of SCV under ultrasound guidance is presumed to be more technically challenging and difficult than the supraclavicular cannulation due to the

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acoustic shadow cast by the clavicle.[7] There are numerous advantages of SCV cannulation over IJV cannulation, its larger diameter, lower risk of central line-associated bloodstream infection, ability to remain patent in shock, increased patient comfort, better tolerance, and an easy, improved accessibility with patients having cervical spine injury, but still, there is currently insufficient evidence for the use of ultrasound guidance for SCV cannulation.[5,8,9] The supraclavicular approach, though an uncommonly used method, has been described in 1965 as a suitable alternative for cannulation of the internal jugular route.[10] It has been observed by Timsit et al., that the long-axis view on ultrasound is able to give a better sonographic visualization of the SCV and may be helpful in-plane (IP) needle approach.[11]

The supraclavicular approach for SCV cannulation is often used in adults. There are no studies comparing the feasibility and complications between IJV and SCV cannulation.

Aims and objectives

The aim of our study was to compare the success rates and the rate of complications between IJV and SCV cannulation techniques using ultrasound.

MATERIALS AND METHODS

This study was a prospective observational study performed in the operating room and intensive care unit (ICU) of a tertiary teaching hospital. All patients who underwent elective and emergency surgeries in the operating room, and those who were admitted to ICU between January 2020 and May 2023 were enrolled in this study. Adult patients (over the age of 18) who needed a insertion CVC as a mandatory part of their medical management for resuscitation, administration of intravenous fluid, and parenteral nutrition for prolonged period were included in the study protocol. Before putting in the central line, either the patient or a close family member was explained the need for the central venous cannulation and the possible complications associated with the central venous cannulation. After explaining, written consent was taken from either the patient or a close family member before enrolling the patient in the study.

Sampling

Central line site insertion into either the IJV or SCV was chosen, depending upon the feasibility, experience, and convenience of the operator or the procedure for which the central line was intended.

Inclusion criteria

SCV was preferred for cannulation where the patient had a history of coagulopathy and was to be operated in sitting position (posterior fossa tumors), right lateral or left lateral position (cerebellopontine angle tumors), prone position (posterior fossa or occipital tumors). IJV cannulation was preferred for patients to be operated in the supine position (frontal, parietal, and temporal tumors).

Exclusion criteria

Exclusion criteria were the presence of any suspected or documented thrombus inside the vein, any congenital or acquired musculoskeletal deformities of the neck or clavicle, any active infections or signs of inflammation over the insertion site, or any previous procedures performed at the cannulation site. Pediatric patients with age <18 years were not included in the study. The data were analyzed after the completion of the procedure by another independent physician not primarily associated with the insertion of the central venous cannulation.

Technique

All catheterizations were performed by a resident anesthesiologist who had more than 3 years of work experience in Anesthesiology. Before doing the procedure, an electrocardiogram, a non-invasive blood pressure cuff, and a pulse oximeter were attached. After cleaning the insertion site with povidone iodine, the patient was draped under all aseptic precautions. If the cannulations were made in an awake patient, an injection of xylocaine 2% (3 mL) was given subcutaneously before doing the central venous cannulation. A head-down position with an inclination of 10° to reduce the risk of air embolisms and improve venous distension was given. The head was gently turned to the side opposite the venipuncture. For IJV cannulation, the ipsilateral arm was held in the neutral position, while as for the SCV, it was held in an adducted position.

For IJV cannulation, the operator approached the patient from the head end (from the patient's upper side of the body). For the SCV cannulation, the operator approached the patient from the corresponding side from which the SCV was to be cannulated. A high-frequency linear array transducer was used for imaging the IJV or the SCV (Esaote MyLab). A 7Fr triple-lumen CVC was used for cannulation.

For IJV cannulation, the probe was placed on the neck on the corresponding side where the vein was to be cannulated. A short axis of the image of the IJV and common carotid artery (CCA) was obtained by placing the transducer in the transverse orientation. The transducer was moved from the sternal notch toward the cephalic end, along the course of the IJV. The point where the IJV diameter was maximum was chosen as the insertion point (Figure 1). The CCA was differentiated from the IJV by observing the pulsatile nature, non-compressibility, and higher velocities in the CCA. After confirming the position of IJV, it was imaged in the center of the screen. A puncture was made at 60° aimed at the IJV under ultrasound guidance tracking the tissue deformation in real time and observing and following the dip in the vein's front wall. The endpoint was taken once the needle tip was visualized as an echogenic shadow in the center of the vein.

The SCV cannulation was achieved after visualizing the short-axis view of the IJV (Figure 2). The IJV was followed toward the supraclavicular fossa. The subclavian artery was delineated to prevent its inadvertent puncture (Figure 2). The probe was tilted forward to get a better view of the brachiocephalic vein (BCV) in its longitudinal axis. This junction marks the point of confluence of the IJV and the SCV. To prevent the pneumothorax during cannulation, a clear visualization of the underlying pleura was made. Doppler imaging was done to differentiate between the subclavian artery and SCV. The needle was directed under ultrasound guidance toward the brachiocephalic SCV junction. In both IJV and SCV groups, catheterization was performed using the Seldinger technique. With the help of ultrasound, the position of the guidewire was confirmed. In case there was any impediment to the passage of the guidewire, the same was noted. In case no blood was noted on aspiration, a repeat attempt was made repeating the procedure. The right side of the body was preferred for central venous cannulation due to the absent thoracic duct, a lower position of the pleural dome, and drainage of the right IJV into the superior vena cava.[12,13]

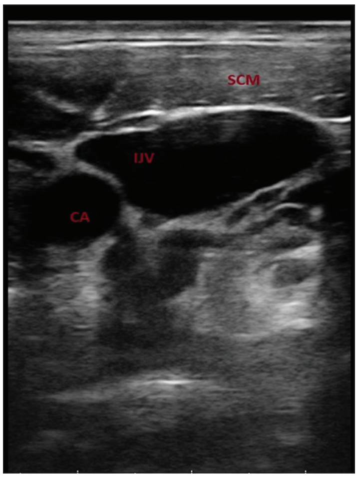

Figure 1: Short-axis image on ultrasound for an internal jugular vein (IJV). The internal jugular vein, common carotid artery (CA), and sternocleidomastoid (SCM) are seen in the same section

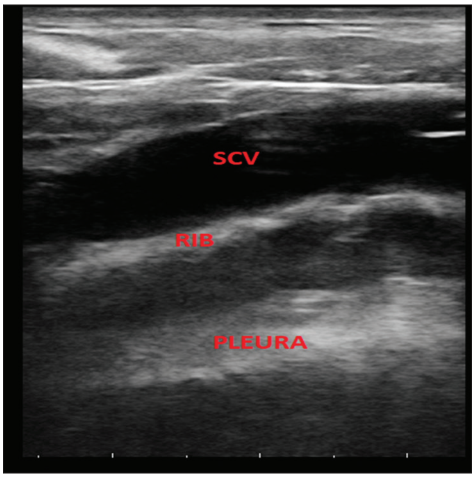

Figure 2: Ultrasound-guided subclavian vein catheterization utilizing the supraclavicular approach. An in-plane view showing the subclavian vein, rib, and pleura. SCV: Subclavian vein

Primary and secondary outcomes

The primary outcome measured was the first success rate, which was defined as the number of attempts made for the insertion of the guidewire into the intended vein after the skin puncture. The secondary outcomes studied included the (1) total time required for ultrasound scanning of the vein; (2) the venous puncture time (time from the first skin puncture to venous blood aspiration); (3) insertion time (time from the first skin puncture to the ultrasound guided confirmation of the correct position of the guidewire into the target vein); (4) and the overall access time (defined as the time between the beginning of the ultrasound scanning and the ultrasound confirmation of the correct position of the guidewire; (5) the number of puncture attempts (defined as the average number of separate skin punctures); (6) the number of needle redirections; (7) the success rate (defined as the proportion of the correct placement of the guidewire into the intended vein and obtained within three punctures); (8) guidewire advancing difficulties; (9) venous collapse rate (defined as the proportion of patients in whom the vein was collapsed; if the visually diameter varies by more than 50% with respiratory movements); (10) the frequencies of artery puncture, hematoma, pneumothorax, and catheter misplacements were used to assess adverse events.

RESULTS

A total of 300 patients were enrolled for the study. Out of these 60 patients had to be excluded due to coagulation disorders, anatomical abnormalities, cannulation site surgeries with some implants *in situ*, infection at the site of infection, or inability to obtain consent from the patient to participate in the study. A total of 240 patients were included in the study which was divided into two groups. In 120 patients, IJV was cannulated while in the other 120 patients, SCV was cannulated using the ultrasound guidance. Figure 3 shows the consort flow diagram for the study subjects.

It was observed that there were no statistically significant differences in the demographic data between the two groups. The age and body mass index between the two groups were comparable. Similarly, there was no difference in the incidence of various comorbidities such as hypertension, diabetes mellitus, ischemic heart disease, asthma, and chronic kidney disease (Table 1).

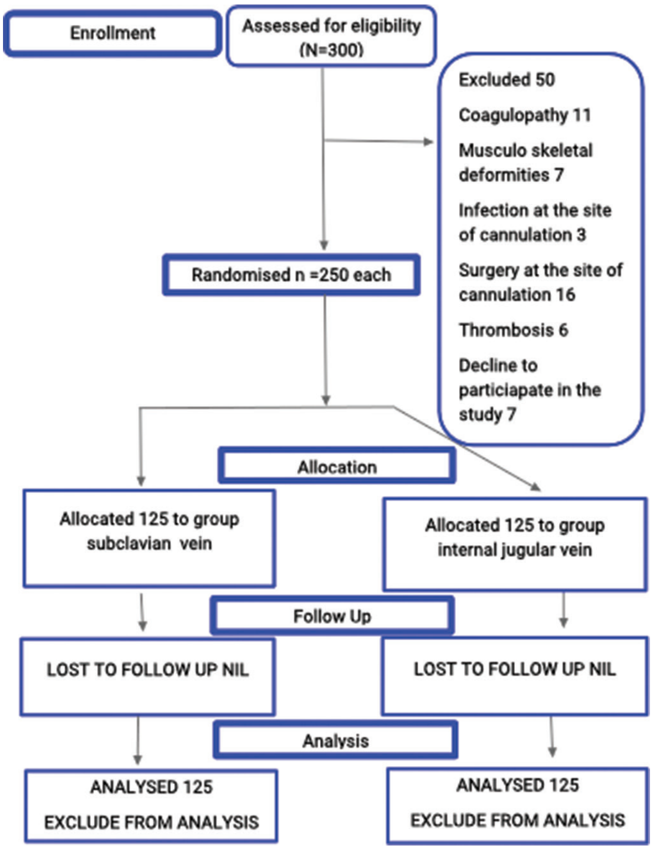

Figure 3: Cohort diagram of the study. N: Total number of patients, n: Number of patients enrolled in each group

The patients did not differ in the presence of factors that could be responsible for difficult venous cannulation nor was there any difference in SOFA score between the two groups. It was observed that the number of patients who were receiving mechanical ventilation was comparable between the two groups. The results from our study showed that the first-pass attempt was reduced significantly in patients where IJV was cannulated. It was seen that the time for ultrasound scanning of the IJV was significantly < that required for SCV. However, there was no difference observed between the ultrasound-guided IJV cannulation and SCV cannulation once venous puncture time, insertion time, and overall access time between the two groups were compared. It was observed from our study that the mean number of puncture attempts, the mean number of needle redirections, and difficulties in passing the guidewire during cannulation were less in IJV once compared with the SCV.

Venous collapse was seen more commonly in IJV than in SCV. The incidence of pneumothorax was seen more commonly in the cannulation of SCV due to close-by relationship of the pleural space nearby. The cannulation of the SCV may have also caused hematomas; the same may be missed due to the overlying clavicle which may make it difficult to appreciate it. The incidence of catheter malpositions was seen in both IJV and SCV cannulation with an equal incidence. All these details have been presented in Table 2.

The long-term follow-up of our patients showed that patients with SCV cannulation were more tolerant to the procedure in ICU underlying lung tissue. Furthermore, it was seen the incidence of carotid artery rupture was seen

Table 1: Demographic characteristics of the study groups

Variable	IJV group (n=125)	SCV group (n=125)	P value
Age, mean±SD, years	57.65±14.17	55.45±15.13	0.103
Gender male: female	70:55	70:55	1.00
Body mass index, mean±SD, kg/m^2	28.91±4.31	27.89±5.70	0.118
Hypertension	42 (33.6)	48 (38.4)	0.510
Diabetes mellitus	21 (16.8)	23 (18.4)	0.674
Ischemic heart disease	17 (13.6)	15 (12.0)	0.814
COPD/Asthma	5 (4.0)	7 (5.6)	0.416
Chronic kidney disease	2 (1.6)	5 (4.0)	0.355
Presence of coagulopathy	4 (3.2)	7 (5.6)	0.253
Admission type, n (%)			
Elective	56 (44.8)	65 (52.0)	0.269
Emergency	69 (55.2)	60 (48.0)	0.261
Presence of risk factors for difficult venous cannulation, n (%)	18 (14.4)	21 (16.8)	0.513
Mechanical ventilation during line placement, n (%)	120 (96.0)	119 (95.2)	0.703
SOFA score at randomization, mean±SD	7.81±2.38	7.59±2.83	0.220

n: number of patients in each group, IJV: Internal jugular vein, SCV: Subclavian vein, SD: Standard deviation, %: Percentage of patients, SOFA: Sequential Organ Failure Assessment, kg/m^2: Kilogram per meter square, COPD: Chronic obstructive pulmonary disease

Table 2: Success and complications of CVC cannulation

Variable	IJV group (n=125)	SCV group (n=125)	P-value
Primary outcome			
First attempt success rate (%)	93.2	62.7	0.001
Secondary outcomes			
US scanning time (s)	6.26±3.02	14.04±12.32	<0.001
Venous puncture time (s)	23.25±13.61	21.31±14.57	0.19
Insertion time (s)	45.10±40.11	49.88±27.57	0.038
Overall access time (s)	55.75±41.68	57.58±37.23	0.73
Mean number of puncture attempts	1.57±0.71	1.36±0.39	<0.001
Mean number of needle redirections	1.18±0.75	0.99±0.68	<0.001
Success rate (%)	98.8	68.4	0.001
Guidewire advancing difficulties (n [%])	4 (3.2)	19 (15.2)	<0.001
Venous collapse (n [%])	3 (2.4)	13 (10.4)	<0.009
Adverse events (n [%])	4 (3.2)	12 (9.6)	0.039
Pneumothorax	2 (1.6)	4 (3.2)	0.409
Hemothorax	0	0	–
Arterial puncture	4 (3.2)	7 (5.6)	0.355
Hematoma	11 (8.8)	3 (2.4)	0.028
Catheter malposition	4 (3.2)	5 (4.0)	0.734

n: Number of patients in each group, IJV: Internal jugular vein, SCV: Subclavian vein, CVC: Central venous catheter, SD: Standard deviation, %: Percentage of patients, SOFA: Sequential Organ Failure Assessment, kg/m2: Kilogram per meter square, COPD: Chronic obstructive pulmonary disease

commonly during the cannulation of IJV. Hematoma formation was also seen more common I IJV cannulation.

DISCUSSION

The IJV is a paired venous structure that collects blood from the brain, superficial regions of the face, and neck, and delivers it to the right atrium.[11] The SCV is classified as a deep vein and is the major venous channel that drains the upper extremities. The SCV continues its path posterior to the clavicle, toward the sternal notch until the medial border of the anterior scalene muscle behind the sternoclavicular joint. Here, it joins the IJV, which becomes the BCV (also known as the innominate vein), to enter the superior vena cava, which drains into the right atrium of the heart.[12]

Over the past decade, there has been tremendous improvement and reduced complications associated with central line placement procedures. With ultrasound guidance, the procedure has become very safe. With the introduction in ultrasound, there has been a dramatic reduction in the incidence of peri-procedural complications as pneumothorax, hemothorax arterial puncture, and hematoma formation.

For IJV cannulation, an out-of-plane (short axis) view or an IP (longitudinal axis) may be used. For SCV catheterization, an IP longitudinal axis view is commonly used.[13] As the incidence of serious immediate complications during CVC is rare, at present, there is insufficient evidence to conclude whether ultrasound-guided IJA cannulation is a superior technique than ultrasound-guided subclavian cannulation.

We found that the first-attempt success rate was significantly higher in IJV group compared to subclavian group (93.2% vs. 62.7%; P=0.001). These results were in contrast to those reported by Gowda et al., comparing the IJV cannulation with BCV cannulation in critically ill children.[14] In another retrospective cohort involving elective central venous cannulation, Beccaria et al., mentioned a higher first-attempt success rate in the BCV (90%) than in the IJV group (85%).[15] Although the subclavian has several anatomical advantages in terms of its large diameter, its intrathoracic position, and its firm attachment to adjacent bony structures, the SCV remains patent and stable regardless of the hemodynamic and respiratory status which facilitates the venous access. However, these advantages may be of help in the cannulation using the anatomical landmarks without the use of ultrasound.[16] Once ultrasound is used, the visualization of the IJV in both IP and out-of-plane approach may be easy than the subclavian approach. There may be a steep learning curve for subclavian cannulation. The imaging of the SCV is usually difficult than the SCV due to obscuring of the vein shadow by the first rib and clavicle.[17] Furthermore, for novices, it may be difficult to differentiate between that subclavian artery and SCV on ultrasound. In contrast, it is easy to differentiate between the IJV and the carotid artery on ultrasound imaging.

The real needle tip can be easily visualized in the cannulation of the IJV with rocking movements of the transducer or gentle creeping movement. This will be helpful in preventing the puncture of the posterior walls in IJV. Furthermore, a dynamic change of view in the short axis, oblique axis, and long axis is possible with the cannulation of IJV.[18] The sonoanatomy of SCV does not give this extent of dynamic flexibility to have a visualization of the anatomy in both IP and out of the plane, which makes it difficult to maneuver the needle during cannulation. Therefore, the operator may inadvertently pass through both vein's walls.

It was observed in our study that SCV took a longer scanning time of 14.04±12.32 min once compared with IJV (6.26±3.02). The longer scanning time in the subclavian vein could be attributed to the associated bony structures and difficulty in delineating the junction between the BCV and SCV.

Our study revealed a similar incidence of adverse events (pneumothorax and hemothorax) in between the IJV group and the SCV group. Although we observed a similar incidence of arterial puncture between the two groups, it was observed that the hematoma formation in the IJV group was more than that of the SCV group. This may have been possibly as a result of the obscuration of a small hematoma in the SCV due to the overlying adjacent bony structure – the clavicle and the first rib. This was similar to the study conducted by Karpanen et al.[19] Although previous reviews showed that SCV is accompanied by a higher incidence of pneumothorax and hemothorax,[20] we found that the incidence was similar between the two groups.

In our study, we saw that the visualization of the introducer needle of the CVC was better in IJV than the subclavian – BCV. This may be again due to the obscuring of the images by the adjacent bony structures in the SCV. Choudhary, Ayden, Scholten and Shinde noted good USG visualization of the introducer needle and guide wire but catheter visualization was not good in both groups.[21-24] However, in our study, the visualization of the catheter was better in the IJV. The differences may have been possibly due to the pediatric population in these studies whereas our study consisted of only adult patients.

Limitations of the study

Our study excluded patients in pediatric age group, hypovolemia, cardiovascular disease which may have an effect on the visualization and ease of cannulation using the ultrasound.

CONCLUSION

USG-guided out-of-plane approach for cannulation of IJV is better once compared with the IP approach of subclavian-BCV cannulation with regard to the overall success rate and first-attempt success rate. The procedural ease with ultrasound-guided IJV and the scanning time is also better for IJV once compared with the brachiocephalic-SCV.

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Authors Contribution:
ZA- Initial data collection, data analysis, prepared the first draft of the manuscript; **AWM-** Literature survey, implementation of study protocol; **IN-** Clinical protocol, manuscript preparation; **SHA-** Editing, and manuscript revision; **AM-** Statistical analysis and interpretation; **MM-** Data collection, data analysis; **ZS-** Data collection, data analysis; and **SAM**- Coordination and manuscript revision.

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