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Comparison of novel anteroposterior short-axis in-plane technique with conventional short-axis out-of-plane technique for ultrasound-guided internal jugular vein cannulation: A randomized-controlled trial

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Abstract:

OBJECTIVES: Various ultrasound (US)-guided probe positioning and needle procedures have been described in the literature for cannulation of the internal jugular vein (IJV). In the present study, we compared the conventional short-axis out-of-plane (SAX-OOP) method with a novel anteroposterior short-axis in-plane (APSAX-IP) technique for IJV cannulation under US guidance. The APSAX-IP method of IJV cannulation has not been compared to other IJV cannulation techniques.

METHODS: A total of 104 patients above 18-year-old were randomly allocated to one of two groups - APSAX-IP or SAX-OOP and evaluated for US-guided IJV cannulation in either the operating room or critical care unit. The primary outcome of this research was the access time for IJV cannulation using both approaches. The secondary outcomes were the number of attempts of needle insertion, success rate, and complications of IJV cannulation.

RESULTS: The access time for IJV cannulation was 13.0 (12.0–15.0) sec in the APSAX-IP group and 13.0 (12.0–14.0) sec in the SAX-OOP group; $P = 0.947$. The number of successful 1st attempts was 90.91%, and the 2nd attempts were 9.09% in the APSAX-IP group and 85.19% and 14.81% in the SAX-OOP group, respectively. Both techniques did not have any complications.

CONCLUSIONS: We conclude that the US-guided APSAX-IP IJV cannulation method has comparable access time to the SAX-OOP technique.

Keywords:

Cannulation, internal jugular vein, out-of-plane, short-axis, ultrasound

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Introduction

Central venous catheter (CVC) cannulation is routinely used in perioperative and intensive care settings. An ideal technique of CVC cannulation should be easy, safe, and efficient with no or few complications. The procedure's success depends greatly on the cannulation technique used. The internal jugular vein (IJV) is often favored due to its anatomy, and its diameter is also increased in the Trendelenburg position.[1]

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Box-ED section

What is already known on the study topic?

- Different ultrasound (US) probe placement and needle insertion strategies have been described to increase IJV cannulation success rates and prevent complications.

What is the conflict on the issue? Has it importance for readers?

- Despite this, numerous techniques using real-time ultrasonography still have limitations and associated challenges.

How is this study structured?

- This study was a prospective randomized-controlled trial conducted at a tertiary care hospital and included data from 104 participants
- Patients were allocated into two groups – conventional short-axis out of plane (SAX-OOP) and a novel anteroposterior short-axis in-plane (APSAX-IP) group for US-guided IJV cannulation.

What does this study tell us?

- For IJV cannulation, the US-guided APSAX-IP technique may be used as an alternative to the SAX-OOP method
- The probe's placement on the lateral side of the neck may overcome space limits in persons with short necks.

As per recent guidelines, ultrasound (US) should be utilized to direct the CVC insertion whenever possible to minimize complications. Multiple studies have demonstrated that the US-guided technique is superior to the traditional anatomical landmark technique because it requires fewer cannulation attempts, has a better first-pass success rate, takes less time, and encounters fewer complications.[2] However, continuous needle visualization under ultrasonography requires practice and dexterity.[3] Alternative techniques of inserting the needle and aligning the US probe have been reported to improve outcomes and limit complications.

When the US probe is positioned transverse to the vessel, the US screen displays a "short-axis (SAX)" view. Although it might be challenging to control the needle tip, an artery and a vein can be seen concurrently in the SAX technique. A "long-axis (LAX)" view is created by aligning the probe of the US parallel to the vessel's route (i.e., an image of the vessel longitudinally).[4] Although the LAX view enhances needle visibility, one can expect difficulty when the patients have short necks. The LAX technique necessitates skill because one has to be able to view both the IJV and carotid artery.

The needle's placement with respect to the US probe's position is denoted by the phrases "out-of-plane (OOP)" and "in-plane (IP)." Using the SAX-OOP approach, the needle is placed out of the plane so that it is perpendicular to the plane in which the probe is positioned. This creates a SAX picture of the desired vein for the cannulation.[5] In the LAX-IP approach, the needle advances parallelly to the US probe, using the LAX view of the IJV as a starting point. The long axis allows easy viewing of the needle and vein, while the short axis enables visualization of the vein's surrounding tissues.[5]

Aithal *et al*. introduced a novel anteroposterior short-axis IP (APSAX-IP) approach of IJV cannulation that integrates the IP technique and SAX view.[6] This approach addresses the limitations of the conventional LAX-IP approach. The US probe is positioned anteroposteriorly on the lateral portion of the neck to address space limits in patients with short necks and the challenges of needle manipulation. This orientation of the probe generates the SAX image, which illustrates the association between the IJV and the carotid artery. The midpoint of IJV is seen in the SAX view.

The APSAX-IP approach has not been compared with other techniques of IJV cannulation in the literature. We hypothesize that there is no difference in access time between the novel APSAX-IP and SAX-OOP techniques of US-guided IJV cannulation. Therefore, in this study, we aim to compare the access time between these two techniques of IJV cannulation.

Methods

Study design

This study was submitted to the Clinical Trials Registry of India (with the clinical trial number of CTRI/2020/12/029725) after receiving clearance from the Institutional Ethics Committee of All India Institute of Medical Sciences (AIIMS), Jodhpur with letter no. IEC/2020/3173 on September 23, 2020. This was a parallel randomized controlled trial with an equal allocation ratio of 1:1, comparing APSAX-IP and SAX-OOP techniques of US-guided IJV cannulation.

Participants

This trial was accomplished at a tertiary care hospital's intensive care unit (ICU) and operating theatre (OT). This research was conducted from July 2020 to December 2021. Eligible participants of either sex who were older than 18 years old and required IJV cannulation were enrolled in this trial. We excluded patients who had undergone surgery at the insertion site; any inflammation or redness around the insertion site; clotting factor abnormalities, aberrant IJV anatomy (agenesis, strictures, or duplication) seen by US imaging and the presence of a thrombus within the IJV and patients having CVCs already in place. Patients were evaluated for any abnormalities in the clotting parameters after obtaining their informed written consent.

Randomization
After enrollment, patients were randomly allocated to one of two groups APSAX IP or SAX-OOP using the computer randomization tool (www.randomizer.org).

Sequence generation
Sequence generation was carried out by an attending physician using the "rand ()" command in Microsoft Excel software who was not involved in USG-guided IJV cannulation.

Allocation concealment
To conceal the identity, the group recognition slip was placed in a prenumbered, packed, and dark-colored envelope.

Implementation
Another physician who was not involved in the study enrolled and assigned patients to one of two groups.

Blinding
Due to the nature of the investigation, blinding the operator to the two techniques of US-guided IJV cannulation was not feasible.

Interventions
IJV cannulation was done by intensivists or anesthesiologists with at least a year of experience performing the procedure under US guidance. IJV cannulation is frequently carried out at our institution using the SAX-OOP technique under US guidance. Reading material, observation, and practical training were employed to instruct the operators on the APSAX-IP technique. The cannulations were performed in the OT or ICU, and patients were monitored for vital parameters (electrocardiogram, blood pressure, and oxygen saturation). The circumstances of each patient and the need for IJV cannulation were used to decide the anesthetic plan. General anesthesia with or without paralysis was used to cannulate surgical patients, whereas local anesthesia was used in the ICU. The cannulation site (right or left) was selected by the primary care physician. One operator carried out the IJV cannulation at a time.

We used an US machine (GE Venue GO R3, GE Healthcare, WI, USA) with a high-frequency (5.0–13.0 MHz) linear probe as the IJV is a superficial structure. We scanned each patient's IJV before the procedure to see whether it was suitable for cannulation. Real-time US guidance was used to complete the IJV cannulation in sterile settings.

Description of techniques
Short-axis out-of-plane technique
The US machine was positioned in front of the operator to see the screen without straining his neck. When using the SAX-OOP technique, the operator stood on the patient's head while holding the US probe anteriorly above and parallel to the clavicle to scan the IJV. Once the artery and vein were visible, the needle was positioned perpendicular to the probe, and the IJV was cannulated using the operator's dominant hand [Figure 1].

Anteroposterior short-axis-in-plane technique
In this method, the US probe is positioned at the side of the neck (laterally) and directed anterior-posteriorly. The operator stood at the patient's side. The US probe was held with the probe marker-oriented anteriorly, parallel to the long axis of the neck. This image illustrates the short axis of the vessels, which is similar to the standard SAX image with a 90° anticlockwise rotation. To maintain the needle as parallel as possible to the US probe and to access the vein's center, the needle's entry point is positioned at a distance equal to the footprint of the transducer to the vein's center. The needle could be seen moving toward the center of the screen as it pierced the vein [Figure 2]. Instead of tilting the needle craniocaudally, the needle may be adjusted by repositioning the needle tip in a lateral or medial direction for up and down motion on the monitor. As the vein is pierced vertically, the needle tip is angled caudally. This causes the guidewire to be guided into the heart. The guidewire's direction inside the IJV may be checked by putting the US probe directly above the clavicle.

Following catheter insertion, it was sutured, and a transparent, sterile adhesive dressing was applied. After the procedure, chest radiographs of each patient were taken to ensure that the catheter was positioned correctly.

Outcome assessments
The primary outcome of this research was the access time for IJV cannulation using both approaches. The secondary outcomes were the number of needle insertion attempts, success rate, and complications such as a puncture of the artery, pneumothorax, posterior vessel wall puncture (PVWP), and misplacements of catheters.

The time between the initial puncture of the skin and the subsequent extraction of venous blood through the needle was defined as the access time. The needle must go forward without traveling backward to qualify as an attempt. Any needle retraction followed by an advancement was counted as an attempt, independent of the puncture site. The cannulation procedure was successful when the guidewire was successfully moved forward in the IJV. However, the technique was considered to have failed if the IJV could not be pierced after five attempts or if the operator could not advance the guidewire following a successful puncture. If the cannulation failed, the conventional approach was used.

Any pulsatile blood reflux visible through the needle during the procedure was considered an arterial puncture.

Figure 1: SAX-OOP technique of IJV cannulation (a) Position of the artery with respect to the vein (b) Probe placement and method of needle insertion (c) Needle tracking along the IJV. SAX-OOP: Short-axis out-of-plane, IJV: Internal jugular vein

Figure 2: APSAX-IP technique of IJV cannulation (a) Position of the vein above the artery (b) Probe alignment and the direction of needle entry (c) Needle tracking in the IJV. IJV: Internal jugular vein, APSAX-IP: Anteroposterior short-axis in-plane

Ultrasonographic detection of the needle tip or guidewire deeper than the posterior wall of the IJV during cannulation efforts was characterized as a posterior vascular wall puncture. After catheter insertion, a chest X-ray was done to identify pneumothorax (a linear shadow of visceral pleura with the absence of lung markings peripheral to the shadow). Misplacement of the catheter was defined as the identification of the catheter tip in a location other than the superior vena cava on the control chest X-ray.

Sample size calculation and statistical analysis

Lal *et al*. reported venous access time for US-guided IJV cannulation by SAX approach as 17.04 ± 3.81 s.[7] To estimate a 15% difference in venous access time by APSAX-IP, we calculated a sample size of 52 per group at 95% confidence interval (Type 1 error α =5%), 90% power, and 10% contingency for dropouts. Data were analyzed using SPSS version 23. The nominal variable was defined using counts and percentages, and the Chi-Square test was employed for analysis. On the Shapiro–Wilk test for normality, the variables of age, weight, height, body mass index, and access time were found to be not normally distributed. Hence, they were described using median and compared using Mann–Whitney U test. A $P = 0.05$ was used to indicate significant data.

Results

Initially, 105 patients were enrolled in this trial based on circumstances and the need for IJV cannulation. One patient declined to participate in the study. Finally, 104 patients were included and assigned at random to the two study groups APSAX-IP and SAX-OP [Figure 3]. Each group had 52 patients.

Both the groups were comparable for demographic parameters. The indications of IJV cannulation and various comorbidities are shown in Table 1. During IJV cannulation, all the patients were hemodynamically stable {mean arterial pressure (MAP) ≥65 mm Hg.}. Three patients in the APSAX-IP group and two in the SAX-OOP group had hypotension, which was managed either with intravenous fluid or vasopressor administered through a peripheral route to increase MAP up to 65 mmHg before IJV cannulation.

In all the patients, right-sided IJV was cannulated. The access time was comparable between the two groups (13.0 [12.0–15.0] sec in the APSAX-IP group and 13.0 [12.0–14.0] sec in the SAX-OP group; $P = 0.947$. The number of attempts was comparable between the two techniques. IJV was cannulated in the first attempt in 47 and 44 patients: And in 5 and 8 patients in the second attempt in the APSAX-IP group and SAX-OP group, respectively ($P = 0.357$) [Table 2]. The cannulation of IJV was successful in all the patients, yielding a success rate of 100% in both groups.

We did not encounter any complications (arterial puncture, pneumothorax, PVWP, and misplacements of catheters) in both groups.

Table 1: Comparison of demographic parameters, comorbidities, and indications of cannulation between the two groups

Parameter	APSAX-IP group (*n*=52)	SAX-OOP group (*n*=52)	*P*
Age (years)	60.0 (45.0-65.0)	47.0 (32.0-63.0)	0.079
Weight (kg)	65.0 (50.0-78.0)	62.0 (49.0-75.0)	0.160
Sex (female/male)	20/32	22/30	0.697
Height (cm)	162.0 (155.0-176.0)	164.0 (153.0-175.0)	0.939
Body mass index (kg/m^2)	24.0 (22.0-25.0)	23.0 (21.0-24.0)	0.784
Comorbidities			
Hypertension	21 (40.38)	23 (44.23)	0.935
Diabetes	16 (30.76)	14 (26.92)	0.762
Respiratory disorders	8 (15.38)	6 (11.53)	0.725
Cardiac disorders	4 (7.69)	5 (9.61)	0.917
Renal disease	3 (5.76)	4 (7.69)	0.897
Place of cannulation OT/ICU	28/24	25/27	0.817
Indication of cannulation			
Infusion of concentrated/irritating fluids/vasopressor	31 (59.61)	29 (55.76)	0.762
Difficult peripheral venous access	12 (23.07)	14 (26.92)	0.887
Monitoring of central venous pressure	6 (11.53)	5 (9.61)	0.932
Hemodialysis	3 (5.76)	4 (7.69)	0.899

Data presented as median (Q1-Q3) or *n* (%). APSAX-IP: Anteroposterior short-axis in-plane, SAX-OOP: Short-axis out-of-plane, OT: Operating theater, ICU: Intensive care unit

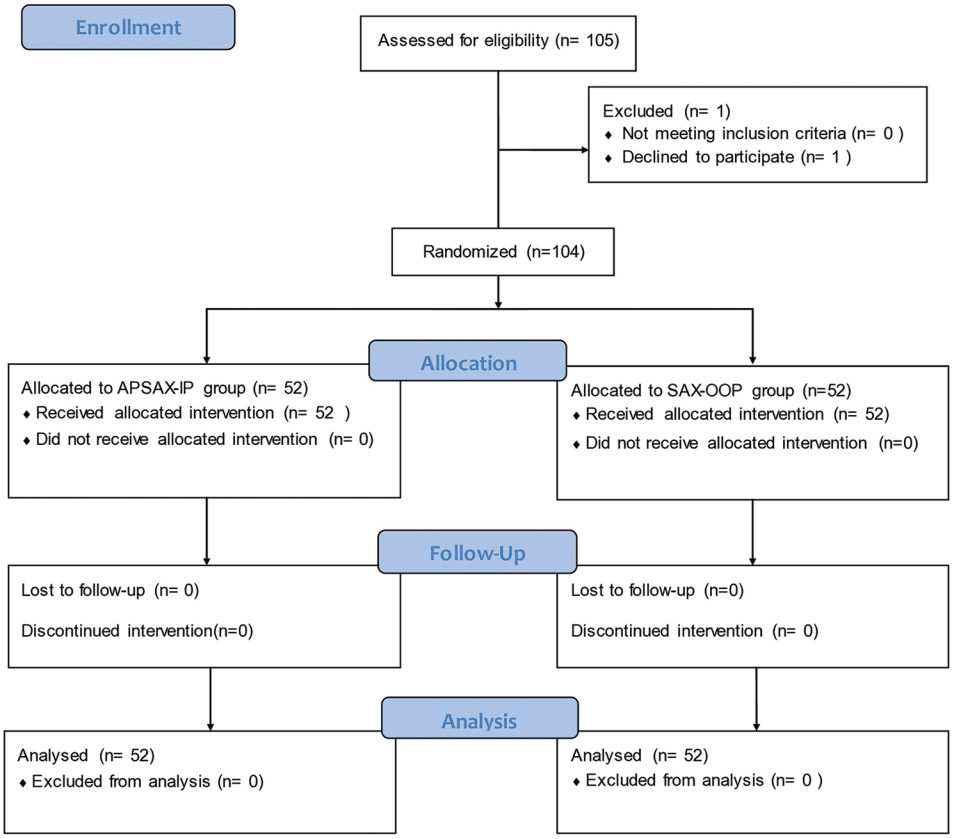

Figure 3: CONSORT Diagram

Discussion

When the IJV is chosen for cannulation, the American Society of Anesthesiologists practice recommendation suggests US guidance for vascular localization and puncture.[8] In this study, the standard SAX-OOP method was compared to a new APSAX-IP approach for the cannulation of IJV under US guidance. In the APSAX-IP method, the US image demonstrates the relationship between the IJV and the carotid artery. A laterally

Table 2: Comparison of access time and number of attempts between the two groups (*n*=52)

Parameter	APSAX-IP group	SAX-OOP group	*P*
Access time (s)	13.0 (12.0-15.0)	13.0 (12.0-14.0)	0.947
Number of attempts			
1	47 (90.91)	44 (85.19)	0.357
2	5 (9.09)	8 (14.81)	

Data presented as median (Q1-Q3) or *n* (%). APSAX-IP: Anteroposterior short-axis in-plane, SAX-OOP: Short-axis out-of-plane

positioned US probe has the additional benefit of not interfering with cannulation. It makes it possible for the needle to be put in an IP direction and perpendicular to the US probe, resulting in a detailed view of the whole needle. The probe is positioned on the lateral part of the neck, which can avoid the space limits of patients with short necks.

Aithal *et al*. investigated the APSAX-IP method of IJV cannulation on 75 adult patients.[6] They concluded that this new technique is not a difficult approach to use, as proven by the mean access time of 27.12 (standard deviation [SD] 21.47) sec, the number of attempts of 1.17 (SD 0.44) sec, and a success rate of 100%. In their study, the first and second attempt success rates were 85.33% and 12%, respectively. In the present study, the APSAX-IP approach had a success rate of 100%, with a median access time of 13.0 (12.0–15.0) sec, 90.91% of first successful attempts, and 9.09% of second attempts being successful.

Chittoodan *et al*. assessed the SAX and LAX approaches of US -guided IJV cannulation on 99 patients scheduled for heart surgeries.[9] The success percentage on the first attempt was substantially greater in the short-axis group of 98% than in the long-axis group of 78%. In our study, the first-attempt success rate for the APSAX-IP method was 90.91%, whereas it was 85.19% for the SAX-OOP method.

Batllori *et al*. compared SAX, LAX, and OAX (oblique axis) methods of IJV cannulation on 220 patients.[4] They concluded that SAX has a greater incidence of PVWP than OAX and that OAX and SAX were better for cannulation than LAX. Cannulations were successful on the first attempts in 69.9% of SAX patients, 52.5% of LAX patients, and 73.6%of OAX patients. The SAX group (15.1%) experienced a greater risk of mechanical complications than the OAX (6.9%) and LAX (4%) groups ($P = 0.047$). In the present study, the success rate at the first attempt for the APSAX-IP approach was 90.91%, while the SAX-OOP technique was 85.19%. We did not observe PVWP in any patient of both the study groups. Tammam *et al*. evaluated the SAX-OOP and the LAX-IP technique for IJV cannulation on 90 patients.[10] They determined that the success rate of IJV cannulation was 100%, and the average number of attempts was 1.13+/−0.35 and 1.17+/−0.38 in SAX-OOP and LAX-IP groups, respectively. Our study also had a success rate of 100%.

Davda and Schrift studied 40 participants without prior US-guided procedural experience to find the incidence of posterior wall puncture on a phantom between the LAX-IP approach and SAX-OOP approach of IJV cannulation.[11] In the SAX-OOP technique, 15% of the posterior wall was punctured, whereas, in the LAX-IP approach, only 2.5% of the posterior wall was punctured. Compared to the SAX-OOP approach, the LAX-IP technique resulted in a few PVWP, better visibility of the needle tip, and greater preference among novices. In our study, there was no PVWP in any of the study groups.

Chennakeshavallu *et al*. examined the SAX, LAX, and OAX methods of US-guided IJV cannulation in 210 patients scheduled for cardiac surgeries.[2] In their research, the first-attempt success rate for the OAX group was 94.2%; for LAX patients, it was 81.4%, and for SAX patients, it was 82.8%. In our study, the success rate on the first attempt was 90.91% for APSAX-IP and 80.19% for SAX-OOP. In their research, the LAX group required a longer time to aspirate blood following skin puncture than the SAX and OAX groups. In the present study, the access time was similar in both techniques. The similar access time in our study might be due to the short-axis view of IJV in both groups. In their research, the SAX group had a posterior wall puncture of 14.2% as opposed to the other two groups. Our study did not have any incidence of posterior wall puncture.

Rastogi *et al*. compared a new technique, the modified SA-OOP (MSA-OOP) approach, with the traditional SAX-OOP approach of IJV cannulation on 120 neonates and infants undergoing major surgeries and in the critical care unit.[12] To guide the puncture needle in the MSA-OOP approach, a radiopaque wire was put at the probe's midpoint. They observed that the success rate of IJV cannulation on the first attempt was higher in the MSA-OOP group than in the SA-OOP group, at 83.1% versus 49.2%. Our study had a first attempt success rate of 90.91% for APSAX-IP and 85.19% for the SAX-OOP approach.

Even when using US guidance, it is possible to puncture the carotid artery while performing an IJV cannulation which can result in significant consequences. Previous studies found 0.5%1.5% carotid punctures using the SAX view.[2,5] In the present study, the IJV and the carotid artery were easily visible in a single picture using the APSAX-IP technique. In addition, the needle was advanced IP, which prevented any puncture to the carotid artery. We had no other complications (pneumothorax, posterior vascular wall puncture, or catheter misplacements) in either group.

Limitations

Our study has certain limitations. The research was conducted in a single center. With the APSAX-IP approach, needle alignment with the US beam could be difficult for inexperienced operators. We did not compare the APSAX-IP approach with other techniques of IJV cannulation apart from SAX-OOP. We only looked at significant complications such as artery puncture and pneumothorax, not milder ones such as insertion-site hematomas. The study is only powered for access time and underpowered for the success rate of IJV cannulation. More studies with larger sample sizes and comparisons with alternative techniques of US-guided IJV cannulation are needed in the future.

Conclusions

We conclude that the US -guided APSAX-IP IJV cannulation approach has a similar access time compared to the SAX-OOP technique. Because the probe is positioned on the lateral portion of the neck in the APSAX-IP approach, it may help to overcome space limits in individuals with short necks.

Author contributions

KOB: Data curation; writing original draft (equal); AS: Conceptualization (lead); writing original draft (equal), review and editing (equal).SG: data curation, review, and editing (equal). NK: review and editing (equal) KK: data curation, review, and editing (equal). ADG: formal analysis. PS: review and editing (equal). PB: supervision.

Conflicts of interest

None Declared.

Ethical approval

Institutional Ethics Committee of All India Institute of Medical Sciences (AIIMS), Jodhpur, India with letter no. AIIMS/IEC/2020/3173 dated September 23, 2020.

Consent to participate

Patients consent has been obtained for this study.

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