Original Article

# Ultrasound guided internal jugular vein cannulation in infants: Comparative evaluation of novel modified short axis out of plane approach with conventional short axis out of plane approach

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## ABSTRACT

**Background and Aims:** Central venous cannulation (CVC) through right internal jugular vein (IJV) route is routinely performed in paediatric patients undergoing major surgery and in those admitted to intensive care units. A novel technique (modified short-axis out-of-plane [MSA-OOP]) to improve first pass success rate of ultrasound-guided IJV CVC in neonates and infants is being compared with conventional SA-OOP method. **Methods:** A total of 120 patients were enroled in the study over a period of 6 months. All paediatric patients with age <1 year and weight <10 kg who underwent a major surgery requiring CVC were included. Patients were randomised to either of the two approaches of ultrasound-guided IJV cannulation; SA-OOP and modified SA-OOP (MSA-OOP). In modified approach, the midline of probe footprint was marked with a radio-opaque barium wire that casted a central acoustic shadow on ultrasound screen. **Results:** In MSA-OOP group, 83.1% of patients were cannulated in the first attempt as compared to 49.2% patients in group SA-OOP. Patients in MSA-OOP group required significantly fewer attempts for successful CVC as compared to patients in the SA-OOP group ( MSA-OOP: median = 1, interquartile range [1-1]; SAOOP: median = 2, interquartile range [1-2], $P < 0.001$, Mann–Whitney U-test). **Conclusion:** The use of MSA-OOP ultrasound technique for IJV CVC cannulation results in a higher first-attempt success rate and reduces the number of cannulation attempts.

**Key words:** Central venous cannulation, ultrasound guided vascular access, neonates and infants

## INTRODUCTION

As compared to adults, central venous cannulation (CVC) in neonates and infants is technically demanding. Difficulty in neonates and infants as compared to adults is because of relatively shorter neck, large head, smaller calibre of vein, greater anatomic variability and closer proximity of vein to the skin.[1] These factors lead to difficulty in positioning, stabilisation of needle and ultrasound probe on the neck. Beginners in paediatric CVC find it difficult even though they may be experienced for adult CVC. The incidence of carotid artery (CA) puncture is higher in children younger than 5 years than in older children during this procedure.[2]

Ultrasound guidance has increased success rate of CVC in all the age groups, but various techniques are still evolving. Common approaches for ultrasound-guided internal jugular vein (IJV) cannulation described in literature are short-axis out-of-plane (SA-OOP),



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long-axis in-plane (LA-IP) and lateral short axis in plane.

A modified short-axis out-of-plane (MSA-OOP) approach for ultrasonography (USG)-guided radial artery cannulation was recently described, to improve the success rate of radial arterial cannulation under ultrasound guidance.[3] A suture is tied on middle of ultrasound probe that produces a visible mark on ultrasound image and acts as a guide to approaching needle for vascular cannulation.

We hypothesise that this ultrasound-guided MSA-OOP approach will improve success rate of IJV cannulation in neonates and infants in terms of reduction of number of attempts, cannulation time and complications.

The primary objective of our study was to compare the first attempt success rate of SA-OOP approach with MSA-OOP approach for IJV CVC. The secondary objective was to compare the cannulation time, cannulation attempts and complications that occurred with the two approaches.

## METHODS

This study was an open-label, randomised, parallel arm study with two treatment groups. A total of 120 patients were enrolled in the study after approval from Institutional Ethical Committee and written informed consent from parents. Children weighing <10 kg and age <1 year were included in the study.

The American Society of Anesthesiologists (ASA) status of all the patients was Grade II/III. All patients were kept nil per oral, as per standard guidelines and their hydration status was maintained with continuous intravenous hydration with Isolyte-P™. An opioid-based general anaesthetic technique was used for induction and maintenance. All patients received positive pressure ventilation during CVC.

The study was conducted in a tertiary care teaching hospital. Using a sealed envelope method, patients were randomised to one of the two methods (allocation ratio 1:1) of IJV cannulation; SA-OOP or MSA-OOP.

In the Short-axis out-of-plane method, the probe was kept perpendicular to the IJV axis visualising IJV and other neighbouring structures in cross section.

In the Modified short-axis out-of-plane method, the midline of probe footprint was marked with a radiopaque barium wire used in gauze pieces thereby casting a central acoustic shadow on ultrasound machine screen [Figures 1a and 2a]. The external mark on the ultrasound probe, acoustic shadow of barium thread and the centre of IJV were aligned [Figure 2b], and cannulation needle was inserted in the same plane.

Anaesthesiologists with >5 years of post-MD experience who were experienced in ultrasound-guided paediatric CVC performed the procedures in both groups. All imaging were done with Sonosite MicroMaxx® portable ultrasound machine (Sonosite Inc., Bothell, WA, USA) using a linear array transducer (8–13 Hz) with 25 mm footprint. Our proposed modification technique is based on the fact that the barium thread does not allow passage of ultrasound waves through it, causing acoustic impedance and thus casting an acoustic shadow on the ultrasound machine screen. This thread guides the operator to mark needle puncture point on skin at the externally visible barium thread, its acoustic shadow on ultrasound screen and IJV are aligned [Figure 2b].

All infants were anaesthetised with a standard general anaesthetic technique, and the airway was secured by tracheal intubation before positioning them for CVC. For ergonomics, the USG machine was placed on right side of operating table in front of anaesthesiologist performing scan who stood at the head end of the infant [Figure 3]. A rolled cotton sheet was placed under infant's shoulder to extend the neck. A pre-procedure USG scan was performed in every case to assess size and patency of right IJV and its relation with neighbouring structures. The procedure was performed with all aseptic precautions. For sterile preparation of ultrasound probe, it was covered with

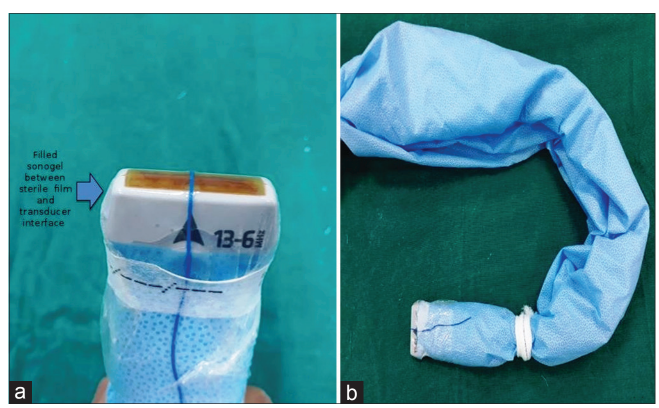


**Figure 1:** (a) High frequency linear transducer of 25 mm footprint with barium wires in centre of probe covered with sonogel and sterile film. (b) Preparation of linear ultrasound probe by wrapping with sterile drape before attempting central venous cannulation

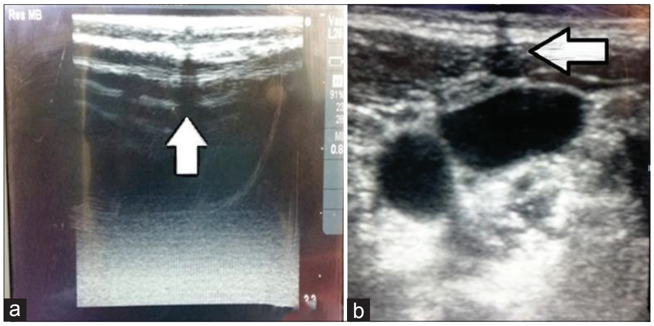


**Figure 2:** (a) Acoustic shadow of barium wire on ultrasound screen, pointed by arrow head. (b) Alignment of acoustic shadow of barium wire and right internal jugular vein just below it in the centre of screen

a sterile disposable sheath and footprint of probe was smeared with sterile sonogel and then covered with sterile plastic film (Tegaderm™) [Figure 1b]. Sector depth on the ultrasound machine screen was adjusted in such a manner so that IJV lay in centre of the screen, and it varied from 1.5 cm to 2.2 cm. After the vessels were identified, the central mark of the probe was placed over the centre of the IJV. The CA and the IJV were differentiated by their shape, size, relative position, pulsatility, compressibility of the vein and increase in calibre of the vein by Trendelenburg position. The skin puncture was then made at the level of barium thread (centre of probe), which was centrally aligned with the IJV. As soon as blood was aspirated through the needle, the probe was placed on the sterile field and the needle was stabilised with the operator's left hand.

Cannulation was performed using the Seldinger technique. A 21-gauge, 4-cm - long needle and a 4.5-French (18 gauge), 8-cm, triple-lumen catheter (B-Braun®) were used in all the study cases.

Cannulation time for successful attempt was defined as the time from the entry of needle tip in the skin to the aspiration of blood from the jugular vein through the distal port of the catheter. The number of attempts was recorded. An attempt was defined as the number of needle entries in the skin.

Sample size was calculated to be 58 in each group at 80% power of the study and 0.05 level of significance ($\alpha$) using two-tailed Chi-square test. This was done to detect an absolute difference of 20% for successful cannulation in the first attempt between the two groups when proportion of first attempt success rate was 90% in Group I (MSA-OOP) and 70% in Group II (SA-OOP). Power analysis and sample size version 8 (2008) was used for sample size estimation.

**Figure 3:** Position of ultrasound machine and operator during procedure

To compare the number of attempts between the groups, Mann–Whitney U-test was used. Chi-square test/Fisher's exact test was used to compare the number of successful CVC in first attempt between the two groups. To compare the mean value of cannulation time for the successful attempt between modified short axis out of plane group and short axis out of plane group independent samples *t*-test was used. $P < 0.05$ (two-sided) was considered as statistically significant. Statistical Package for Social Sciences Version 23 (23, IBM, Chicago, USA) was used for analysing the data.

## RESULTS

A total of 120 patients were enroled in this study. Two patients were excluded from the study, one of which had thrombus in vein and the other had an aberrant anatomy of IJV, on pre-procedure scan. Finally, data of 59 patients in each group were analysed. Children requiring CVC were undergoing following surgeries; ventricular septal defect repair ($n$ = 14), patent duct arteriosus closure ($n$ = 6), Kasai operation for biliary atresia ($n$ = 22), choledochal cyst excision ($n$ = 18), correction of anorectal malformation ($n$ = 10), Wilms tumour excision ($n$ = 12), congenital diaphragmatic hernia repair ($n$ = 6), hepatoblastoma ($n$ = 2), neuroblastoma ($n$ = 5), brain tumour ($n$ = 16) and germ cell tumour excision ($n$ = 9).

All patients were successfully cannulated in our study. Groups were comparable in terms of age, weight and ASA status [Table 1]. In MSA-OOP group, 10 patients (16.9%) required >1 attempt whereas 30 patients (50.8%) in SA-OOP group required >1 attempt and their cannulation details are shown in Table 2.

Cannulation time for the successful attempt in the two groups was comparable (Group MSA-OOP, 3.35 ± 1.59 min; Group SA-OOP, 3.95 ± 1.65 min, $P > 0.05$). Patients in MSA-OOP group required significantly fewer attempts for successful CVC as compared to patients on SA-OOP group (MSA-OOP: median = 1, interquartile range (1-1); SAOOP: median = 2, interquartile range (1-2), $P < 0.001$, Mann–Whitney U-test). In MSA-OOP group, 83.1% of patients were cannulated in the first attempt as compared to 49.2% patients in group SA-OOP and this difference was statistically significant [Table 3].

One (1.69%) patient in MSA-OOP group and 2 (3.38%) patients in SA-OOP group had CA puncture, and the difference was not statistically significant. One (1.69%) patient in MSA-OOP group and 3 (5.08%) patients in SA-OOP group had hematoma formation at puncture site and the difference was not statistically significant. More serious complications such as pneumothorax or haemothorax were not observed in any of the patients in both groups [Table 3].

**Table 1: Demographic data**

| Demographic variable | Mean±SD | | *P* |
|---|---|---|---|
| | Group MSA-OOP (*n*=59) | Group SA-OOP (*n*=59) | |
| Age (months) | 4.19±2.44 | 3.46±1.745 | 0.065 |
| Weight (kg) | 5.03±1.32 | 5.41±1.39 | 0.660 |

MSA-OOP – Modified short-axis out-of-plane method; SA-OOP – Standard short-axis out-of-plane method; SD – Standard deviation

**Table 2: Data of patients who required more than one attempt for central venous cannulation**

| Cannulation data | Group I (MSA-OOP) | Group II (SA-OOP) | *P* |
|---|---|---|---|
| Total number of patients | 59 | 59 | - |
| Number of patients requiring >1 attempt | 10 (16.9%) | 30 (50.8%) | <0.001 |
| Cannulation in second attempt (number of patients) | 6 (10.2%) | 16 (27.1%) | 0.018 |
| Cannulation in >2 attempts (number of patients) | 3 (5.1%) | 11 (18.6%) | 0.023 |
| Cannulation after change of site (number of patients) | 1 (1.7%) | 3 (5.1%) | 0.619 |

MSA-OOP – Modified short-axis out-of-plane method; SA-OOP – Standard short-axis out-of-plane method

## DISCUSSION

In our study we found that with the MSA-OOP approach, the first attempt success rate for IJV cannulation in neonates and infants was over 83%, compared to 49% in the conventional SA-OOP approach. In addition, fewer attempts at successful cannulation were required in the MSA-OOP approach.

Introduction of ultrasound for CVC in 1977 has led to marked reduction in the number of attempts, complication rate associated with CVC and there is an increase in the number of modifications in the approach to ultrasound-guided CVC.[4-7] Failure rates for CVC placement in children range from 5% to 19% with reported complication rates from 2.5% to 22%.[8] A meta-analysis by Hind *et al*. reported that the use of two-dimensional ultrasound guidance was associated with increased success of cannulation of IJV and subclavian vein.[9] Literature has conclusively demonstrated usefulness of ultrasound for CVC in adults. However, in children, the data are limited and have shown mixed results.[10,11] Bruzoni *et al*. demonstrated 53.5% success rate of CVC using landmark technique and >98% success rate using USG-guided CVC.[12]

SA-OOP method is preferred in infants because a number of difficulties are encountered using LA-IP technique in them, which are primarily because of short neck and superficial site of IJV. The short neck in infants leaves little space for needle insertion after placing ultrasound probe in long axis over IJV, even after using 25 mm footprint linear probes, (in contrast to 38 mm linear footprint probes used in adults). It is also difficult to insert the puncture needle at an optimum angle because the needle hub abuts the lower margin of the mandible in the long axis approach, due to the short neck of the infant. Superficial position of IJV in infants renders entire the length of IJV compressible, resulting in difficulty in visualising vessel with this technique. All these factors make SA-OOP approach the preferred

**Table 3: Comparative Performance of both methods for ultrasound-guided central venous cannulation**

| Cannulation data | MSA-OOP group | SA-OOP group | *P* |
|---|---|---|---|
| Total cannulation time in minutes (mean±SD) | 3.35±1.59 | 3.95±1.65 | 0.280 |
| Total number of attempts: median (inter quartile range), minimum-maximum) | 1 (1-1) ,1-3 | 2 (1-2),1-4 | <0.001 |
| Number of successful CVC in first attempt (%) | 49 (83.1) | 29 (49.2) | <0.001 |
| Number of patients with carotid artery puncture (%) | 1 (1.69) | 2 (3.38) | 0.342 |
| Number of patients with haematoma formation at puncture site (%) | 1 (1.69) | 3 (5.08) | 0.309 |

CVC – Central venous cannulation; MSA-OOP – Modified short-axis out-of-plane method; SA-OOP – Standard short-axis out-of-plane method; SD – Standard deviation technique in this specific population. SA-OOP approach by rendering a transverse view provides side-by-side visualisation of neighbouring structures like common CA, which is characteristically variable in its position in infants, and its puncture carries risk of ominous implications. However, the disadvantage is that unlike LA-IP only the tip of the needle is visible in SA-OOP approach. This disadvantage can be minimised by following the tip of needle from the point of entry into the skin. Puncture of the posterior wall of the IJV was prevented as the tip of the needle was followed under ultrasound guidance from the point it punctured the skin, till the tip was shown indenting the anterior wall of the IJV before it entered the lumen; at this point further advancement of the needle was stopped.

With USG-guided cannulation, alignment of the probe should focus vessel in the centre of the ultrasound screen. In SA-OOP, the position of the needle should be such that at the time of cannulation, needle and vessel should lie in the centre of the ultrasound screen. In the authors' experience, this is the main factor that imposes subjectivity in this technique and operator's experience becomes deciding factor for success of the procedure. The MSA-OOP technique has proved useful in reducing this subjectivity by aligning centre of probe with centre of vein with the help of acoustic shadow casted by radiopaque wire fixed on probe. Anaesthesiologists performing CVC found it easy to align centre of probe with centre of IJV lumen with the MSA-OOP technique, which resulted in higher successful cannulation in the first attempt.

In our study, successful cannulation could be performed in all patients in both groups although more attempts and change of site were required in the SA-OOP group. In our study, 56 patients (94.9%) could be cannulated without changing the site in the SA-OOP group, which is comparable with the success rate quoted in literature earlier,[12] though more patients (50.8%) in the SA-OOP group required > one attempt for successful CVC. In MSA-OOP group, 58 patients (98.3%) could be cannulated without changing the site and only 15.2% patients required more than one attempt before changing the site. Major improvement in MSA-OOP technique was that significantly higher number of patients could be cannulated in first attempt itself. We measured cannulation time of the successful attempt of CVC; however, total cannulation time for multiple unsuccessful attempts was not measured because if number of attempts are more in a patient; logically, it will increase total duration of the procedure for CVC.

Another subjective feeling opined by the operators performing cannulation was that the probe with wire had better stability over children's neck, therefore was convenient to use. It could have been because of friction produced by wire over the linear probe.

The developing line technique results in a better correlation between the midline skin puncture and IJV cannulation in the centre of the ultrasound screen. MSA-OOP approach could be especially useful for beginners performing ultrasound-guided IJV cannulation in infants and neonates.

The MSA-OOP reduces the ultrasound co-ordination time and time till guide wire insertion but does not have any effect on overall cannulation time, as cannulation includes the additional task of catheter insertion over guide wire.

The depth of IJV from skin and its width in short axis view was not measured and could be one of the limitations of our study. This factor could well be incorporated in future studies to find out association between IJV depth from skin and width of vein with that of success rate of cannulation.

One disadvantage of the MSA-OOP technique was that every time a barium thread had to be inserted in the centre of the probe, which increased the preparation time of the ultrasound probe for cannulation.

## CONCLUSION

The modified short axis out-of-plane approach using a radio-opaque barium wire on ultrasound transducer for casting an acoustic shadow in middle of ultrasound screen lead to increased first attempt success rate of internal jugular venous cannulation in infants.

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Nil.

### Conflicts of interest

There are no conflicts of interest.

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