Ultrasound-guided internal jugular catheterisation in paediatric cardiac surgical patients: a prospective observational study

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Background
Obtaining central venous access in paediatric patients is challenging and failure rates range from 5 to 19%. Ultrasound guidance has been newly introduced to our resource-limited set-up, and our aim was to evaluate the success rate during internal jugular catheterization in paediatric cardiac surgical patients.
Patients and methods
Over a period of 6 months, 106 consecutive paediatric patients scheduled for cardiac surgery requiring cannulation of the right internal jugular vein were enrolled in the study. The outcome measure was to find out the correlating factors for the number of attempts required and the rate of complications along with the success rate and time taken for successful cannulation.
Results
The overall success rate was 100% with a rate of successful catheterization in the first attempt being 76.41% [95% confidence interval (95% CI): 68.33–84.49]; second attempt was required in 16.98% (95% CI: 9.83–24.13) and the third attempt in 5.66% (95% CI: 1.26–10.06). The mean number of attempts for successful cannulation was 1.29±0.59. The mean time from skin prick to blood aspiration after successful cannulation was 134.06±81.59 s. The overall complication was 10.4% (95% CI: 4.59–16.21) among which arterial puncture and haematoma formation was seen in all 11 cases; pneumothorax and haemothorax were seen in one (0.9%) of those patients The number of attempts required showed weak negative correlation with age, height, body weight, body surface area and cross-sectional area.
Conclusion
Ultrasound guidance for central venous cannulation in paediatric patients has acceptable success rates. Arterial puncture with haematoma formation is the most common complication. The overall complication rate is directly related to the number of pricks.

Keywords:
cannulation, central, technique, ultrasound

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Background

Paediatric patients require central venous cannulation (CVC) for the delivery of medications, blood products and parenteral nutrition. It is also used for renal replacement therapy and is routinely indicated for haemodynamic monitoring during cardiac surgical procedures and in the intensive care unit [1]. It might be challenging to put a catheter in the central vein in paediatric patients. The reported failure rate is up to 19% and complication rate ranges from 2.5 to 22% [2]. Various complications have been reported in the literature [3,4].

There have been several reports which show that two-dimensional ultrasound guidance reduces the time required for catheterization. It also improves the success rate and has shown to decrease the complication rates [3–5]. Ultrasound guidance is a well-established and preferred method and the National Institute for Clinical Excellence had recommended the use of ultrasound for CVC in paediatric patients back in 2002 [6].

However, reports of ultrasound-guided CVC from the resource-constrained set-up are limited especially in paediatric patients. The currently available data is still insufficient to support the regular use of ultrasound for CVC. Moreover, the use of ultrasound for vascular access in a resource-limited set-up might be hindered by the popular belief that the success rate with ultrasonography (USG) does not change much. So, funding for an ultrasound machine would not be available without a justification. Fortunately, we

were able to acquire a machine and were able to design the study. The aim of our study was to find out the correlating factors for successful cannulation and the incidence of complications along with success rate, number of attempts and access time in paediatric population using ultrasound as guidance during CVC after we just started using ultrasound at a heart centre.

Patients and methods

After clearance from the institutional review board, informed written consent was taken from the patients' guardians. Clinical trial registration was done (ClinicalTrials.gov identifier: NCT02687126; registration date: 15 January 2016; clinical trial registration URL: https://clinicaltrials.gov/ct2/show/NCT02687126) and S.S. Parajuli was the principal investigator.

This was a prospective observational study performed at an operation theatre of a heart centre. All consecutive paediatric patients aged up to 16 years scheduled for cardiac surgery requiring CVC of the right internal jugular vein (IJV) during the 6 months period from February 2016 to July 2016 were enrolled into the study. The exclusion criteria included patients' guardian's refusal, previous catheter placement, bleeding disorders, clotting abnormalities (platelets $<75\,000$, international normalised ratio >2), a local site of infection and underlying pneumothorax, pleural effusion or preoperative insertion of a chest tube.

The patient's age, weight, height and body surface area were recorded. In the operation room, intravenous access was made with appropriately sized intravenous canula and multimodality monitors were attached which included ECG, noninvasive blood pressure or invasive blood pressure, and pulse oximeter. The standard technique of general anaesthesia was used and the patient was kept on mechanical ventilation. Initial ultrasound scan of the chest was done to identify the baseline status of pleural effusion and possible pneumothorax. Patients were painted and draped. The baseline pulse rate and mean arterial blood pressure were noted. An ultrasound scanner with a cordless linear vascular probe (Siemens Medical, Acuson, Chicago, USA) was used. On linear probe of the ultrasound, the ultrasonic gel was applied which was then covered with a sterile transparent sheath or sterile glove and was fixed with sterile rubber bands. The patient was positioned in the supine and the head turned to the other side. The depth in the ultrasound machine was adjusted to 1.5–6 cm to optimise the view of the vessel. The view of the IJV was adjusted in with out-of-plane technique to guide needle insertion. The transducer was placed perpendicular to the vessel at the apex of the triangle formed by the two heads of the sternocleidomastoid muscle and clavicle. The IJV was identified as an oval thin-walled hypoechoic compressible structure lying lateral and superficial to a noncompressible, pulsating carotid artery. The IJV picture was centred in the acoustic window as indicated by the marker on the display screen. The cross-sectional area of the vein was calculated by using the area measurement tool of the USG machine. An introducer needle with an attached syringe was inserted under the probe at an angle of 45°. The movement of the needle tip was continuously followed and the changes in the shape of the vein were carefully observed. The tip of the needle lying intravascularly was visualised clearly on the image and the free flow of blood upon aspiration was taken as confirmation of the correct position of the needle. The guidewire was then passed and the catheter was railroaded over it after dilatation of the tissue plane.

The time to successful completion of cannulation in the study was the time from the skin puncture to blood aspiration through the catheter immediately following the guidewire removal. An attempt was considered unsuccessful if complete withdrawal of the puncturing needle out of the skin surface was required. The procedure was regarded as a failure if the operator was unable to cannulate the vein in three attempts.

Haemodynamic variables, i.e. heart rate, mean arterial blood pressure and changes in ECG rhythms were recorded after correct placement. Local site haematoma and carotid artery puncture, if present, were noted. Pneumothorax and haemothorax, if present, were confirmed by USG after completion of the procedure. Pneumothorax was defined as loss of lung sliding over the midclavicular line at the highest point of ipsilateral haemithorax in supine position. Haemothorax was defined as an anechoic space between the visceral and parietal pleura at the level of posterior axillary line with the patient in supine position. This space may change in shape with respiration. Haemothorax, if present, on USG was confirmed by direct visualisation of any blood collection in the thoracic cavity after the sternotomy/thoracotomy was done in the patients. The complications were managed by placing a chest tube (which is a regular practice in the cardiac surgery patients) and by other medical interventions as per the hospital protocol.

Collected data was analysed by means of statistical software SPSS-16 (SPSS Inc., Chicago, Illinois, USA). Descriptive statistics were expressed in numbers, percentages and their 95% confidence intervals (95% CI). Bivariate correlations were obtained for all the variables. We used Pearson's correlation coefficient (*r*) for the analyses between all linearly related variables to determine the significance and strength of associations.

Results

Altogether 106 patients who met the criteria for study in the 6-month period were enrolled into the study. The demographic data of patients studied is shown in Table 1. The mean number of attempts for successful cannulation was 1.29±0.59. The mean time from skin prick to blood aspiration after successful cannulation was 134.06±81.59 s. The overall success rate was 100% with a rate of successful catheterisation for the first attempt was 76.41% (95% CI: 68.33–84.49), and a second attempt was required in 16.98% (95% CI: 9.83–24.13) and a third attempt was required in 5.66% (95% CI: 1.26–10.06). The overall complication was 10.4% (11 out of 106 cases, 95% CI: 4.59–16.21) among which arterial puncture and haematoma formation were seen in 10.4% (11 out of 106 cases, 95% CI: 4.59–16.21) and pneumothorax and haemothorax were seen in 0.9% (one out of 106 cases, 95% CI: -0.9–2.7) as shown in Table 2.

The primary outcome of this study number of attempts showed weak negative correlation with age, height, body weight, body surface area and cross-sectional area. However, it had a strong positive correlation with duration from a skin puncture to blood aspiration as shown in Table 3.

Discussion

Central venous catheterisation is a routine procedure to be done in patients undergoing cardiac surgery. There are several techniques of CVC. In this study, USG-guided apical IJV approach was used after the introduction of ultrasound in our resource-limited setting. Successful cannulation with minimisation of the inadvertent side effects is a challenge, especially in the paediatric population.

In our study, the median age was 60 months (range: 1.5–196 months), the median weight was 15 kg (range: 3–54 kg) and the median cross-sectional area of IJV was 0.775 cm^2 (range: 0.12–2.01 cm^2). By the use of USG, we could successfully cannulate all of the vessels within three attempts despite their smaller age, body weight and cross-sectional area.

In our study, the number of attempts showed a strong positive correlation with duration from skin puncture to blood aspiration and our mean number of attempts for successful cannulation was 1.29±0.59. As the number of attempts increased the duration for successful cannulation also increased and so did the overall complication rate. The overall success rate was 100%. The rate of successful catheterisation for the first attempt was 76.41% (95% CI: 68.33–84.49), a second attempt was required in 16.98% (95% CI: 9.83–24.13) and a third attempt was required in 5.66% (95% CI: 1.26–10.06). Similar results were seen in the study done by Asheim *et al.* [7]. They studied the success rate of ultrasound-guided IJV cannulation in 42 infants. They found that they could puncture the IJV on the first attempt in 40 patients. Similarly, Chuan *et al.* [8] have compared landmark and ultrasound prelocation technique in 62 infants with a body weight of less than 12 kg. They found that the median numbers of attempts for successful cannulation

Table 1 Demographic variables

Variables	Median (range)
Sex (male : female)	41 : 65
Age (months)	60 (1.5–196)
Weight (kg)	15 (3–54)
Height (cm)	102 (51–163)
BSA (m^2)	0.655 (0.22–1.52)
IJV cross-sectional area (cm^2)	0.775 (0.12–2.01)

BSA, bovine serum albumin; IJV, internal jugular vein.

Table 2 Outcome variables

Variables	*n* (95% CI)
Number of attempts (mean±SD)	1.29±0.59
Time to successful cannulation (mean±SD) (s)	134.06±81.59
Arterial puncture	11 (4.59–16.21)
Haemothorax	1 (–0.9–2.7)
Haematoma	11 (4.59–16.21)
Pneumothorax	1 (–0.9–2.7)
Overall complications	11 (4.59–16.21)

CI, confidence interval.

Table 3 Pearson's correlations of variables against the number of attempts

Variables	Number of attempts	*P* value
Age	–0.152	0.120
Height	–0.144	0.140
Body weight	–0.119	0.226
Body surface area	–0.140	0.152
Cross-sectional area	–0.192	0.049
Duration from skin puncture to blood aspiration	0.792	0.000

was one in the ultrasound group and two in the landmark group.

In our study, the mean time in seconds from skin prick to blood aspiration after successful cannulation was 134.06 ±81.59. Our findings were similar to the study done by Verghese *et al*. [9] where they have shown that the time for successful cannulation in infants and children using the USG technique was 3.3 min compared with the landmark technique of 10 min. The visualisation of the location of the vein by the use of USG might have reduced the overall time for successful cannulation.In our study, the number of attempts showed a weak negative correlation with age, height, body weight, body surface area and cross-sectional area. In another study done by Hayashi *et al*. [10], catheterisation time increased when the age and weight of the child were less. They also found that central venous pressure did not influence the rate of successful cannulation and the time taken for central venous catheterisation. Hence when the age, body surface area or cross-sectional area is small successful cannulation attempts will increase and so does the time.

Various studies have shown that an increase in the number of attempts increased the overall complications rate. McGee and Gould [11] have studied the complications with respect to the number of attempts. They found that the increase in the number of attempts from one to three had increased the mechanical complication rate by six times. In our study, the overall complication was 10.4% (11 out of 106 cases) among which arterial puncture and haematoma formation were seen in 10.4% (11 out of 106 cases) and pneumothorax and haemothorax were seen in 0.9% (one out of 106 cases) which had moderate negative correlation with the number of attempts.

The main limitation of the study was its observational nature. A comparison with traditional landmark technique would have been more informative; still, in view of the paucity of results on the use of ultrasound guidance for CVC in paediatric patients, especially from the developing world, with a relatively large sample gives our study its strength.

Conclusion

Our study has shown that the use of ultrasound-guided CVC in paediatric patients has an acceptable success rate and was less time consuming compared with published reports on the traditional technique. Arterial puncture with haematoma formation is the most common complication. The overall complication rate is directly related to the number of pricks. We suggest that this method should be preferred in paediatric cardiac surgical patients to have a better success rate with decreased overall complication rate and the use of ultrasound should not be decided by resources.

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S.S. Parajuli and A. Sharma designed the study, took part in acquisition, analysis and interpretation of data, created the initial draft of the manuscript and made critical revisions.

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Conflicts of interest

There are no conflicts of interest.

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