Comparative study of ultrasound guided subclavian venous cannulation versus conventional technique: Advantages and disadvantages

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Abstract
Background: Procedures involving pediatric group is always challenging. Our aim is to compare conventional anatomical landmark technique versus the ultrasound-guided technique for Subclavian vein (SCV) cannulation in pediatric cardiac surgical patients.
Material & Methods: 100 patients between 2-12 years who required Subclavian vein (SCV) cannulation received catheter insertion either by conventional [n=50] or by ultrasound-guided technique [n=50] in cardiac surgeries. We observed time taken for preparation for the procedure, failed catheter placement, risk of complications, number of attempts and time to successful catheterization and infection rate, cost, incidence of venous thrombosis by ultrasound on removal of catheter in both the group were observed.
Observation & Results: The overall complication rate was higher in conventional group than in the ultrasound-guided group. The number of attempts for successful placement was significantly higher in conventional group, which was accompanied by an increased access time. Infection rate was even slightly more in conventional group. Although there were a higher number of attempts, longer access time, and a more frequent complication rate in conventional group, the success rate was found to be comparable between both the two groups. In conventional group 1 patient was found with thrombosis in the vein after removal of catheter, which may be due to multiple punctures in the vein.
Conclusion: Ultrasound guidance improved the success rate in terms of reducing morbidity of central line cannulation in Cardiac patients. Our study indicates that ultrasound guided Subclavian vein cannulation requires less time and lower rate of immediate complications.
Keywords: ultrasound, Subclavian vein cannulation, cardiac surgery

1. Introduction

Paediatric cardiac surgical patients need safe intravenous access for hemodynamic monitoring, drug infusion, parenteral nutrition, post operative difficult peripheral venous access, blood withdrawal for lab investigations for post operative period, blood product transfusion. Internal Jugular vein insertion caused discomfort and pain to patients while femoral venous cannulation causes increased chances of infections. So, it is necessary to have safe alternative which is easy to maintain for pediatric groups. Subclavian vein cannulation has certain advantages like consistent anatomical landmark and vein location with more patient comfort.

Different types of procedural complications occur more frequently through the subclavian vein (SCV) route if
compared with the internal jugular vein (IJV) and to the femoral vein routes\textsuperscript{1,2} and incidence of pneumothorax is higher in Subclavian venous cannulation. To make venous access through Subclavian route more safer ultrasound guided technique was adopted. Ultrasound (US)-guidance technique is becoming the gold standard for Subclavian vein catheterization because it can increase the success rate and decrease the complications related to central venous catheter (CVC) placement.\textsuperscript{1,2} In the literature, the routinely practices technique for SCV catheterization in children is associated with an incidence of arterial puncture and pneumothorax of up to 14\% and 6\%, respectively.\textsuperscript{3,4} Moreover, young age decreases success rate and increases complication rate.\textsuperscript{5,6} When using US scanning for IJV (Internal Jugular Vein) cannulation, we found that the SCV can be easily visualized in the infraclavicular and supraclavicular area. We therefore decided to perform a pilot study to evaluate a new approach for US-guided SCV catheterization.

Ultrasound assisted location of the vein has been reported to have no effect on the rate of complications or failures of SCV catheterization in previous reports. In the past ultrasound technique of ‘mark and go’ which was not real time ultrasound was used for subclavian vein cannulation.\textsuperscript{5,6}

In this study we have shared our experience of real time ultrasound guided SCV cannulation and their comparison with gold standard conventional-landmark technique in 50 pediatric patients between 2-12 years posted for cardiac surgery.

2. Material & Methods

In this prospective randomized study, after approval from ethical committee and informed consent from patient’s parents, total of 100 patients who required Subclavian vein cannulation were randomly assigned to receive Subclavian vein (SCV) cannulation with antimicrobial impregnated catheter using either Landmark technique \([n=50]\) or ultrasound-guided technique \([n=50]\) in Pediatric Cardiac Surgery patients posted for last 4 years. Right Subclavian preferred as it has lower chance of damaging thoracic duct then left subclavian vein cannulation.

2.1 Inclusion Criteria

1. Paediatric patients posted for cardiac surgery, with informed written consent from their parents.
2. Patients who are under anaesthesia.
3. Patients who need central venous catheter for longer duration.

2.2 Exclusion Criteria

1. Urgency of central venous cannulation if patient becomes unstable.
2. Patients who needed subclavian cannulation under local anaesthesia.
3. Patients with reported thrombosis of subclavian vein.

A normal chest radiography was used to assess the placement of the catheter’s tip after the shifting the patient to post operative ward and it is a routine post operative protocol though US guided subclavian venous cannulation does not need confirmatory X-ray. In conventional landmark method if there is any dilemma regarding venous or arterial access ,it is checked by measuring pressure waveform or blood gas measurement. Mechanical complications were defined as artery puncture, hematoma, hemothorax, pneumothorax, injury to the brachial plexus as well as to the phrenic nerve, catheter misplacement, and cardiac tamponade.

Cardiac Tamponade observed up to the opening of the pericardium Phrenic and brachial plexus injury can also happen during cardiac surgery so we have not given much importance to these two though we have included it in our study. Subclavian artery puncture was noted by forceful pulsatile expulsion of bright red blood from the needle. All mechanical complications were evaluated clinically by a chest radiograph, by means of ultrasonography and by other laboratory investigations as found appropriate. If a catheter was misplaced, the position was corrected by manipulation of the catheter under ultrasonographic guidance for patients who were in the ultrasound group or by reinsertion in the landmark group. Phrenic nerve injury was assessed by a chest radiograph and other investigative tool as described\textsuperscript{14}. Pneumothorax was treated with Intercostal Chest Drainage Tube at the end of the surgery and its impact on patient in terms of economic burden,ICU stay and morbidity if any also taken in to account. Infection rate was also compared in both the groups by Catheter tip culture method.
2.3 Conventional Technique

For the conventional technique, anaesthetized patients who were on operating tilting table placed in a Trendelenburg position with the folded sheet between the shoulder blades. Head down position given to reduce the risk of air embolism, chances of subclavian vein getting dilated by Trendelenburg position is less because of adjacent structure. The ipsilateral anterosuperior region of the chest was prepared in a sterile fashion with an appropriate disinfectant. The needle was inserted 1 cm inferior the junction of the middle and lateral thirds of the clavicle towards the supraclavicular notch under posterior surface of the clavicle (infraclavicular approach). 

Withdrawal of the dark venous, non pulsatile blood into the syringe attached to the needle considered as sure sign of entry in to the vein for the non cyanotic patients while for the cyanotic patients dark coloured non pulsatile blood considered as sign of entry in to the vein. Guide wire is inserted through the needle in to the venous system, if arrhythmia is elicited then it is a good sign of perfect placement of guidewire in the RA (withdraw the guide wire to stop arrhythmia). If arrhythmia is not elicited then there is a possibility of wire in the arterial system or going in to the internal jugular vein. Catheter was placed by catheter over guide wire technique as previously described which we call Seldinger technique. Notably, all patients underwent ultrasound scanning of the infraclavicular area to look for the presence of venous thrombosis. We had excluded such patients from the study but patients in whom cannulation was not possible with the conventional method were subsequently had the procedure performed with ultrasound on the contralateral side and was considered as failed landmark method.

2.4 Subclavian vein cannulation with ultrasound guidance technique:

Routine presurgical ultrasound scanning of supraclavicular and infraclavicular area was carried out to gauze the distance and diameter of the axillary vein and Subclavian vein and their luminal patency, any abnormality of external structures and variation in anatomy were evaluated. Subclavian vein is a non pulsatile structure with respiratory variation in size. Doppler is not much effective in locating subclavian vein as probe is perpendicular to the direction of the flow across the vein. On the longitudinal axis, supraclavicular view used sonoanatomic landmarks such as the acoustic shadows of the clavicle and the underlying first thoracic rib to select an area of interest; thereafter, maneuvers of the transducer were performed to depict the axillary vein and its continuation the SCV on the longitudinal axis and to achieve an optimum plane of cannulation. The needle was pierced in the way very slowly which makes detection of its tip and trajectory more apparent. The needle was advanced in real-time toward the lumen of the vein on the longitudinal axis, while it was purposefully directed toward the acoustic shadow of the thoracic rib underneath. This was very helpful in reducing the chances of puncturing pleura and lung. Hence, the needle entered the lumen of the vessel either at the level of the axillary vein or at the point where the latter continued medially as the Subclavian Vein. This is dependent on the angle of penetration and the depth from the skin surface that the vein is located.

Also, the course of the needle is dependent on the adjustments performed by the operator to visualize its trajectory on the longitudinal axis. Hence, the angle of penetration and the course of the needle could be modified in each individual catheterization scenario. The guide wire was advanced according to the Seldinger’s technique; thereafter, the ipsilateral IJV and the contralateral SCV were scanned to identify possible misplacements; hence, the catheter could be repositioned under ultrasound guidance. In our setup, our study was conducted in cardiac set up in non-emergent elective situation and ultrasound was performed by the skilled personnel having good eye hand reflexes had more than 5 years of experience for the same. This technique needs a sterile sheath to cover ultrasound probe (6 to 13 MHz), sterile gel for to maintain acoustic coupling and an assistant to put the probe in sterile sheath.

2.5 Statistical analysis

All data were analyzed statically using T-test and a value of P<0.05 was considered significant. The data’s were presented as Mean ± SD and percentage. The data was analyzed by the computer software named as Graphpad Prism V.6.0

3. Observation and results

A total of 100 patients were recruited for the study. There were no significant differences between the two groups in demographic data such as age, sex, site of catheterization, incidence of previous catheterization, any history of previous mechanical complications, untreated coagulopathy, skeletal deformity, any anatomical variation or any known vascular abnormality. (Table 1)
Table 1: Demographic Profile

<table>
<thead>
<tr>
<th>Demographic Characteristics</th>
<th>Ultrasound Group (N=50)</th>
<th>Landmark Group (N=50)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>5.4 ± 2.9†</td>
<td>5.1 ± 2.2*</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>18 ± 3.2</td>
<td>19 ± 2.9</td>
<td>P&gt;0.05</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>28/22</td>
<td>26/24</td>
<td>-</td>
</tr>
<tr>
<td>Site of Catheterisation (Right/Left)</td>
<td>45/5</td>
<td>46/4</td>
<td>-</td>
</tr>
<tr>
<td>Previous Catheterization</td>
<td>2 (4%)</td>
<td>2 (4%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Previous Difficult Catheterization</td>
<td>1 (1%)</td>
<td>1 (2%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Previous mechanical complications</td>
<td>0 (0%)</td>
<td>1 (2%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Known vascular abnormality</td>
<td>1 (2%)</td>
<td>1 (2%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Patients with Cynotic heart disease</td>
<td>12 (24%)</td>
<td>11 (22%)</td>
<td>p&gt;0.05</td>
</tr>
<tr>
<td>Skeletal deformity</td>
<td>1 (2%)</td>
<td>0 (0%)</td>
<td>p&gt;0.05</td>
</tr>
</tbody>
</table>

P > 0.05 – Non significant; p < 0.05 – Significant; † mean ± SD

Table 2: Outcome measures in both the groups

<table>
<thead>
<tr>
<th>Outcome Measures</th>
<th>Ultrasound Group (N=50)</th>
<th>Landmark Group (N=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access Time (seconds)*</td>
<td>23.6 ± 9.2 (15.6 – 32.7)</td>
<td>48.3 ± 23.4 (33.4 – 88.8)</td>
</tr>
<tr>
<td>Number of Attempts</td>
<td>1.13 ± 0.19</td>
<td>1.78 ± 0.29</td>
</tr>
<tr>
<td>Success rate</td>
<td>50 (100%)</td>
<td>48 (96%)</td>
</tr>
<tr>
<td>Artery Puncture</td>
<td>0 (0%)</td>
<td>4 (8%)</td>
</tr>
<tr>
<td>Hematoma</td>
<td>1 (2%)</td>
<td>5 (10%)</td>
</tr>
<tr>
<td>Haemotherax</td>
<td>0 (0%)</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>0 (0%)</td>
<td>2 (4%)</td>
</tr>
<tr>
<td>Catheter Tip – Blood culture#</td>
<td>0 (0%)</td>
<td>2 (4%)</td>
</tr>
<tr>
<td>Use of another triple lumen set</td>
<td>0 (0%)</td>
<td>3 (6%)</td>
</tr>
<tr>
<td>Discrepancy of SpO₂ in both upper limbs</td>
<td>0 (0%)</td>
<td>4 (8%)</td>
</tr>
<tr>
<td>Brachial Plexus Injury</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Phrenic nerve injury</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Venous thrombosis after removing catheter</td>
<td>0 (0%)</td>
<td>1(2%)</td>
</tr>
<tr>
<td>Cardiac temponade</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

* Access time was considered as time to locate the IJV in both the groups
# Catheter tip – blood culture was done in those patients only which shows signs of infection.

In ultrasound group all patient underwent successful catheterisation. A patient with prior catheterisation or previous difficult catheterisation was found thrombus in ultrasound. So he was cannulated with USG on opposite side. While in conventional group, 1 patient was converted into ultrasound group. That is mainly because of high echo reflective vein with with anatomical variation. This is the reason why conventional method could not be helpful.

Results using the conventional technique are in contrast to those obtained by the ultrasound method (Table 2). Success rate was significantly higher, whereas the rate of mechanical complications and the number of attempts were significantly lower in the ultrasound group as compared with the landmark group (p<0.05) (Table 2). In the landmark group, several mechanical complications were recorded. We found only 2% patient who hematoma except that no other mechanical complications were observed in ultrasound group. In conventional group, we have observed 10% of patients who developed hematoma out of which 4% who developed infection in catheter tip blood culture. Those were treated with higher antibiotics. We have also seen skeletal abnormality (bilateral cervical rib) in 2% patient of ultrasound group in which successful catheterization done in second attempt. We have also encountered kinking of guidewire in 12% patients in landmark group due to which we need to use new set of triple lumen catheter as well. We have not observed brachial plexus injury, Phrenic nerve injury or cardiac temponade in any patient of both the groups.

Expertise is needed in depicting a clear two-dimensional infraclavicular image of the SCV and performing
adjustments on the longitudinal axis to visualize the trajectory of the needle, because there is a narrower footprint of the probe compared with a transverse technique. However, we managed to depict an optimum plane to cannulate the vessel in real-time. We found out that an area of interest could be identified, on a two-dimensional image, at the level where the axillary vein continues medially as the SCV (Fig. 1). The actual point of insertion of the needle in the lumen of the vessel and thus the angle of penetration was dependent on the operator and on the anatomic diversities that were encountered in each individual patient (e.g., obese patients). The insertion of the needle in the lumen of the vessel was identified either at the level of the axillary vein (Fig. 1D) or at the point where the latter continues medially as the SCV (Fig. 2A). There were 12% patients who were grossly obese 2 in landmark group and 1 patient in ultrasound group in which we have encountered difficult catheterisation and required multiple attempts.

Access time is defined as the time period between post-painting and drapping till the localization of the vein. This time is significantly low in Ultrasound group as compared to palpation group (p <0.05). Even number of attempts require is quite a less in ultrasound group that is also significant (P <0.05). We found 100% success rate in ultrasound.

4. Discussion

We have previously studied ultrasound guided IJV cannulation in comparison with palpation method. However, ultrasound guided SCV cannulation is very demanding and has its own benefits and drawbacks. Previous studies demonstrated that mechanical complication are commonly occurred in 2-8%7,8 of patients, while infectious complication in 5-12%9, and thrombotic complications in 2-12%10,11.

We have used longitudinal approach to avoid injury to pleura or lungs and also to have better visualization of the course of the vein. There is as such no specific guideline for ultrasound approach of SCV cannulation. It depends on the choice of clinician only. The SCV is 3–4 cm long and lies posterior to the medial third of the clavicle; anterior to the anterior scalene, the brachial plexus, and the subclavian artery; and superior to the first rib12. The vein may stay patent even in hypovolema because the vessel is surrounded by connective tissue, which is attached to adjacent structures13. Serious complications can occur more commonly with SCV catheterization than with other routes due to its anatomical structure5,6.

In our study, we have 100% success rate in ultrasound group as compared to 96% in conventional group. It remains consistent with previous studies as well. Thus, this method improves the success rate and reduce the complications rate that was previously associated with IJV cannulation7,9,10. Our study also demonstrates the effectiveness of using ultrasound in SCV cannulation to reduce mechanical complications. Using the ultrasound method, we found a higher success rate and a decreased incidence of mechanical complications as compared with the landmark one (p <0.05). As Access time was significantly low in ultrasound group and also number of attempts which ultimately leads to lower rate of catheter related infection in ultrasound group. Previous studies demonstrated that more number of punctures causes increase chance of infection14. So rate of infection is quite high in conventional group. (p <0.05). All these patients were treated with higher antibiotics.

In our study, overall rate of mechanical complication is around 10% which includes hematoma formation, pneumothorax, haemothorax and venous thrombosis. Previous studies explained that length of cardiac recovery or ICU stay is significantly increased in those patients who developed mechanical complication post venous cannulation14,15. Rate of mechanical complication in ultrasound group is 0-2% which is mainly because ultrasound provides real-time images while cannulation.

One very important issue needs to be considered while puncturing for SCV cannulation is skin beneath the puncture site is in very close proximity of axillary region and thus it increases chances of injury to axillary vein or brachial plexus. Fortunately we have not encountered any such complications in our study in any of the group. When you are cannulation using ultrasound you have added benefits such as identification of surrounding structure, careful penetration by identifying tip of needle and purposeful targeting thoracic rib as the needle advances deeper to avoid injury to pleura and lung. Risk factors for the SCV cannulation such as a body mass index >30 and <20 kg/m² and two or more needle passes, which are associated with both higher complication and failure rates, are well established in the literature1.

This study has some limitations in conventional group specifically. It is mainly related to position of the patient while performing cannulation. It is the most important contributing factor especially for SCV cannulation. Success rate and access time also depends on position of the patient. As in our study, all the patients were cannulated in non-emergent cardiac OT set-up so such factors were avoided but for ICU setup and emergency cannulation it is a very important factor.

Previously established guidelines have included USG guided vascular access in top of 11 evidence based
Though it requires expertisation, it is very much helpful in cannulation SCV in pediatric patients as chances of mechanical complications are high in pediatrics.

5. Conclusion

We conclude that USG guided SCV cannulation is more beneficial and has lesser rates of complication and higher success rate with very less access time. Though it requires expertisation and the instrument required for it is quite costlier as well so it is definitely helpful but expertisation in conventional method is required as well. As in our setup we have Echo machine readily available so it does not cost any extra burden to the patients or to the institute but such places where this facility is not available SCV cannulation by conventional method is still the ideal method of choice. We still want to put emphasis on that to use USG all the time if you have availability as it has outright benefits compare to conventional method.

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References