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Özgün Araştırma / *Original Article*

Ultrasound-Guided Infraclavicular Axillary Vein Cannulation: - Is it a Good Alternative to Internal Jugular Vein Cannulation in Pediatric Cardiac Surgery?

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Ultrasonografi Kılavuzluğunda İnfraklaviküler Aksiller Ven Kanülasyonu: - Pediyatrik Kalp Cerrahisinde İnternal Juguler Vene İyi Bir Alternatif midir?

ABSTRACT

Objective: *This study was designed to compare the rates of successful first attempt and mechanical complications between internal jugular vein (IJV) and axillary vein (AXV) cannulation.*
Methods: *This prospective, randomized, comparative, controlled study included 220 pediatric patients with age range 1 to 12 years scheduled for cardiac surgery. Patients were allocated into 2 equal groups as IJV and AXV groups. The rates of successful first, second and third puncture attempts and the mechanical complications (arterial puncture, pneumothorax, catheter occlusion, catheter malposition, nerve injury) were investigated.*
Results: *There was no statistically significant difference (p=0.053) in the first skin puncture success rates in both groups (AXV group 80% and IJV group 68%). There were no significant differences regarding the second and third skin puncture success rates. The incidence rates of failed vein punctures were similar in IJV (3%) and AXV (2%) groups. The vein puncture and catheter insertion times and the rates. Arterial puncture, pneumothorax and catheter malposition were similar in IJV and AXV groups (12% vs 11%, 4% vs 1%, 3% vs 5% respectively). The rates of catheter occlusion with sternal retraction were significantly higher (p=0.029) in AXV than IJV group (6% vs 0%). Postoperative phrenic (IJV group) or brachial plexus nerve injury (AXV group) was not developed in any patient.*
Conclusion: *Ultrasound-guided cannulation of both infraclavicular AXV and IJV were similarly associated with high success rates and low incidence of mechanical complications.*

Keywords: *Axillary, vein, ultrasound, jugular, pediatric cardiac surgery*

ÖZ

Amaç: *Bu çalışma, internal juguler ven (IJV) ve aksiller ven (AXV) kanülasyonu arasındaki başarılı ilk girişim ve mekanik komplikasyon oranlarını karşılaştırmak için tasarlanmıştır.*
Yöntem: *Bu prospektif, randomize, karşılaştırmalı, kontrollü çalışma, kalp cerrahisi yapılacak olan 1-12 yaş aralığında 220 pediyatrik hastada yapıldı. Hastalar, IJV grubu ve AXV grubu olmak üzere 2 eşit gruba ayrıldı. Başarılı birinci, ikinci ve üçüncü ponksiyon girişimlerinin ve mekanik komplikasyonların (arteriyel ponksiyon, pnömotoraks, kateter tıkanması, yanlış kateter pozisyonu, sinir yaralanması) sıklığı araştırıldı.*
Bulgular: *Her iki grubun ilk girişimindeki başarı oranında istatistiksel olarak anlamlı bir fark yoktu (p=0.053) (AXV grubunda %80 ve IJV grubunda %68). İkinci ve üçüncü girişimdeki başarı oranları arasında da fark bulunmadı. IJV (%3) ve AXV (%2) gruplarının başarısız ven ponksiyonu insidansları da benzerdi (p=1.000). Yine IJV ve AXV gruplarının ven ponksiyonu ve kateter yerleştirme süreleri ile arteriyel ponksiyon, pnömotoraks ve kateter malpozisyonu oranları benzerdi (sırasıyla %12'ye karşı %11, %4'e karşı %1, %3'e karşı %5). Sternum retraksiyonu ile kateter oklüzyonu, AXV grubun'da IJV grubundan (%6'ya karşı %0) anlamlı şekilde daha yüksekti (p=0.029). Hiçbir hastada postoperatif frenik sinir (IJV grubu) veya brakiyal pleksus sinir hasarı (AXV grubu) gelişmedi.*
Sonuç: *Hem infraklaviküler AXV hem de IJV'nin ultrasonografi kılavuzluğunda kanülasyonu yüksek başarı oranı ve düşük mekanik komplikasyon insidansı ile ilişkilidir.*

Anahtar kelimeler: *Aksiller, ven, ultrasonografi, juguler, pediyatrik kalp cerrahisi*

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INTRODUCTION

Insertion of a central venous catheter (CVC) into a central vein is a routine maneuver in children submitted for cardiac surgery. However, such procedure may be technically difficult in pediatric patients, and may be associated with serious complications [1,2]. Any complication related to central venous catheter placement in children such as iatrogenic pneumothorax can be challenging. In addition, these patients will be fully anticoagulated with heparin before going on cardiopulmonary bypass, so inadvertent arterial puncture may complicate the perioperative course. Central venous catheter is most frequently inserted into internal jugular vein (IJV). Ultrasonographic (US) guidance is now used routinely for insertion of CVC into IJV [3,4].

The subclavian vein (SCV) is used as an alternative to the IJV despite of its serious complications. Localization of subclavian vein using ultrasound is difficult. Anatomically, the axillary vein becomes the subclavian vein as it crosses the lateral border of the first rib and its imaging using US is much easier than the subclavian vein. Ultrasound-guided (USG) axillary vein (AXV) cannulation has been shown to be a useful and reliable technique for insertion of the central venous catheters into the infraclavicular region and not the axilla [5].

Ultrasound-guided axillary vein cannulation has many benefits compared to subclavian vein cannulation including effective control of bleeding in case of inadvertent arterial puncture by direct external compression, lower risk of pneumothorax, hemothorax, and chylothorax as the axillary vein puncture is an extra-thoracic procedure [6].

The aim of the current study was to compare the rates of success and complications of US-guided IJV and AXV cannulation in children undergoing cardiac surgery. We hypothesized that AXV cannulation would be safer with fewer mechanical complications than IJV cannulation. The primary endpoint of this randomized study was to compare the first attempt vein puncture success rate of IJV and AXV catheterization, while the secondary endpoints were to compare the rates of mechanical complications.

MATERIAL and METHOD

This prospective, randomized, controlled, open-label study was carried out after receiving an approval letter from our local ethical committee. A written informed consent was obtained prior to surgery from the parent(s) or legal guardian(s) of the patients.

This study was conducted on 220 patients of either sex with their age ranging from 1 to 12 years submitted for on-pump elective cardiac surgery. Patients were excluded from the study in case of refusal to participate in the study, history of AXV or IJV cannulation, failed vein cannulation or occurrence of any mechanical complication during the failed trial, local infection at the site of puncture, coagulopathy or bleeding disorders, distorted anatomy of the clavicle or the neck, underlying pleural effusion or pneumothorax and 3 failed attempts of the skin puncture with the introducing needle. Patients were randomly allocated into 2 groups using computer- generated numbers and sealed opaque envelope method. The study was open label as the blindness couldn't be applicable because two different interventions were applied.

All patients were premedicated with intramuscular midazolam 0.1 mg kg^{-1}, ketamine 2 mg kg^{-1} and atropine 0.02 mg kg^{-1}, thirty minutes before induction of anesthesia to facilitate separation of the children from their guardians. The patients were monitored initially with pulse oximetry, 5-lead electrocardiography and noninvasive arterial pressure measurements. Anesthesia was induced with inhalation of sevoflurane in oxygen, a peripheral venous catheter was inserted and the patient received rocuronium 0.9 mg kg^{-1} and fentanyl 5 µg kg^{-1}, then an appropriately sized, non-cuffed endotracheal tube was inserted. Anesthesia was maintained with isoflurane 0.2% - 1.5% in 50% oxygen, rocuronium 5 µg kg^{-1} min^{-1} and fentanyl 5 µg kg^{-1} h^{-1}. An arterial catheter was inserted either into the radial or femoral artery under complete aseptic precautions. For CVC insertion the patients were randomly assigned into two equal groups as follows:

Internal jugular vein (IJV) group: The central venous catheter was inserted into the right IJV.

Axillary vein (AXV) group: The central venous catheter was inserted into the left AXV.

The patient was placed in a supine position with 15-degree head down, appropriate extension of the neck by placing a shoulder roll between the 2 scapulae, the head slightly rotated to the contralateral side and the arm abducted 45 degrees. Complete aseptic precautions were taken which included, antiseptic hand-washing, wearing sterile gown and gloves, preparation of the CVC insertion site with 2% chlorhexidine in alcohol and its isolation from its surrounding area with sterile drapes. After its lubrication with US gel, the ultrasound probe was placed inside a sterile sleeve.

Axillary and internal jugular veins were visualized by using a high-frequency linear vascular probe of ultrasonography machine (GE Vivid S5). For AXV cannulation the US probe was placed in the sagittal plane just below the middle third of the clavicle with ite probe pointing toward the patient head. The US probe was moved laterally and very slowly till visualization of the axillary vein and artery through short axis view (Figure 1 A). The vein was easily differentiated using color-Doppler US from the artery, as it was compressible, larger, not pulsating, oval while the artery was circular. The US probe was then rotated 90 degrees to get a long axis view of AXV, the introducer needle was advanced in an in-plane technique at 45 degrees to the skin under the linear probe which provided a long view to the axillary vessels till the needle tip was seen compressing the vein wall and then puncturing its wall (Figure 1 B) as was confirmed by aspiration of non-pulsating dark blood. Then the guide wire was introduced through the needle and a plastic dilator was advanced over the guide wire. Then a double or triple lumen CVC of appropriate size (4.5 or 5.5 French) was advanced to a depth of 5 to 8 cm. The final position of the catheter tip at the junction between superior vena cava and right atrium was confirmed by transesophageal echocardiography (TEE).

For IJV cannulation, we followed the same steps as in AXV but the needle was inserted in out plane manner. The linear probe was placed at the apex of the triangle formed by the 2 heads of sternocleidomastoid muscle and clavicule perpendicular to IJV and

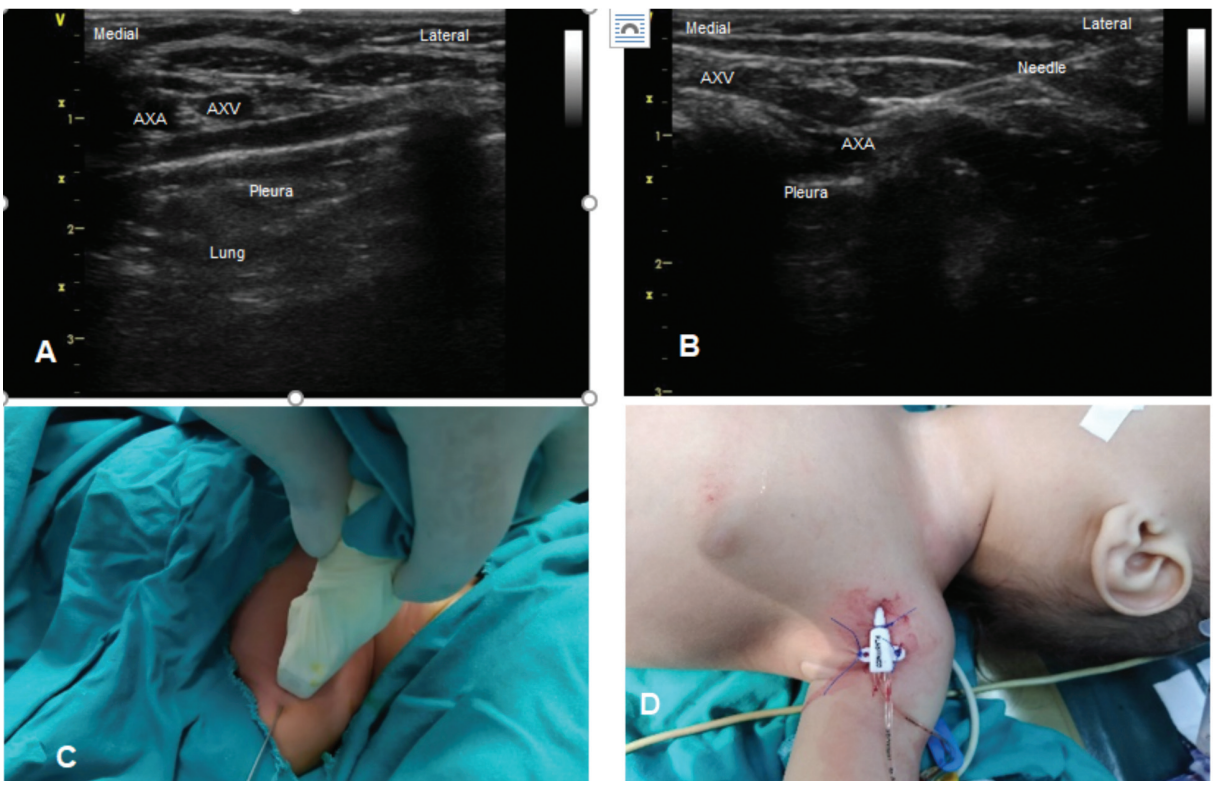

Figure 1. Ultrasound images of axillary vein catheterization. A: short axis view; B: long axis view with needle bevel inside axillary vein; C: In plane US probe and needle position; D: Final catheter position. AXA: axillary artery; AXV:axillary vein

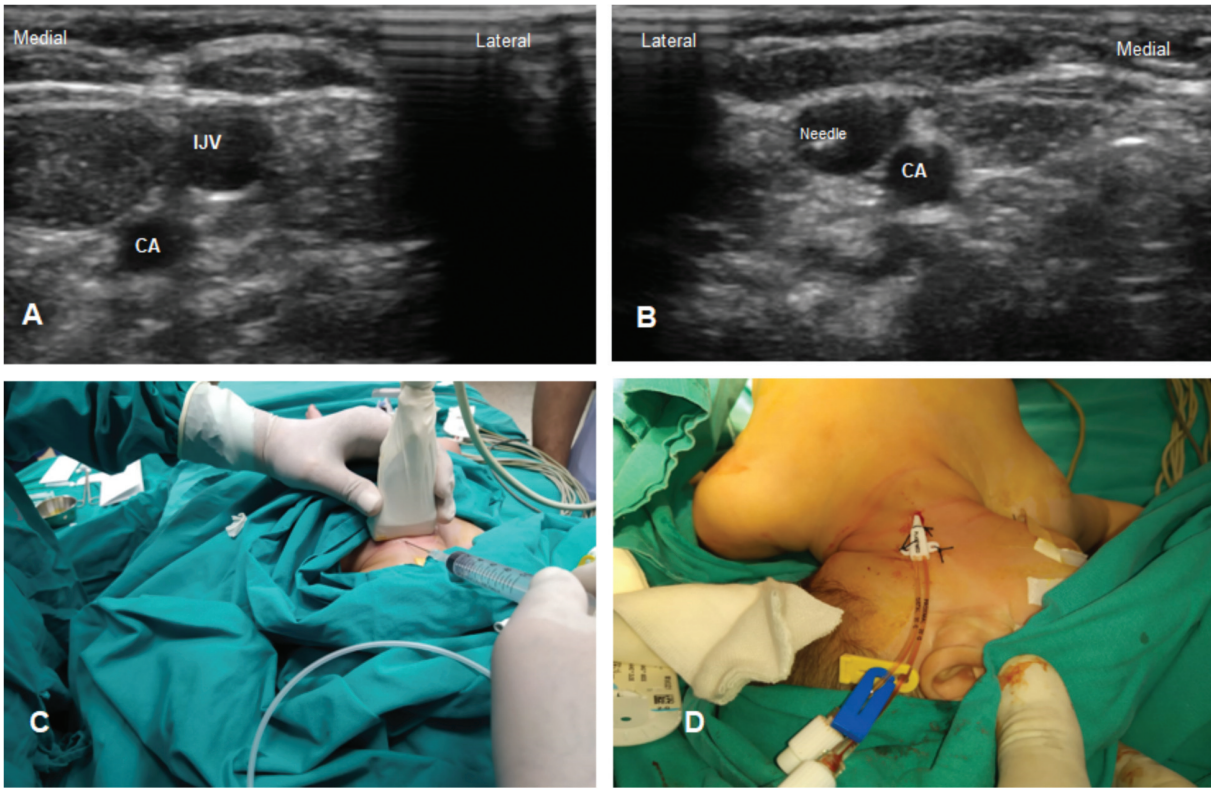

Figure 2. Ultrasound images of internal jugular vein catheterization. A: short axis view; B: needle bevel inside IJV vein; C: out plane needle and US probe position; D: Final catheter position. IJV: internal jugular vein; CA: carotid artery

internal carotid artery (Figure 2). Any changes in mean arterial pressure, heart rate and rhythm during CVC insertion were observed.

The surgical approach to the heart was made through the standard median sternotomy. The patient was fully anticoagulated by administration of heparin 3-4 mg kg^{-1} through CVC to achieve an activated clotting time greater than 480 seconds. The myocardium was preserved by performing cardioplegia using either a crystalloid solution (Custodiol) or blood depending on the complexity of cardiac repair. At the end of surgery, the intubated and mechanically ventilated patient was transferred to intensive care unit (ICU).

Collected data

The primary outcome measure was the first successful needle puncture attempt to approach the AXV or IJV. Successful attempt is defined as free aspiration of blood and free passage of guide wire inside the vein with subsequent successful cannulation and working all ports. The secondary outcome measures included, the number of skin puncture attempts (only 3 consecutive skin punctures were allowed before it was considered a failed attempt), the number of failed attempts at CVC insertion, the time taken to puncture the vein and to insert CVC and the rate of mechanical complications. The duration of CPB and surgery were also recorded. Mechanical complications included, arterial puncture which was identified by the backflow of pulsating blood, presence of hematoma, or arterial wave after connecting the CVC to the transducer; pneumothorax which was identified after sternotomy by direct visual inspection of the pleura, catheter occlusion after sternal retraction, catheter malposition (any position other than inside superior vena cava or right atrium which was identified by the surgeon after sternotomy) and the occurrence of brachial plexus (AXV puncture) or phrenic nerve (IJV puncture) injury.

Statistical Analysis

To test the primary endpoint of the study, we hypothesized that the success rate of the first puncture attempt for CVC insertion through AXV was higher than that of IJV. To calculate the required

sample size, we used the normal success rate of the first puncture attempt of IJV (70%) [7]. Using the G power program and chi-square test, sample size analysis revealed that 95 patients per group were needed to detect an increase in the success rates of the first attempts from 70% to 85% with a power of 80% (for alpha <0.05). The number of patients was increased to 110 per group to avoid 10% dropped out cases.

Shapiro-Wilk test was used to test the normality of data distribution. Data were expressed as median (interquartile ranges) values, numbers and percentages. All nonparametric quantitative variables were analyzed with Mann-Whitney U test. Categorical data were analyzed by using Pearson chi-square test and Fisher's exact test. Data analysis was done to compare the variables between the two groups. All statistical tests were done by using SPSS version 21 software (IBM Corporation, Armonk, NY, USA) for Windows/Macintosh (Microsoft Corporation, Redmond, WA, USA). P value was considered statistically significant if it was <0.05.

RESULTS

A total of 220 patients were included in this randomized, controlled, prospective study and 20 patients were excluded as their legal guardian's declined to participate (n=7) or they were not meeting the study inclusion criteria (n=13) as shown in Figure 3.

Characteristics of the patients and surgical procedures are shown in Table I. The patients' age, weight, height and gender were comparable in both groups. The numbers and percentages of different cardiac

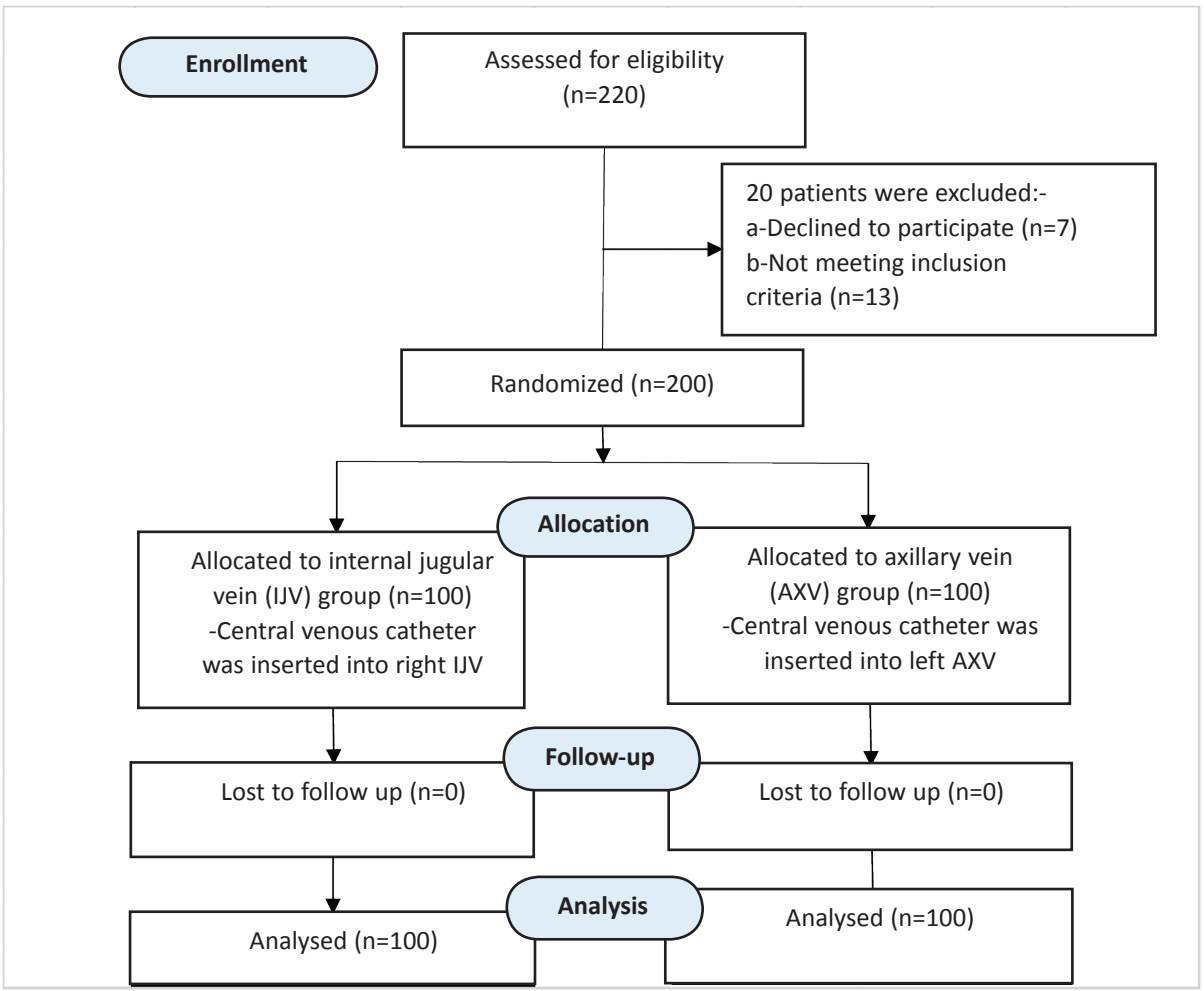

Figure 3. Flow Chart

lesions were comparable in the studied groups. The duration of CPB and surgery did not show significant difference between both groups.

Table I. Patients and surgical characteristics

Variable	Axillary Group (n=100)	Internal Jugular Group (n=100)	p value
Age (year)	4 (2-8)	4 (2-8)	0.851
Weight (kg)	15.05 (12.225-20.6)	16.3 (12.25-22.95)	0.405
Height (cm)	96 (85-117.75)	98 (87-117.75)	0.447
Gender (male/female)	50/50	47/53	0.777
Cardiac lesion (n/%)			
ASD	15 (15%)	19 (19%)	
VSD	20 (20%)	27 (27%)	
Fallot's tetralogy	23 (23%)	19 (19%)	0.571
CAVC	19 (19%)	19 (19%)	
TAPVC	16 (16%)	9 (9%)	
Mitral stenosis	7 (7%)	7 (7%)	
CPB duration (min)	98 (72.5-125)	86.5 (65-121.5)	0.155
Surgery duration (min)	233.5 (201-295)	201 (173-298)	0. 149

Data are expressed as median (interquartile range), number (n), and percentage (%).
ASD: atrial septal defect; VSD: ventricular septal defect; CAVC: common atrioventricular canal; TAPVC: total anomalous pulmonary venous connection; CPB: cardiopulmonary bypass.

Needle puncture characteristics and central venous catheter insertion time are presented in Table II. There was no statistically significant difference (p=0.053) as for the first skin puncture success rates between both groups (AXV group 80% and IJV group 68%). There were no significant differences regarding the second and third skin punctures success rates. The incidence of failed vein puncture (3 failed consecutive attempts) was similar (p=1.000) in IJV (3%) and AXV (2%) groups. The vein puncture and catheter insertion times were similar in both groups.

Table II. Needle puncture characteristics and central venous catheter insertion time

Variable	Axillary Group (n=100)	Internal Jugular Group (n=100)	p value
Successful punctures (n/%)			
First puncture	80 (80%)	68 (68%)	0.076
Second puncture	12 (12%)	19 (19%)	0.120
Third puncture	6 (6%)	10 (10%)	0.296
Failed puncture (n/%)	2 (2%)	3 (3%)	0.500
Time to puncture (min)	5 (5-6)	5 (4-8)	0.986
Time to CVC insertion (min)	11 (11-13)	11 (10-15)	0.932

Data are expressed as median (interquartile range), number (n), and percentage (%)

Central venous catheter associated mechanical complications are listed in Table III. There were no significant differences in the incidence of complications related to CVC insertion. In IJV and AXV groups the incidences of arterial puncture, pneumothorax and CVC malposition were (12% vs 11%, 4% vs 1%, 3% vs 5%) respectively. Catheter occlusion with sternal retraction was higher (p=0.029) in AXV than IJV group (6% vs 0%). No patient developed postoperative phrenic (IJV group) or brachial plexus nerve injury (AXV group).

Table III. Central venous catheter-associated complications

Variable (n/%)	Axillary Group (n=100)	Internal Jugular Group (n=100)	p value
Arterial puncture	11 (11%)	12 (12%)	0.500
Pneumothorax	1 (1%)	4 (4%)	0.184
Catheter malposition	5 (5%)	3 (3%)	0.360
Catheter occlusion with sternal retraction	6 (6%)	0 (0%)	0.014*
Nerve injury	0 (0%	0 (0%)	

Data are expressed as number (n) and percentage (%)
**p<0.05 is statistically significant when compared with internal jugular group*

DISCUSSION

In this randomized, controlled study we found no significant differences between the US-guided infraclavicular AXV and IJV cannulation regarding the success rate of needle puncture and the incidence of catheter insertion-related complications in children undergoing open heart surgery. Depending on the above findings, infraclavicular AXV is considered a good and safe alternative for IJV for insertion of CVC in pediatric cardiac surgery.

Pediatric patients undergoing open heart surgery usually suffer from a compromised cardiopulmonary function, and the occurrence of any mechanical complication related to CVC insertion may cause hypoxia, hypercapnia or hypotension that aggravate this compromised function. Moreover, these patients will be fully anticoagulated with heparin 3-4 mg kg^{-1} prior to CPB, so inadvertent arterial puncture may add additional risk to these compromised patients and complicate their perioperative course.

In their prospective, randomized, controlled study that included 100 adult patients undergoing on-pump cardiac surgery, Shinde, et al. [8] evaluated the efficacy and safety of US-guided infraclavicular AXV cannulation as an alternative to IJV cannulation. They found that, the rate of the first successful needle puncture was comparable in both groups (98% in IJV group and 95% in AXV group) and the time to successful needle puncture was similar in both groups, but in contrast to our study, the total duration of CVC insertion was significantly longer in IJV than AXV group. They also reported nonsignificant differences between the rates of mechanical complications in both groups.

In our study we reported that US-guided AXV was associated with the first skin puncture success rate of 80%. Kim et al. [5] compared real-time US-guided AXV approach for insertion of the CVC using the conventional, anatomical landmark for infraclavicular subclavian vein catheterization in 132 children scheduled for cardiac, general and neurological surgeries. They found that the first puncture success rate was 46% for the US-guided AXV group and 40% for the landmark group without any significant difference in the complication rates between both groups. They concluded that US-guided in-plane technique AXV cannulation was effective and useful in pediatric patients. Czarnik T et al. [9] performed 202 in-plane US-guided trials for AXV cannulation in critically ill ventilated adult patients. The first puncture success rate was 84.1%; and the overall success rate was 98.5%. They reported few complications as malposition (13.4%); pneumothorax (0.5%) and axillary artery puncture occurred in 5 (2.5%) patients. In their retrospective study that included 236 patients, who had undergone AXV cannulation, He YZ et al. [10] compared the rates of successful needle puncture and mechanical complications between procedures performed through long- and short-axis views. They reported higher first attempt success rate in long (91.7%) than short (82.8%) axis view. The only reported complication was arterial puncture that occurred in 1 of 120 patients using long and in 2 of 116 patients using short-axis needle punctures.

In our study we abducted ipsilateral arms of the patients by 45 degrees during AXV punctures to increase the needle puncture success rate. Sivashanmugam T et al. [11] reported that, ipsilateral arm abduction in mechanically ventilated adult patients improved the sonographic view of axillary vessels and increased-though not statistically significantly-the first puncture success rate from 70% to 80%

In-plane ultrasonographic view provides good visualization of the whole length of the axillary vein and the puncturing needle, the needle bevel advancement till puncturing the vein wall and the course of the guidewire inside the vein lumen [12].

The AXV begins at the axillary fold and ends at lateral border of the first rib where it continues as the subclavian vein. The entire length of AXV is located outside the thoracic cage, thus, the risk of serious complications such as hemothorax, mediastinal hematoma, pneumothorax and iatrogenic tracheal injury is almost completely avoided [13]. The extrathoracic course of AXV makes its use for CVC insertion safer than the subclavian or internal jugular approaches with easier compression of the hematoma that results from axillary artery puncture [12].

Malposition of CVC may complicate this intervention and is more common with subclavian than internal jugular vein cannulation [14]. The tip of venous catheter in case of subclavian vein cannulation may be found in ipsilateral internal jugular vein, inside the right atrium or in contralateral axillary vein [14]. Both studies showed that the rate of catheter malposition was higher with internal jugular vein cannulation than subclavian cannulation [15,16] while another study reported that there was no difference in the rate of catheter malposition [17].

The rate of catheter occlusion with sternal retraction was significantly higher in AXV than IJV group (6% vs 0%). Retraction of the sternum may compress the CVC between the first rib and the clavicle that may occlude one or more lumen of the venous catheter. In case of occlusion of all lumens of CVC, the surgeon is asked to decrease the degree of sternal retraction to relieve CVC occlusion.

Our study have the following limitations: 1) The age of children included in the study was above 1 year, so further studies on neonates and infants are required

to evaluate the usefulness of AXV cannulation in this young age group with small vein caliber, 2) We could not study the rate of delayed complications related to catheterization, such as catheter-related infection and thrombosis as we monitored the patients only for 24 hours after endotracheal extubation, 3) All central venous cannulations were performed only by one experienced pediatric cardiac anesthesiologist and the first puncture success rate may vary according to the experience of the operator.

CONCLUSION

From the findings of the current study we concluded that, US-guided cannulation of both infraclavicular axillary vein and IJV were similarly associated with high success rate and low incidence of mechanical complications, but the incidence of catheter occlusion was higher with AXV.

Clinical Trial Registry: The study was registered at pan African Clinical Trial Registry (PACTR201909663728514).

Conflict of Interest: The authors have no conflicts of interest to declare.

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Informed Consent: A written informed consent was obtained prior to surgery from the parent(s) or legal guardian(s) of the patients.

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