Iranian Heart Journal; 2023; 24 (2)

Original Article

Comparison Between Central Venous Catheter Placement and Ultrasound Guide and Anatomical Landmarks in Pediatric Patients Undergoing Cardiac Surgeries

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ABSTRACT

Background: Controversies exist surrounding the advantages and disadvantages of anatomical landmarks (ALs) and ultrasound (US) guidance as 2 methods of central venous catheter (CVC) placement among pediatric patients. The present study compared the success rate and complications of CVC placement in the internal jugular vein between US guidance and traditional AL methods among pediatric patients.

Methods: The present open-labeled randomized clinical trial was performed on 120 pediatric patients aged 3 months to 6 years undergoing cardiac surgeries. The patients were randomly allocated to the US-guided and AL groups. After the induction of anesthesia and intubation, the CVC was placed according to the placement method of each trial group. The success rate of first-attempt CVC placements was the primary outcome, while placement time, vein punctures, and arrhythmias constituted the secondary outcomes.

Results: The trial assessed 120 patients (63, 52.5% female). The mean CVC placement time was 204.1±111.7 seconds. The success rate of first-attempt CVC placements was the same in both groups (47/60; 78.33%). The AL group experienced significantly more side effects than the US-guided group (23 arrhythmias [38.33%] and 5 arterial punctures [8.33%] vs 2 arrhythmias [3.33%] and 3 arterial punctures [5%]; $P<0.001$).

Conclusions: The complication rate of CVC placement in the US-guided group was lower than that in the AL group; thus, the former method can be considered safer in pediatric patients. ***(Iranian Heart Journal 2023; 24(2): 55-61)***

KEYWORDS: Anatomical landmark, Central vein catheter placement, Complications, Safety, Ultrasound guide

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Received: January 30, 2022 **Accepted:** April 10, 2022

Iranian Heart Journal; 2023; 24 (2)

Central venous catheter (CVC) placement is an essential procedure in pediatric cardiac anesthesia and intensive care. CVC placement in pediatric patients, especially infants, is more challenging than in adult patients due to the small size of their veins, lack of cooperation, and higher frequencies of anatomical variants in veins. Moreover, in the intensive care unit (ICU), additive risks, such as hypotension, hemorrhage, and hypovolemia or volume overload, are added. Anesthesiologists need multiple punctures at different veins for CVC placement, and within this process, they encounter serious complications such as arterial punctures and pneumothoraces. [1-3] Nonetheless, traditional CVC placement via anatomical landmarks (ALs) is widely used. The success rate of the AL method is related to the natural situation of the vein and the absence of venous thrombosis. Investigators in recent studies have found several anatomical variants, including 18% in the internal jugular vein and 24% in the femoral vein, among pediatric patients. They believe that these variants might have negative impacts on the CVC placement success rate via the AL. [4,5] Ultrasound (US)-guided CVC placement was introduced in the 1990s to resolve the limitations of AL procedures. [6]

Scientific evidence supports the use of CVC placement, indicating that US can help anesthesiologists observe anatomical variants and assess the opening of the target vein. [7]

Pediatric anesthesiologists face controversies surrounding the advantages and disadvantages of the use of US guidance and ALs for CVC placement. Recent studies on pediatric intensive care have suggested the superiority of the US method for CVC placement in the internal jugular vein. [8,9] In a cohort prospective study, investigators reported that CVC placement via US guidance had fewer puncture sites and tries and lower placement time than that via the AL method without improving their success rate. [10] In another study, US-guided CVC placement in the femoral vein had a higher success rate and fewer attempts and complications among neonates. [11] In a multicentric study aimed at comparing the outcomes of the 2 CVC placement methods among patients below 18 years, the US-guided method had a higher success rate on the first try and fewer arterial punctures and complications than the AL method. [12] In a randomized clinical trial, investigators concluded that CVC placement in the femoral vein via the US method increased the success rate on the first try and decreased the arterial puncture risk. [13] While some studies have underscored the advantages of the US-guided method, only a few studies have compared the success rate and complications between the 2 methods, especially among children. [12-14] In the present study, we compared the success rate and complications of CVC placement in the internal jugular vein between the US-guided and traditional AL methods among pediatric patients undergoing cardiac surgeries.

METHODS

Trial Design

The present open-labeled randomized clinical trial was performed with a parallel design on pediatric patients undergoing cardiac surgeries in a university referral heart hospital.

Participants

The study patients were randomly selected from pediatric patients referred to the hospital for cardiac surgeries. The inclusion criteria were patients between 3 months and 6 years old undergoing cardiac surgeries. The exclusion criteria were the insertion of tunneled CVCs without thrombosis in the central vine, coagulation disorders (INR>2.5), a history of CVC placement in the femoral central or subclavian vine, infection at the puncture site, and known

anatomical or functional changes in the cardiovascular system. The study protocol was approved by the Ethics Research Committee of Iran University of Medical Sciences (code: IRCT20210905052379N1 and ethical code: IR.RHC.REC.1400.037). Written informed consent was obtained from the parents of the included children.

Randomization and Blinding

Totally, 120 patients who met the trial's inclusion criteria were randomly selected via the consecutive sampling method. They were randomly allocated to 2 study groups according to the random sequences produced with the aid of a sealed envelope software program. Based on random accidental number tables, the patients were allocated to either the US-guided group (n=60) or the LA group (n=60). The allocated patients were labeled with special codes produced by randomization software, and they were blinded to their trial group (Fig. 1).

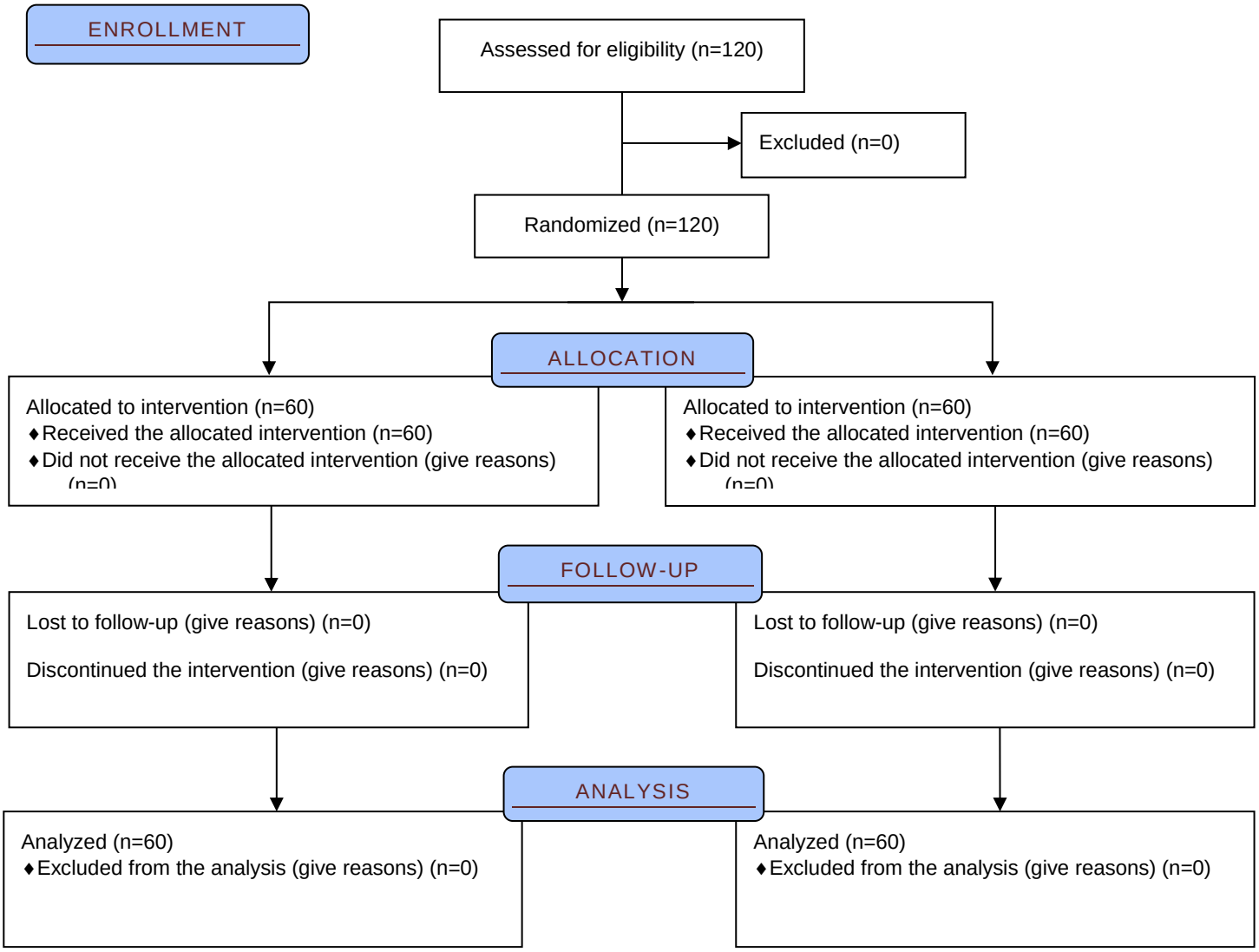

Figure 1: The image presents the flow diagram of the study participants.

Intervention

According to the type of cardiac surgery and the patient's situation, after anesthesia induction and intubation, electrocardiographic monitoring, an arterial line was established. The patient's bed was elevated to a comfortable height for the procedure, and the patient was placed in the supine and Trendelenburg position (the bed tilted head down 10° to 15°) to distend the internal jugular vein and prevent air embolism. The patient's head was turned only slightly (or not at all) to the contralateral side to expose the internal jugular vein but not cause overlap with the carotid artery. The neck and upper chest of the patient were disinfected and covered with sterile perforate surgical drapes, and internal jugular vein placement was performed.

In the AL group, placement was performed via the Seldinger method. The finder syringe was entered at the vertex of the triangle between the sternocleidomastoid heads and the clavicle bone. Aspiration was performed with the finder syringe on the nipple side to detect the internal jugular vein; then, the main catheter and syringe were entered. A special CVP wire was entered into the main syringe, and electrocardiographic monitoring was performed for arrhythmia occurrence. After the wire was positioned, the main syringe was withdrawn, and the dilator was entered into the guide wire and fixed with a silk suture. In the US-guided group, sonography was performed before cannulation to assess the vein.

In the current trial, in addition to demographic variables, such as age, sex, height, and weight, surgery-related outcomes, including the access sites of the veins (internal jugular and subclavian), were assessed.

Trial Outcome

The primary outcome was the success rate on the first try for placement, and the secondary outcomes were placement time (the time between the first puncture and placement), additional vein punctures needed, and mechanical complications (eg, arterial punctures, pneumothoraces, vascular hematomata, and arrhythmias).

Statistical Analysis

The data were entered into the SPSS software, version 21.0, for statistical analysis. Quantitative variables were described as the mean and the standard deviation (SD), and qualitative variables were presented as frequencies and percentages. The normal distribution of the variables was assessed using the Wilk–Shapiro test. The mean of the variables was compared between the 2 trial groups using the independent samples *t* test. The qualitative variables were compared using the χ^2 and Fisher exact tests. All *P* values ≤ 0.05 were considered significant results.

RESULTS

Finally, 120 patients (63, 52.5% female) were included in the study. The mean age of the study participants was 30.33±24.17 months. The mean height and mean weight of the patients were 80.90±23.87 cm and 13.90±17.80 kg, respectively. A comparison of the demographic variables between the 2 study groups showed that the US-guided group and the AL group had a statistically meaningful difference only in height. The details of the comparisons of study variables between the 2 study groups are presented in Table 1.

Table 1: Comparisons of demographic variables between the 2 study groups

Variable		Ultrasound-Guided Group (n=60)	Anatomical Landmark Group (n=60)	*P* value
Age, mon		30.33±25.92	30.32±22.49	0.99
Height , cm		74.41±26.50	87.40±19.01	0.003
Weight, kg		16.41±24.57	11.41±4.77	0.13
Sex	Male	30 (50%)	27 (45%)	0.72
	Female	30 (50%)	33 (55%)	

Table 2: Comparisons of catheter placement-related variables between the 2 study groups

Variable		Ultrasound-Guided Group (n=60)	Anatomical Landmark Group (n=60)	*P* value
First-attempt success		47 (78.33%)	47 (78.33%)	1.00
Cannulation time (s)		188.08±43.10	220.17±150.92	0.12
Another central venous placement		16 (26.66%)	14 (23.33%)	0.67
Side Effects	Arrhythmias	2 (3.33%)	23 (38.33%)	0.001
	Arterial punctures	3 (5%)	5 (8.33%)	0.001

Placement-related variables were compared between the study groups. The success rate of first-attempt placements in the US-guided group and the AL group was the same (47/60 vs 78.33%) and showed no statistically significant difference (*P*=1.00). Twenty-five (20.83%) patients had arrhythmias, and 8 patients (6.67%) had arterial punctures. The AL group experienced significantly more side effects than the US-guided group (23 arrhythmias [38.33%] and 5 arterial punctures [8.33%] vs 2 arrhythmias [3.33%] and 3 arterial punctures [5%]; *P*<0.001). The use of other veins for CVC placement was not statistically significantly different between the 2 groups (*P*=0.67). The details of placement-related variables are presented in Table 2.

DISCUSSION

In our study, although the success rate of CVC placement on the first try had no significant differences between the US-guided and AL groups, the former group experienced significantly fewer side effects. Our results indicate the superiority of US-guided CVC placement for pediatric patients. The frequency of complications in CVC placement reportedly ranges between 5% and 20% in similar studies. [15-17] A prior investigation reported that the US-guided method for CVC placement decreased complications to 12% compared with 20% in the AL method. In most similar studies, the differences in the complication rate between US-guided groups and AL groups were clinically significant. The results of similar studies support our findings; accordingly, we can suggest the US-guided method for CVC placement among pediatric patients due to its safety and low complication rate.

The success rate of CVC placement in our study was similar in the US-guided group and the AL group. Still, the US-guided method had fewer complications and was safer than the AL method. We suggest that anesthesiologists undergo training courses in US-guided CVC placement. Our literature review yielded several studies with different success rates for CVC placement. In a previous study, investigators reported success rates of 91.5% and 72.5% for US-guided and AL CVC placement methods, respectively. [18] In another study, a 22% increase in the success rate was reported for US guidance compared with the AL method. [19] Nevertheless, CVC placement via the US-

guided method is underutilized, despite its impacts on patients' safety, especially infants. [15, 17, 20] In line with the noted study, the overall rate of US guidance use for CVC placement ranges between 28.9% and 58%. [17, 21] It is essential to note that the diameter of patients' vessels is strongly related to their age and weight, and this relation can explain the challenging nature of CVC placement procedures in children, particularly infants. [18] We chose the internal jugular vein as the main vein for CVC placement in our study. Similar studies have reported that the success rate of CVC placement is enhanced by the US-guided method in the internal jugular vein. [19] Nonetheless, the first choice of pediatric cardiac anesthesiologists for CVC placement is the subclavian approach via ALs. Recent studies have reported that US-guided CVC placement is used in pediatric emergency departments around the globe primarily for therapeutic and diagnostic purposes in more than 60% of patients. [22]

CONCLUSIONS

The findings of the present study among pediatric patients indicated that US-guided CVC placement, by comparison with the traditional AL method, reduced the complication rate, although both methods had the same success rate. In light of our results, we suggest that the US-guided method may enable pediatric cardiac anesthesiologists to reduce CVC cannulation complications.

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