Medical Research
Volume 6, Issue 2, 2024, Page 17–28
https://doi.org/10.6913/mrhk.060202

Medical Research

Comparison of alfentanil and fentanyl in painless colonoscopy in children

Xueqing WANG[1], Yuanzhen CHEN[1], Jing ZHAO[1], Dajun XING[1], Bo XU[2*], Liang XU[1*]

1.Department of Anesthesiology, Shenzhen Children's Hospital, Shenzhen, PR China 2.Department of Anesthesiology, General Hospital of the Southern Theater Command of the Chinese PLA, Guangzhou, PR China

**These two author contribute equally in this manuscript.*

Abstract

Background Catheter tip malposition is commonly observed during subclavian vein catheterization. This study aimed to investigate whether positioning and partially retracting the guide wire could reduce catheter malposition. **Methods** Children needing right subclavian venipuncture catheterization were randomly divided into two groups: test group A (82 patients) and control group B (82 patients). In group A, catheterization was performed with the patient in a supine position and the guide wire partially retracted during placement. In contrast, in group B, catheterization was done with the patient in Trendelenburg position without partial retraction of the guide wire. The catheter tip direction was examined using intraoperative ultrasound, and a postoperative chest X-ray was obtained. **Results** The rate of correct catheter tip direction at first insertion was higher in group A compared to group B (86.2% vs. 66.7%, $P < 0.05$). There were no significant differences in incidence and general data between the two groups. Repeated vascular puncture was unsuccessful in three patients (2 cases in group A and 1 case in group B), necessitating the use of the right internal jugular vein catheter instead. **Conclusions** Partially retracting the guide wire in the supine position can reduce catheter tip malposition during right subclavian venipuncture in children.

Keywords children, subclavian vein, catheter tip

1 Background

Central venous catheterization provides venous access for intravenous nutrition, fluid infusion, drug administration, blood purification, stem cell transplantation, hemodynamic monitoring, interventional examination, and interventional therapy. Notably, the position of the subclavian vein is relatively fixed, and the success rate of puncture is high. Additionally, the patient' s postoperative head and neck movement is less restricted, making it easier to fix and maintain, and the central venous catheter can be indwelled for a long time[1]. However, catheter tip malposition is commonly observed in practice. It has been reported that the malposition rate is higher in right subclavian vein catheterization than in left subclavian vein catheterization[2]. Moreover, the right side lacks the thoracic duct confluence, and the right lung apex is lower than the left lung apex; therefore, the risk of chylothorax or pneumothorax is lower on the right side than on the left side.

Catheter malposition occurs when the tip of the catheter is pointing in the wrong direction (i.e., not in the superior vena cava) or when the catheter is placed too shallow or too deep despite the tip being properly oriented. The appropriate position of the catheter tip is from the inferior third of the superior vena cava to the opening of the right atrium[3]. In a previous study, chest X-rays revealed that the appropriate position of the tip was from the carinal process to the two vertebral bodies below it[4], i.e., approximately at flat T4 T6. Catheter malposition can easily lead to complications such as thrombophlebitis, vascular injury, venous channel obstruction, and abnormal hemodynamic monitoring[5]. Therefore, improving the rate of correct tip direction in pediatric right subclavian vein catheterization and predicting catheter insertion depth is of high clinical significance.

In the traditional method of catheter placement, the guide wire directs the catheter into the vascular lumen throughout the process of catheterization, and the direction of the guide wire determines the direction of the catheter. According to a previous study, the soft catheter easily floats in the direction of blood flow[6]. Moreover, it was assumed that the front end of the catheter softens after the guide wire is withdrawn; in the supine position, the speed of blood return to the heart is accelerated. Therefore, the catheter can easily follow the blood flow to the heart.

In several studies, the rate of catheter malposition was reduced by reducing the angle between the internal jugular and subclavian veins, i.e., by changing the head[7] or shoulder position[8] of the patient. However, to the best of our knowledge, there are no studies on the role of the guide wire and patient positions in reducing catheter malposition during catheterization. Therefore, this prospective, randomized, controlled study aimed to investigate the effect of partially retracting the guide wire in the supine position on reducing catheter malposition during right subclavian vein catheterization in children.

2 Methods

This study was approved by the Ethics Committee of Shenzhen Children's Hospital, Guangdong Province, China. Overall, 164 patients who underwent subclavian vein catheterization at the

Department of Hematology and Oncology of Shenzhen Children' s Hospital from May 2021 to March 2023 were enrolled in the study. Using a random number table, the participants were classified into experimental group A (n = 82) and control group B (n = 82).

The inclusion criteria were as follows: age 4–8 years; children with ASA I–III; normal head and neck movement; elective subclavian vein puncture; children and their families who voluntarily participated in the study and provided written informed consent.

The exclusion criteria were as follows: children with obvious abnormal coagulation function; children with scar or infection at the puncture site and surrounding skin; children with abnormal head and neck movement or immobilization due to disease or treatment measures; children with serious skin damage in the right puncture field; children with a central venous catheter or infusion port.

Patients in both groups were treated with intravenous combined anesthesia (non-tracheal intubation) and local infiltration anesthesia. Electrocardiogram findings, noninvasive blood pressure, and arterial oxygen saturation were monitored after admission. As intravenous combined anesthesia, 2–3 mg/kg propofol, 0.05 0.1 mg/kg midazolam, and 1–3 μg/kg fentanyl were administered. When the patients were unconscious, their heads were inclined to the left at approximately 30°, a soft pad was placed in the interscapular area, the neck and upper chest wall were fully exposed, the towel was disinfected, and local infiltration block was performed at and around the puncture site with 1% lidocaine.

The depth of central venous catheter insertion (D) was calculated using the length of the right clavicle (A) and the vertical distance between the right clavicle head and the sternal angle (B) as follows: D = ½A + B (Fig. D).

Fig.D epth of central venous catheter placement = ½A+B

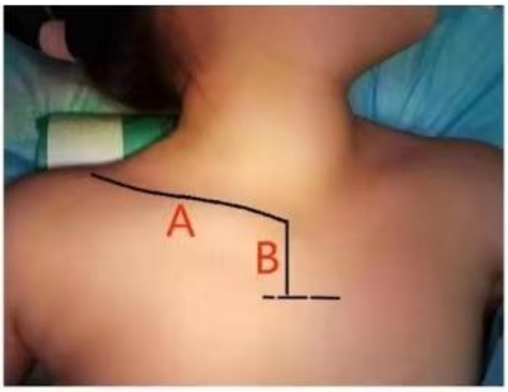
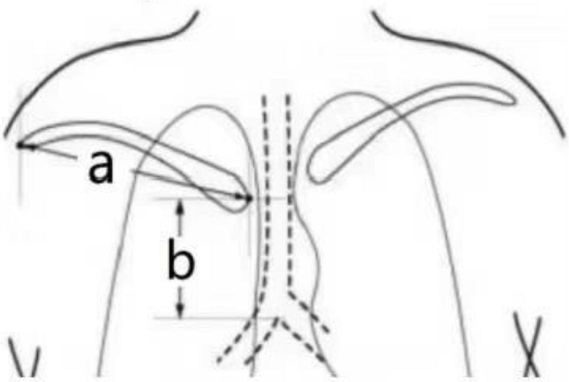


Fig.d epth of central venous catheter placement = ½a+b



Patients in group A were placed in the supine position, while those in group B were placed in the Trendelenburg position. Ultrasound was used to examine the subclavian vein near the midpoint of the right clavicle to obtain the best image (Fig. a right). A syringe was connected to a 4.7 cm long indwelling needle, approximately 30° from the skin, with negative pressure suction applied during the puncture directed towards the Adam's apple (Fig. a left, white arrow).

Fig.a Ultrasound-guided subclavian venipuncture was performed

After successful puncture in patients in group A, the core of the indwelling needle was removed, and the guide wire was inserted through the cannula of the indwelling needle. The puncture tunnel was expanded, and the double-lumen central venous catheter was placed approximately 4 cm into the vascular cavity via the guide wire. Further, the right venous angle was visualized using ultrasound to avoid catheter placement beyond the right venous angle. The guide wire was retreated to approximately 1 cm below the skin puncture site, and the leading end of the double-lumen catheter was placed approximately 22 cm from the end of the guide wire. At this point, the position of the guide wire was kept fixed, and the catheter was placed into the vascular lumen at the estimated depth of D; subsequently, the guide wire was withdrawn.

In patients in group B (those who underwent catheterization via the traditional method), after successful puncture, the core of the needle was removed, the guide wire was inserted, the puncture tunnel was expanded, and the double-lumen central venous catheter was placed into the estimated depth D via the guide wire. The guide wire was then withdrawn.

Ultrasound examination of catheter tip direction was performed using a high-frequency linear array probe to scan the right internal jugular vein and suprasternal fossa, respectively. If a bright double track sign was found in the right internal jugular and left brachiocephalic veins, the catheter tip direction was deemed incorrect, as shown in Figs 1, 2, and 3 (the red arrow refers to the central venous catheter). In contrast, the catheter tip was deemed to be correctly directed if a highlighted double track sign was found in the right brachiocephalic vein and no highlighted double track sign was found in the right internal jugular or left brachiocephalic vein (Fig. 4). The catheter was then fixed, and a sterile patch was applied. After healthy vital signs were observed, the patient was transferred to the postanesthesia care unit for resuscitation and subsequently returned to the ward.

If the tip of the catheter was found to be in the wrong direction by intraoperative ultrasound examination, the catheter was repositioned according to the method used for group A. In cases

Fig.1 The right internal jugular vein was scanned using ultrasound and the catheter was misplaced in the right internal jugular vein

Fig.2 The right internal jugular vein was scanned using ultrasound and the catheter was misplaced in the right internal jugular vein

Fig.3 An ultrasound probe was placed in the suprasternal fossa and the left and right brachiocephalic trunk were scanned. The catheter was heterotopic in the left brachiocephalic trunk.

Fig.4 An ultrasound probe was placed in the suprasternal fossa and the left and right brachiocephalic trunk were scanned. The catheter was in the right brachiocephalic trunk.

where two adjustments of catheter direction were necessary, other methods such as head turning, ear touching the shoulder, and internal jugular vein compression were used in combination. Chest X-rays were obtained 4 hours postoperatively to check for the presence of pneumothorax or hemothorax and to determine the position of the catheter tip.

Observation Indicators

The following factors were examined:

1. General data, including the patient’ s age, weight, and height.
2. Operative time (t), defined as the time from the start of local anesthesia to the end of sterile film fixation.
3. Whether the tip alignment of the catheter was correct at the first catheterization (N_1).
4. Whether there was a switch to other catheterization methods or abandonment (G).
5. The position of the ectopic catheter tip (W).
6. Complications associated with puncture and catheterization.
7. Position of the tip of the catheter on postoperative chest X-ray (T).

Statistical Methods

SPSS 22.0 was used for the statistical analysis of data. The t-test was used for data with normal distribution, presented as the mean ($\bar{x}$), for between-group comparisons. The numerical data were presented as rates (%) and analyzed using the χ^2 test. A P-value of <0.05 was considered to indicate a significant difference.

Materials and Equipment

The following materials and equipment were used:

- 5F central venous catheter package (Brand: Arrow International Inc; Manufacturer: Telifu Medical Equipment Trading (Shanghai) Ltd; Specification model: CS-14502)
- Disposable central venous catheter puncture package (Brand: Sujia; Manufacturer: Zhejiang Sujia Medical Device Ltd; National machinery label: 20163030366)
- Portable color ultrasound diagnostic instrument (Brand: Sonuo Sound; Manufacturer: Dongguan Kebei Medical Equipment Ltd; Specifications: M-Turbo)
- Portable ultrasonic probe (high frequency) (Brand: Sono Sound; Manufacturer: Nanchang Danjie Trading Ltd; Specifications: C60X)
- Ruler

3 Results

Right subclavian vein catheterization failed after three attempts of puncture in two cases in group A and one case in group B. Catheterization for these cases was subsequently changed to the right internal jugular vein puncture. Finally, complete experimental data were obtained for 80 cases in group A and 81 cases in group B. There were no significant differences in age, height, weight, or operation time between the two groups ($P > 0.05$) (Table 1).

Table 1 Comparison of age, height, weight, and time between the two groups (group A [n = 80] and group B [n = 81])

Group	Weight (kg)	Height (cm)	Age (year)	Time of operation (min)
A	19.54 ± 4.22	114.56 ± 9.30	5.96 ± 1.45	17.35 ± 7.68
B	19.57 ± 3.75	114.43 ± 8.54	5.73 ± 1.39	16.11 ± 8.73
t	−0.050	0.098	1.045	0.956
p	0.960	0.922	0.297	0.341

The correct rate of catheter tip direction at the first insertion (R1) in group A (69/80 cases, 86.2%) was significantly higher than that in group B (54/81 cases, 66%; P < 0.05). The rate of catheter tip misplacement at the first placement in the right internal jugular vein (R2) was significantly lower in group A (8/80 cases, 10.0%) than in group B (24/81 cases, 29.6%; P < 0.05). The rate of catheter tip misplacement at the first placement in the left brachiocephalic vein (left subclavian vein) was R3, accounting for three cases each in groups A and B (3/80 [3.8%] and 3/81 [3.7%], respectively; $P > 0.05$) (Table 2)

Table 2 Comparison of correct rate of catheter tip direction and rate of catheter tip misplacement between the two groups (group A [n = 80] and group B [n = 81])

Group	R1	R2	R3
A	69 (86.2)	8 (10.0)	3 (3.8)
B	54 (66.7)	24 (29.6)	3 (3.7)
χ^2	8.560	9.738	0.000
P	0.003	0.002	0.988

R1: Correct rate of catheter tip direction at the first catheterization; R2: Rate of catheter tip misplacement at the first placement in the right internal jugular vein; R3: Rate of catheter tip misplacement at the first placement in the left brachiocephalic trunk

In two and three cases in groups A and B, respectively, adjustment of the catheter failed twice. After adjusting the catheter using other methods (internal jugular vein compression and shoulder elevation methods), an ultrasound examination finally revealed that the tip of the catheter was correctly oriented. Hematomas at the puncture site did not differ significantly between the groups ($P > 0.05$) (Table 3).

Table 3 Percentage of complications in group A (n = 80) and group B (n = 81)

Group	Hematoma at the puncture site
A	1 (1.3)
B	2 (2.5)
χ^2	0.327
P	0.567

Postoperative chest radiographs were obtained, and the position of the catheter tip is reported in Table 4.

Table 4 Catheter tip position

Catheter tip position	Cases, n (%)
T4–T6	148 (91.9)
T7	13 (8.1)

4 Discussion

4.1 Central Venous Catheterization

Central venous catheterization is a crucial clinical technique for patients undergoing hemodialysis, volume resuscitation, central venous pressure monitoring, transvenous temporary pacing, and long-term chemotherapy. There are three main venous approaches available for central venous catheterization: the internal jugular vein, femoral vein, and subclavian vein. Each of these approaches has its advantages, disadvantages, and potential complications [9,10,11].

Subclavian vein catheterization is associated with a reduced risk of catheter-associated infection and thrombosis compared with internal jugular vein or femoral vein catheterization [12]. It can reduce patient discomfort, particularly in long-term intravenous treatments such as parenteral nutrition and chemotherapy. The success rate of subclavian vein puncture did not differ between the superior and inferior approaches; however, there was a higher risk of accidental artery puncture with the superior approach compared to the inferior approach [13]. Considering that the subclavian approach offers more convenience for children's daily activities and nursing care, it was chosen for this study.

Ruesch et al. [9] performed a meta-analysis of internal jugular and subclavian vein punctures and reported that the overall ectopic rate of subclavian vein puncture was 9.3%. Pandey et al. [14] and Sanchez et al. [15] revealed that the incidence of adult subclavian vein catheterization malposition was 5.5% and 5.4%, respectively. Notably, the rate of subclavian vein malposition in children is higher than that in adults. According to Camkiran Firat et al. [16], among children undergoing cardiac surgery, the rate of catheter malposition of subclavian vein puncture in children was 17%. Among the cases of subclavian vein catheterization via the inferior approach in our hospital from 2018 to 2020, the incidence of catheter tip orientation error was approximately 30% based on intraoperative ultrasound examination.

Central venous catheter misplacement increases the risk of catheter-related complications, such as vessel perforation, local venous thrombosis, catheter dysfunction, and intracranial retrograde injection. If left untreated, it can cause serious complications. Therefore, reducing the rate of catheter tip misplacement in subclavian vein puncture is of great clinical significance.

4.2 Study Findings

In the present study, the age, height, and weight of the patients did not significantly differ between the two groups. Group A had more operation steps than group B, but the correct rate of catheter tip direction in group A was higher than that in group B (R1: group A, 86.2%; group B, 66.7%; $P < 0.05$). The catheters in group A exhibited a lower likelihood of requiring adjustment compared to those in group B, resulting in no significant disparity observed in the overall operative time between the two groups.

The correct rate of catheter tip direction for the first time was higher in group A (86.2%) than in group B (66.7%). The rate of catheter tip misplacement at the first placement in the right internal jugular vein was significantly lower in group A (10.0%) than in group B (29.6%). The venous angle is defined as an angle between the right subclavian vein and the outer superior portion of the right internal jugular vein, and this angle is close to a right angle. However, it becomes obtuse when the head of the patient is tilted to the left, and the guide wire is easily misplaced into the right internal jugular vein. In group A, the guide wire was partially withdrawn in the supine position, and the tip of the catheter was approximately 3 cm without the support of the guide wire, maintaining the flexibility and randomness of the catheter. The posterior end of the catheter was supported with a guide wire to increase the hardness of the catheter and facilitate the forward insertion of the catheter to prevent distortion during insertion.

The direction of blood flow has a remarkable effect on the direction of the catheter. In group B, the traditional head-down position was used, and the blood flow returning to the right atrium from the head and neck was reduced, the reflux speed slowed down, and the filling of the right internal jugular vein was more obvious [17]. During spontaneous breathing, the diaphragm is elevated, and compared with the supine position, the negative pressure of the thoracic cavity is reduced in the head-down position. Based on this hemodynamic feature, we speculated that the soft catheter can easily follow the direction of blood flow and move to the direction of low venous pressure [6]. Therefore, at the first catheterization, the correct rate of catheter tip direction in group A was higher than that in group B, and the incidence of the ectopic catheter, i.e., misplacement to the right internal jugular vein, was lower in group A than in group B.

The incidence of catheter tip misplacement into the left brachiocephalic vein at the first catheterization did not significantly differ between the two groups. According to Hempling et al. [18], the confluence point of the mutant left brachiocephalic vein and the right brachiocephalic vein was above the normal confluence point; thus, the angle between this point and the right subclavian vein decreased. Moreover, the right subclavian vein and the left brachiocephalic vein were at the same level. Consequently, the guide wire or catheter easily entered the left brachiocephalic vein when the right subclavian catheter was placed.

Although the ectopic catheters were adjusted twice, we failed to adjust a small number of catheters. When adjustment fails more than twice, various methods should be integrated to adjust or change other puncture routes to reduce vascular mechanical damage [19]. For example, compression of the right internal jugular vein, change of head bias, change of shoulder position, etc. One patient in group A and two patients in group B had puncture failure due to repeated punctures more than three times, causing hematoma at the puncture site.

4.3 Puncture Depth Measurement

In the retrospective study by Uchida et al. [20], the appropriate depth of the right subclavian vein puncture catheter was measured as follows: $d = \frac{1}{2}a + b$, where the length of the right clavicle was a, the vertical distance between the right clavicle head and the carinal process was b, and the catheter insertion depth on the preoperative chest X-ray was d (as shown in Fig. d). On the body surface, the right clavicle is easily accessible, the length is easy to measure, and the trachea carinatum corresponds to the sternal angle. Therefore, in the present study, the length of the right clavicle (A) and the vertical distance from the right clavicle head to the sternal angle (B) were measured on the body surface, and the depth of central venous catheter insertion (D) was estimated as follows:

D = ½ A + B. Postoperatively, all patients underwent chest X-ray examination. Their chest X-rays revealed that 92.1% of the catheter tips were at the T4 T6 level, and 100% of the catheter tips were at the T4 T7 level. The method of estimating the insertion depth of the central venous catheter by measuring the body surface landmarks is simple and easy to perform with high accuracy. In this study, the puncture approach used was the subclavian approach, and the puncture site was near the midpoint of the clavicle. Further studies are required to investigate the depth of central venous catheter insertion for the inner or outer third of the subclavian approach.

4.4 Limitations

Children aged 4-8 years were included in the present study, and the age range was relatively limited. Therefore, the methods of puncturing, catheterization, and ectopic adjustment of catheters may not be applicable to younger children. In younger children, the distance from the puncture site to the venous angle is shorter, and the catheter remaining in the vascular lumen is shorter after partial withdrawal of the guide wire; thus, the catheter may accidentally dislocate from the vascular lumen.

5 Conclusion

The method of partial withdrawal of the guide wire in a supine position can improve the correct rate of catheter tip direction in right subclavian vein catheterization in children.

Funds

This work was supported by the National Natural Science Foundation of China (Grant No.62076253).

Author Biography

XUEQIN WANG, https://orcid.org/0000-0002-9720-0329.

Bo XU and Liang XU contribute equally in this manuscript.

Corresponding author: Bo XU, Email richie441111@126.com.

Corresponding author: Liang XU, Email:865681475@qq.com.

Abbreviations

SCV:subclavian veins; SCA:subclavian artery; IJV:internal jugular veins; ICA:internal carotid artery; LBCV:left brachiocephalic vein; RBCV:right brachiocephalic vein

Authors' contributions

XW, BX and LX designed the study. XW wrote the manuscript. YC, JZ and DX collected, analyzed, and interpreted the data. BX and LX critically reviewed, edited, and approved the manuscript. All authors read and approved the final manuscript.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate.

This study was approved by the Institutional Review Board for Human Studies in Shenzhen Children's Hospital, China. Written informed consent of legal guardians regarding surgery and anesthesia was obtained before the procedure.

Competing interests

The authors declare that they have no competing interests.

Article History

Received: March 12, 2024 **Accepted:** March 16, 2024 **Published:** June 30, 2024.

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To Cite This Article Xueqing WANG,et al. (2024). Comparison of alfentanil and fentanyl in painless colonoscopy in children . *Medical Research*, *6*(2), 17-28. https://doi.org/10.6913/mrhk.060202

Medical Research, ISSN 2664-0333 (print), ISSN 2664-0341 (online), DOI 10.6913/mrhk, a bimonthly, founded on 2018, Indexed by CNKI, Google Scholar, AIRITI, Scilit, CrossRef, Elsevier PlumX, etc., published by Creative Publishing Co., Limited. Email: wtocom@gmail.com, https://mrhk.cc, https://cpcl.hk.