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Fluoroscopy-guided subclavian vein catheterization in 203 children with hematologic disease

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Abstract

Subclavian vein catheterization plays an important role in the treatment of children with hematologic disease. However, catheter placement is a difficult and high-risk procedure in children.

Fluoroscopy-guided subclavian vein catheterization was used in 203 children (mean age, 6.99 years ± 3.722 years; range, 1–16 years) with hematologic disease. The number of vein punctures, catheterization success rate, fluoroscopy time, operation time, and surgical complications were recorded.

There was a 100% success rate for fluoroscopy-guided subclavian vein catheterization. A total of 124 cases (61.1%) were successful on the first venipuncture attempt; 171 cases (84.2%) achieved success within 3 attempts. Twenty-five cases had 4 to 6 time venipunctures and the remaining 7 cases underwent ≥7 time venipunctures. All catheter tips were successfully placed at the junction of the superior vena cava and the right atrium. Fluoroscopy times ranged from 16 to 607 seconds (mean, 65.46 ± 85.864 seconds). Operation time ranged between 5 and 25 minutes (mean, 10.38 ± 4.036 minutes). Arterial punctured was happened during surgery in 2 cases. There were 2 cases of catheter-related infection, but no other complications. The mean follow-up time was 35 days; range 20 to 50 days.

Fluoroscopy-guided subclavian vein catheterization in children is a safe procedure, with a high success rate, resulting in a reduced number of venipunctures, optimal catheter placement, and reduced complications.

Abbreviations: CRT = catheter-related thrombosis, CVC = central venous catheterization, CXR = chest radiograph, DSA = digital subtraction angiography, RA = right atrium, SVC = superior vena cava, US = ultrasound.

Keywords: children, fluoroscopy, hematologic disease, subclavian vein catheterization, venipuncture

1. Introduction

Central venous catheterization (CVC) via the subclavian vein plays an important role in the treatment of children with hematologic disease. However, the young age and small caliber of the blood vessels, the anatomical proximity of the subclavian vein to other vessels and structures, and the risk of vascular thrombosis and infection are factors that contribute to the high risk of central venous catheterization and the low success rate.[1–4] Children with hematologic disease may also have clinical contraindications to venipuncture, including impaired blood coagulation and low platelet count. Improvement in the success of venous catheterization, together with fewer venipuncture attempts, is required to mitigate these contraindications, and this demands more sophisticated catheterization techniques.

Traditional subclavian vein catheterization was performed for 56 children with hematologic disease pretransplantation of bone marrow in our center on 2012. The technical success rate was only 80%. The rate of complications including hematoma, hemothorax, and pneumothorax was 10%. Bruzoni and colleagues reported that using an anatomical positioning-based method and the ultrasound-guided subclavian venous catheterization method that the prevalence of complications during central venous access was 4.5%, with complications including hematoma, hemothorax, and pneumothorax. Other complications include relocation of the site of the venipuncture (20.7%) and accidental puncturing of the artery (19.4%).[5] The difficulty in clearly identifying vessels and peripheral tissues of traditional method increases the venipuncture number and the risk of complications.[1,2,5,6] It had been reported that ultrasound (US)-guided venipuncture can clearly define the location of target vessels and enhance the success rate of venipuncture.[5–9] However, we can only operate without the help of ultrasound in China for the time being. On the other side, traditional method and ultrasound-guided approach cannot detect the exact placement of the catheter tip inside the thoracic cavity.[10,11] The malposition of CVC is associated with hemodynamic inaccuracies, venous thrombosis.[1] Venography can clearly identify vein location, and fluoroscopy can monitor the tip of catheter. So fluoroscopy-guided subclavian vein catheterization was created for the first time and applied to practice.

Therefore, a study about fluoroscopy-guided subclavian vein catheterization was undertaken in children with hematologic disease. The aim of the study was to determine whether fluoroscopy-guided subclavian vein catheterization could improve the success rate of venous catheterization, reduce the

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total number of venipunctures, improve catheter tip placement, and reduce the incidence of complications of the procedure.

2. Methods

2.1. Ethical

Institutional Review Board approval was obtained before initiation of this study, parental consent was obtained in each case too.

2.1.1. Patient inclusion criteria. Children with hematologic disease and required subclavian vein catheterization pretransplantation of bone marrow were included in the study.

2.1.2. Patient exclusion criteria. Patients were excluded from the study for the following reasons: a serious blood coagulation dysfunction, including a prothrombin time >16 seconds or a platelet count $<50\times10^9$/L; known bilateral occlusion of the subclavian veins; and infection in the area of the venipuncture site.

2.1.3. Patient anesthesia. For patients who were 8 years old and younger, venipunctures were performed under intravenous anesthesia combined with local anesthesia at the venipuncture point. Patients who were older than 8 years-of-age received local anesthesia at the venipuncture point. However, if the patient was unable to tolerate any aspect of the procedure, intravenous anesthesia was utilized, as necessary.

2.1.4. Fluoroscopy-guided subclavian vein catheterization procedure. Fluoroscopy-guided subclavian vein catheterization was performed in an interventional operating room. Patients were placed in supine position on the digital subtraction angiography (DSA) examination table, and a lead apron was used to protect the thyroid gland and gonads. Because the right subclavian vein was preferentially punctured, the patient's head was positioned to the left. The right shoulder was kept relaxed, a thick towel was placed under the back of the right shoulder, and the right side of the chest was slightly raised to widen the gap between the right shoulder and right clavicle and to facilitate venipuncture. Both upper limbs were stretched and positioned close to the body.

2.2. Subclavian vein radiography

A trocar was positioned within a superficial vein of the patient's right upper limb. A 10 mL mixture, composed of 5 mL contrast agent (Iodixanol) and 5 mL 0.9% saline, was slowly injected by hand through the trocar. Imaging using fluoroscopy showed the location at which the axillary vein joined the right subclavian vein (point A), the path of the subclavian vein and its mid point (point B), and its position relative to the clavicle, ribs, and other anatomical structures. The fluoroscopy image was saved (Fig. 1). If any cause of venous occlusion was present, the procedure was moved to the opposite side.

2.3. Venipuncture

Combined with the saved fluoroscopy image, points A and B were marked on the patient's body under fluoroscopy, and connected by a line that extended to the shoulder joint (Fig. 2). Following adequate skin disinfection and local anesthesia, venipuncture was performed using a 21 G micropuncture needle. The skin entry point was selected on the line extending between point A and B, which was close to the lateral one-third of the clavicle. The subclavian vein between the 2 points was the puncture target, with the micropuncture needle entering at an angle of 10 to 20° from the chest wall, coinciding with the line between point A and B. The venipuncture was successful when dark red, nonpulsating blood was drawn back by the micropuncture needle. If the venipuncture needle was blocked by the clavicle or the puncture was unsuccessful, the venipuncture depth and the entry angle of the venipuncture needle were adjusted accordingly.

2.3.1. Modifications to the procedure. If venipuncture was still unsuccessful, the following 3 methods could be used. First, using

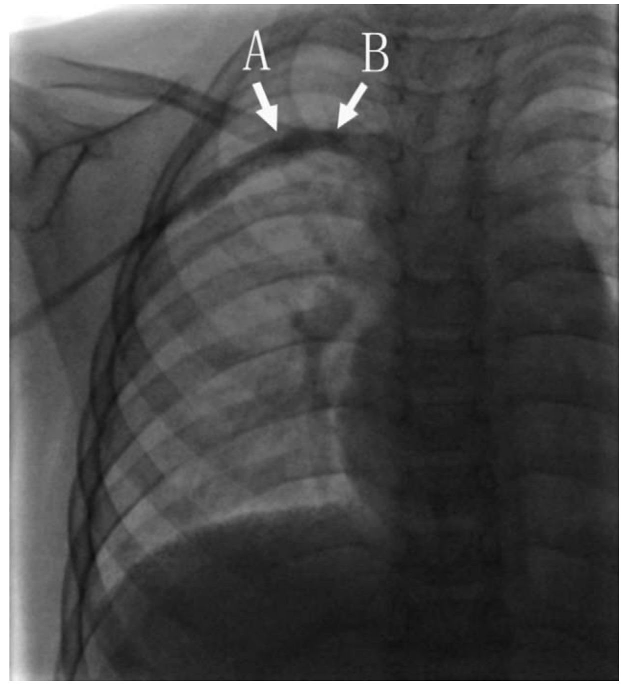

Figure 1. Imaging using fluoroscopy showed the right subclavian venous. Point A: the axillary vein joined the right subclavian vein. Point B: the midpoint of subclavian venous.

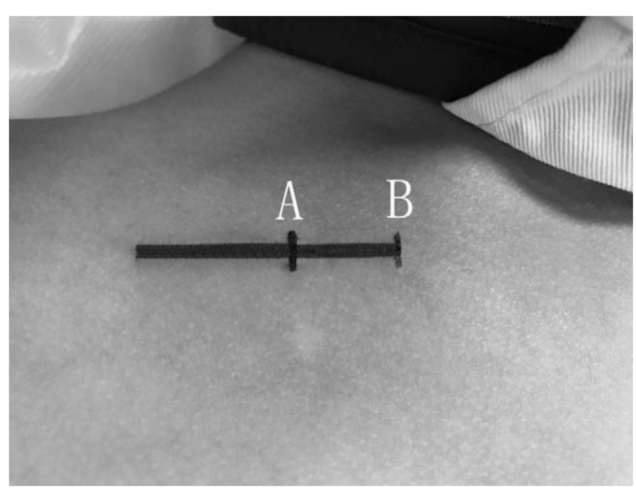

Figure 2. The line combined with point A and B was marked on the patient's body.

Table 1

The characteristics of children included in this study.

Pt No	Age*	Male No	Female No	Diagnosis (No)						
				MA	AML	AA	ALL	MDS	CML	ALD
203	6.99	130	73	145	16	15	14	7	3	3

AA = aplastic anemia, ALD = adrenoleukodystrophy, ALL = acute lymphoblastic leukemia, AML = acute myeloid leukemia, CML = chronic myeloid leukemia, MA = β-thalassemia, MDS = myelodysplastic syndromes, No = number.
* Years.

the saved radiographic image, and according to the anatomical location of the subclavian vein, clavicle, and rib cage, the direction of the venipuncture was adjusted under fluoroscopic guidance. Second, if the venipuncture was unsuccessful, the needle was kept in place, and contrast agent was injected again via the indwelling trocar to develop an image of the subclavian vein catheterization and to understand the positional relationship with the micropuncture needle, which could be adjusted fluoroscopically. Third, the radiograph of the subclavian vein catheterization path could be evaluated under fluoroscopy, and the vein punctured under the guidance of the radiograph.

2.3.2. Fluoroscopic placement of the catheter tip. After successful placement of the catheter, radiography was performed to confirm the position of the catheter tip, which was placed between the superior vena cava and the right atrium, while the side hole was kept as far from the catheter's entry point in the subclavian vein as possible. The angle formed by contact between the catheter and the superior vena cava was avoided. When the position of the catheter was confirmed, heparinized saline was injected to prevent thrombus formation in the catheter.

2.3.3. Data documentation. The catheter was locally fixed, catheter depth was recorded, and a dressing plaster was used to cover the catheter and the puncture point in the skin. Finally, fluoroscopic chest imaging was performed to monitor for pneumothorax and hemopneumothorax.

During the operation, the total number of punctures, fluoroscopy time, operation time (from local anesthesia to successful catheterization), intraoperative observations, and complications were recorded by the same nurse. Complications during intraoperative artery puncture included local hematoma, arrhythmia, pneumothorax, hemopneumothorax, and mediastinal hematoma. Catheter-related infection and catheter-related thrombosis (CRT) during the postoperative stage of catheter use were also documented.

2.3.4. Patient follow-up. Following the patient's return to the ward, the catheter depth was recorded every day, heparinized saline was used to flush and seal the catheter, and the dressing was changed twice each week. Patient follow-up included the time between successful venous catheterization and the end of treatment when the catheter was removed.

3. Results

3.1. Patients

Between October 2013 and October 2016, fluoroscopy-guided subclavian vein catheterization was performed for a total of 203 children with hematologic disease. The pediatric patients were between 1 and 16 years old (mean, 6.99 years ± 3.722 years). There were 130 male and 73 female. Of the 203 patients, there were 145 children with severe β-thalassemia, 15 children with severe aplastic anemia, 14 children with acute lymphoblastic leukemia and 29 children with other blood diseases (Table 1).

3.2. Fluoroscopy-guided subclavian vein catheterization procedure

The venipunctures were performed for 130 patients under intravenous anesthesia combined with local anesthesia at the venipuncture point; 73 patients received only local anesthesia. In 200 cases, the venipuncture and catheterization were performed in the right subclavian vein. In 3 cases, the angiography showed that the right subclavian vein was either occluded or too narrow, and venipunctures were performed at the left subclavian vein.

Venipuncture and catheterization were successfully performed for all 203 children (100%). A total of 124 cases (61.1%) were successful on the first venipuncture attempt; 171 cases (84.2%) achieved success within 3 attempts. There were 25 cases of successful venipuncture with between 4 and 6 attempts, 5 cases of success with 7 attempts, and 2 cases where ten attempts were required. None of the venipunctures required a switch to the left side. The shortest procedure time was 5 minutes, in 33 cases; the longest was 30 minutes, in 2 cases; within 10 minutes in 142 cases (70.1%); and between 10 and 20 minutes in 56 cases, and longer than 20 minutes in 5 cases. The longest fluoroscopy time was 10 minutes, in 2 cases (Table 2).

3.3. Complications

The only intraoperative complication that occurred was right subclavian artery puncture (twice each for 2 patients), but there was no postoperative hematoma. All patients showed no signs of hematoma, hemopneumothorax, cardiac arrhythmias, or other complications.

Table 2

The data of result.

Venipuncture attempt	1	<3	4–6	7	10
No	124 (61.1%)	171 (84.2%)	25 (12.3%)	5	2
Procedure time	5 min	<10 min	10–20 min	>20 min	30 min
No	33 (16.3%)	142 (70.1%)	56 (27.6%)	5	2

No = number.

3.4. Follow-up

The mean follow-up time was ± 35 days: range 20 to 50 days. In the course of catheter use, catheter-related infections occurred in 2 cases; no arrhythmias or catheter-related thrombosis occurred.

4. Discussion

Children with hematologic disease often need treatments with cytotoxic drugs that are delivered intravenously by infusion via a central venous catheter. Because pediatric patients have small-caliber blood vessels, there may be difficulty in catheterization of the subclavian vein, with complications including bleeding, pneumothorax, or hemopneumothorax.[1,5]

One drawback of anatomical positioning-based venous catheterization is the inability to identify clearly the venipuncture target and peripheral tissues, leading to more procedural complications.[1,3,6] Currently, operators may use ultrasound-guided approach to determine the position of vascular, improve the success rate of the venipuncture. However, there are still many departments in China that do not have the right conditions to carry out ultrasound-guided venipuncture. So fluoroscopy-guided subclavian vein catheterization were created for the first time and applied to practice. The skin entry point, puncture direction, and puncture target can be determined postfluoroscopy. Compared with the traditional landmark catheterization, a determined puncture target can raise the success rate of catheterization and reduce the complication rate without the help of US. Fluoroscopy-based guidance allows better control of venipuncture depth, the incidence of accidental arterial puncture was also low in the present study. A success rate of 45% with a single venipuncture attempt and 74% with 3 venipuncture attempts of traditional method were reported by Bruzoni et al.[5] The success rate of the fluoroscopy-guided catheterization in this study was 61.1% with a single venipuncture attempt and 84.2% with 3 venipuncture attempts. When compared the above 2, fluoroscopy-guided method has a considerable advantage over traditional method in terms of visualization, thereby increasing the success rate and decreasing the venipuncture attempts. Additionally, in the study by Bruzoni et al,[5] both the anatomical landmark method and the ultrasound-guided method had an approximately 4.5% complication rate.[5] In contrast, no postoperative complications were reported in the present study.

Another drawback of anatomical positioning-based venous catheterization is the risk of catheter misplacement in the operation. Complications of catheter tip malposition include cardiac perforation and tamponade, cardiac arrhythmias, and catheter-induced thrombosis.[12] precise and suitable placement of the catheter tip are important for preventing complications such as cardiac arrhythmias or postoperative CRT.[10–14] According to the study by Diamanti et al,[15] because of the smaller vascular diameter in children, the possibility of CRT is 20% greater in children than in adults. Interventional radiology societies have published reports that appropriate position of tip is in the superior vena cava (SVC)—right atrium (RA) junction or RA.[16] To date, the most commonly used reference standard to detect CVC malposition is still postprocedural chest radiograph (CXR).[17] Several research studies have used varied US approaches to detect CVC positioning after subclavian and internal jugular CVC placement currently.[10–14] The results show US performed similarly to CXR for the detection of malpositioned subclavian and internal jugular CVCs.[10–14] But looking at the exact data of every study, the accuracy rate of the CXR is slightly higher. It is unknown whether ultrasound can completely replace CXR. On the other side, ultrasound has the intrinsic limitation that it cannot detect the exact placement of the catheter tip inside the thoracic cavity (from the clavicula to the SVC-RA junction).[13] This means that the tip might be anywhere distal the brachiocephalic vein. In the present study, angiography which can show brachiocephalic vein under the DSA was performed to check the exact place of the tip. Fluoroscopy can ensure that the tip of the catheter is in the best position and avoid contact of the catheter with the blood vessel wall in the operation without a delay. No CRT occurred postoperatively in the present study, which supports the advantage of fluoroscopy-guided venipuncture in the placement of the tip of the catheter.

The limitation of the method of fluoroscopy-guided subclavian vein catheterization is that pediatric patients need to be exposed to radiation during the catheterization process. Therefore, protective measures were taken for all pediatric patients, with X-ray radiation exposure time limited to <2 minutes for 90% of the children. In this study, a total of 28 children who were 5 years-of-age and 11 children who were 10 years-of-age were included. Using current guidelines,[18–20] during fluoroscopy-guided catheterization the average radiation dose for each 5-year-old boy was 0.047 ± 0.004 mSv, and the risk coefficient of developing a lethal tumor after exposure was 0.4×10^{-5}; the average radiation dose for each 5-year-old girl was 0.045 ± 0.004 mSv, and the risk coefficient of developing a lethal tumor after exposure was 0.6×10^{-5}.[7,8] The average radiation dose each 10-year-old boy received was 0.029 ± 0.005 mSv, and the risk coefficient of developing a lethal tumor after exposure was 0.2×10^{-5}.[18,20] The average radiation dose each 10-year-old girl received was 0.019 ± 0.003 mSv, and the risk coefficient of developing a lethal tumor after exposure was 0.2×10^{-5}. The radiation risk coefficients for the fluoroscopic procedure and the development of malignant tumors were not significantly different from the incidence rate of pediatric malignant tumors in China, and the small amount of radioactivity received during catheterization was within a range regarded as safe for the patients.

5. Conclusion

Fluoroscopy-guided subclavian vein catheterization in children with hematologic disease ensures a higher success rate, requires fewer venipuncture attempts, and improves the proper placement of the catheter tip. The dose of the radiation exposed in operation is safe for children. But some further comparative randomized studies about fluoroscopy-guided approach are needed in the future.

Author contributions

Acquisition of data: Huajin Pang, Peng Ye
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Critical revision: Yong Chen
Data curation: Xiaofeng He, Peng Ye.
Drafting of manuscript: Huajin Pang
Investigation: Qingle Zeng.
Study conception and design: Huajin Pang, Yong Chen
Writing – original draft: Huajin Pang.
Writing – review & editing: Yong Chen.

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