Original Article

Less Invasive Cardiac Catheterization via Carotid Artery Puncture Using a 3-French Sheath System in Children

Mizuhiko Ishigaki, MD, Sung-Hae Kim, MD, Takehiro Tanabe, MD, Keisuke Sato, MD, Jun Yoshimoto, MD, Norie Mitsushita, MD, Masaki Nii, MD, PhD, and Yasuhiko Tanaka, MD

Department of Cardiology, Shizuoka Children's Hospital, Shizuoka, Japan

Background: A carotid artery approach is advantageous for cardiac catheterization in infants and children. Conventionally, the surgical cutdown access method is popular; however, recent advancements in medical device technology have led to the development of the percutaneous carotid access method. This study aimed to evaluate the advantages and safety of percutaneous carotid access using 3-French sheath compared with those of surgical cutdown access.

Methods: We retrospectively reviewed data of 17 children who underwent cardiac catheterization via the carotid access approach between January 2003 and April 2021. Patients were divided into two groups: those who underwent surgical cutdown (Cutdown group, 2003–2013; $n=10$) and those who underwent percutaneous carotid access (Puncture group, 2014–2021; $n=7$).

Results: The median ages at the time of procedure were 2 months and 1 month in the Cutdown and Puncture groups, respectively ($p=0.13$). In the Cutdown group, three, four, and three patients required sheath sizes 3-French, 4-French, and 5-French or larger, respectively; on the other hand, a 3-French sheath was used in all patients in the Puncture group. The median time to vascular access and that from sheath removal to exit the room were 33 min and 36 min in the Cutdown group, and 3 min and 25 min in the Puncture group, respectively ($p=0.01$). No patients exhibited complications related to vascular access.

Conclusions: The percutaneous carotid access approach with a 3-French sheath in infants has the potential to reduce procedure time and to provide a comparable or safer, less invasive catheterization than with the conventional method.

Keywords: carotid artery approach, percutaneous carotid access, surgical cutdown, 3-french sheath, less invasiveness

Introduction

The carotid artery access approach in cardiac catheterization is advantageous for infants and children if a femoral artery approach is not feasible. The carotid access with surgical cutdown technique for pediatric cardiac catheterization was first reported in 1973.[1] Since the 1990s, several studies have reported the usefulness of the carotid surgical cutdown approach in balloon valvuloplasty for aortic stenosis,[2, 3] establishing it as an alternative to femoral access for pediatric catheterization. Since the 2000s, percutaneous access via the carotid artery has been used in neurosurgery.[4]

In our hospital, the carotid artery access was selected in the following two situations: 1) a poor angle of approach for intervention and 2) high risk of vascular trauma from femoral artery access, e.g., low bodyweight such as less than 2000 g. In the case of the carotid access approach, since 2014, our hospital has utilized the percutaneous access with a 3-French sheath as an alternative

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Corresponding author: Mizuhiko Ishigaki, MD, Department of Cardiology, Shizuoka Children's Hospital, 860 Urushiyama Aoi-ku, Shizuoka 420–8660, Japan
E-mail: mizu.ishi.917@gmail.co.jp
ORCiD: Mizuhiko Ishigaki (https://orcid.org/0000-0002-1424-786X)
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to the surgical cutdown access to cardiac catheterization.

In this study, we evaluated advantages and safety of percutaneous carotid access compared with those of surgical cutdown access as a historical control.

Materials and Methods

We retrospectively reviewed the records of pediatric patients who underwent cardiac catheterization via the carotid artery approach between January 2003 and April 2021. Patients were divided into two groups according to the method of vascular access: the Cutdown group comprised those who underwent surgical cutdown access before 2013, and the Puncture group comprised those who underwent percutaneous carotid access since 2014. In the Puncture group, a 3-French sheath was used in all cases to ensure hemostasis. In addition, since 2014, no one had undergone surgical cutdown access, i.e., no patient required a large-bore sheath of 4-French or greater. Furthermore, there were no cases of axillary approach since this method was not yet used in our hospital at this time.

In the Puncture group, the 3-French sheath used was the Medikit Super sheath (Medikit Corporation, Tokyo, Japan), and punctures were performed with the supplied 22G puncture needles and 0.025-inch wires by the pediatric cardiologist. All patients underwent echo-guided puncture with only the anterior wall, not Seldinger technique, under general anesthesia. The echocardiography used was SonoSite (Fujifilm Corporation, Tokyo, Japan) with linear probe and a frequency of 13 MHz. Heparin was used at 50 U/kg and additional doses were administered every hour based on the activated clotting time (ACT), and protamine was not used at the end of the catheterization. In low birth weight infants, the dose was adjusted from 0 to 100 U/kg, with reference to the 200 s of ACT. Hemostasis was achieved by compression hemostasis as usual, i.e., application of pressure until the bleeding stopped, and the patient was intubated overnight due to concerns about rebleeding and airway obstruction by the hematoma. In the case of very low birth weight infants, tobacco sutures were added.

The cutdown was performed by a cardiovascular surgeon, and after exposure of the carotid artery, the sheath was inserted by puncture under direct vision, and hemostasis was achieved by wound closure.

To investigate advantages and safety of percutaneous access in the carotid access approach, we compared the aspects related to the blood access procedure and its complications. We reviewed patient data, including procedure conducted, age and weight at the time of procedure, and sheath size. Moreover, the following data were collected: time required to successful vascular access, sheath dwell time, wound closure time, and time from sheath removal to exit from the catheterization laboratory. Vascular access time was defined as the time from the start of the procedure to sheath insertion. Due to the presence of two different procedures, sheath dwell time, as well as procedure time, fluoroscopy time, and radiation dose were not compared; however, sheath dwell time was indicated in relation to complications. Wound closure time was defined as the time from sheath removal to the end of the surgical procedure. Procedural successes and failures, carotid complications such as stenosis, occlusion, and thrombosis, and any neurological complications were also reviewed. Echocardiography in all patients, and additional computed tomography (CT) in some cases, was performed during follow-up. Values were expressed as median following the range. A Mann–Whitney *U* test was performed to compare the two groups, and a p-value <0.05 was considered significant. This review was approved by the institutional review board of Shizuoka Children's Hospital, and the requirement for informed patient consent was waived due to the study's retrospective design.

Results

Between January 2003 and April 2021, 17 pediatric patients underwent cardiac catheterization via the carotid artery approach. The Puncture group included seven patients who underwent the following procedures between 2014 and 2021: patent ductus arteriosus stenting ($n=2$), pulmonary artery recanalization with or without stent implantation through the modified Blalock–Taussig shunt ($n=3$), and stenting for aortic coarctation in extremely low birth weight infants ($n=3$) (Table 1). Indications for the carotid artery access approach were the following: angle of approach ($n=4$) and high risk of vascular trauma from femoral artery access due to low bodyweight ($n=3$).

The Cutdown group included 10 patients who underwent the following procedures between 2003 and 2011: balloon aortic valvuloplasty ($n=4$), stent implantation to modified Blalock–Taussig shunt ($n=2$), angioplasty at the Damus–Kaye–Stansel anastomosis ($n=1$), pulmonary artery recanalization with stent implantation

Table 1 Characteristics of the Puncture group

Weight (kg)	Diagnosis	Intervention	Indication for the carotid approach
① 4.8	DORV, PA, Trisomy 18	Stent-imp PDA	Angle
② 6.6	LAI, PA, s/p BTS Pulmonary artery occlusion	Recanalization with BAP	Angle
③ 3.3	TGA, PS	Stent-imp PDA	Angle
④ 0.91	CoA	Stent-imp CoA	FA diameter
⑤ 8.4	RAI, PA, MAPCA, s/p BTS, UF Pulmonary artery occlusion	Recanalization with Stent-imp	Angle
⑥ 0.84	CoA	Stent-imp CoA	FA diameter
⑦ 0.50	CoA	Stent-imp CoA	FA diameter

BAP, balloon angioplasty; BTS, modified Blalock–Taussig shunt; CoA, coarctation of the aorta; DORV, double outlet right ventricle; FA, femoral artery; LAI, left isomerism; MAPCA, major aortopulmoary collateral artery; PA, pulmonary atresia; PDA, patent ductus arteriosus; PS, pulmonary stenosis; RAI, right isomerism; Stent-imp, stent implantation; TGA, transposition of great arteries; UF, uniforcalization.

Table 2 Characteristics of the Cutdown group

Weight (kg)	Diagnosis	Intervention	Indication for the carotid approach
① 3.2	cAS	BVP	Angle
② 5.4	SV subAS CoA s/p DKS, CoA repair	BAP to DKS	Angle
③ 3.2	cAS	BVP	Angle
④ 3.2	cAS	BVP	Angle
⑤ 3.6	PAVSD	Stent-imp PDA	Angle
⑥ 2.8	TAC IAA s/p Arch repair, PAP, BTS	Stent-imp BTS	Angle
⑦ 14	PAVSD MAPCA s/p BTS Pulmonary artery occlusion	Recanalization with Stent-imp	Angle
⑧ 2.3	cAS	BVP	Angle
⑨ 26	PAVSD MAPCA s/p BTS, UF Pulmonary artery occlusion	Stent-imp BTS	Angle
⑩ 8.7	Mid-aortic syndrome	Stent-imp CoA	FA diameter

BAP, balloon angioplasty; BTS, modified Blalock–Taussig shunt; BVP, balloon valvuloplasty; cAS, critical aortic stenosis; CoA, coarctation of the aorta; DKS, Damus–Kaye–Stansel anastomosis; FA, femoral artery; IAA, interruption of the aorta; PAP, pulmonary artery plasty; PAVSD, pulmonary atresia with ventricular septal defect; PDA, patent ductus arteriosus; Stent-imp, stent implantation; SV, single ventricle; TAC, truncus arteriosus; UF, uniforcalization.

through the modified Blalock–Taussig shunt ($n=1$), stenting for aortic coarctation ($n=1$), and patent ductus arteriosus stenting ($n=1$) (Table 2). Indications for the carotid artery access approach were the following: angle of approach ($n=9$) and high risk of vascular trauma from femoral artery access ($n=1$).

The vascular access data in this study is summarized in Table 3. The median age of patients at the time of procedure was 2 months (range, 0–162 months) in the Cutdown group and 1 month (range, 0–22 months) in the Puncture group ($p=0.13$). The median weight at the time of procedure was 3.4 kg (range, 2.8–26.5 kg) in the Cutdown group and 3.3 kg (range, 0.50–8.4 kg) in the Puncture group ($p=0.10$). The following sheath sizes were used in the Cutdown group: 3-French ($n=3$), 4-French ($n=4$), and 5-French or larger ($n=3$); on the other hand, a 3-French sheath was used in all patients in the Puncture group. All procedures and cases of percutaneous carotid access were successful. The median time required for vascular access was 33 min (range, 25–52 min) in the Cutdown group and 3 min (range, 2–9 min) in the Puncture group ($p<0.01$). The median sheath dwell time was 175 min (range, 63–252 min) in the Cutdown group and 163 min (range, 49–252 min) in the Puncture group ($p=0.29$). The median time from sheath removal to exit from the catheterization labo-

Table 3 Vascular access data of the two groups

	Cutdown group ($n=10$)	Puncture group ($n=7$)	p-value
Date	2003–2011	2014–2021	
Age (months)	2 (0–162)	1 (0–22)	$p=0.13$
Weight (kg)	3.4 (2.8–26.5)	3.3 (0.50–8.4)	$p=0.10$
Sheath size			
3-Fr	3	7	
4-Fr	4	0	
≥5-Fr	3	0	
Vascular access time (min)	33 (25–52)	3.0 (2–9)	$p<0.01$
Time from sheath removal to exit the room (min)	36 (28–65)	25 (8–45)	$p=0.02$
Complications of vascular access	0	0	

ratory was 36 min (range, 28–65 min) in the Cutdown group and 25 min (range, 8–45 min) in the Puncture group ($p=0.02$). The median time required for wound closure was 24 min (range, 16–40 min) in the Cutdown group. There was no rebleeding or recompression in either group. According to these results, the overall procedure time associated with sheath was shorter for the Puncture group by approximately 40 min. The median follow-up time after catheterization was 95 months (range, 1–213 months) in the Cutdown group and 41 months (range, 0–70 months) in the Puncture group. For imaging of the carotid artery, echocardiography was performed in all patients, and CT was performed in eight patients (80%) in the Cutdown group and five (86%) in the Puncture group during follow-up. No vascular occlusion or stenosis was shown in either group.

Discussion

The carotid access approach with surgical cutdown for pediatric cardiac catheterization was first reported in 1973.[1] Subsequently, because the development of percutaneous puncture sheaths was associated with a reduction in arterial complications, the femoral artery access approach was preferred. In the 1980s, the advancement of catheterization, which required larger sheaths, resulted in an increased incidence of injury and occlusion of the femoral artery.[5] In the 1990s, carotid surgical cutdown access emerged as an alternative to femoral artery access and was performed mainly in cases of neonatal critical aortic stenosis. Since then, carotid access has been predominantly performed as a direct route for interventions such as balloon valvuloplasty for aortic stenosis, patent ductus arteriosus stenting, and Blalock–Taussig shunts,[6] due to the relatively high association between the femoral arterial access approach and arterial occlusion in low-weight infants.

In recent years, studies have reported on the percutaneous carotid access approach[7, 8] but have not compared its procedure time with that of the surgical cutdown access approach. Our study revealed that the overall procedure time for the percutaneous carotid access approach, including time to successful vascular access and from sheath removal to exit from the catheterization laboratory, was reduced by approximately 40 min compared with that of the surgical cutdown approach. This could be due to procedures required in the surgical cutdown method, such as skin incision, exposure of vessel, sheath fixation, and wound closure after sheath removal. This reduction in procedure time would lead to less invasive catheterization, which is an advantage especially in premature and low birth weight infants in poor condition. Furthermore, in these patients, decrease in procedure time could affect systemic management such as anesthesia time and temperature control, which could result in improved safety.

In this study, neither group exhibited thromboembolism or vascular injury. In a previous study, one-third of patients developed severe stenosis or complete occlusion of the carotid artery following surgical cutdown access.[9] In contrast, according to another study following the percutaneous carotid access approach, the carotid artery patency rate was 100%, and the worst case of stenosis demonstrated narrowing of only 12%.[8] However, it was difficult to make direct and accurate comparisons due to the heterogeneity in patients' characteristics. Our study suggests that percutaneous carotid access is as safe in terms of complications as surgical cutdown access. Other advantages of percutaneous carotid access are the aesthetics of the neck and uncomplicated re-access of the same vessel.[7, 8] A disadvantage, if any, is insufficient hemostasis that may result in hematoma formation and tracheal compression.[7] Therefore, we selected the thin

3-French sheath for maximum hemostasis and continued endotracheal intubation until the next day for airway maintenance; this process was successful without any complications. The outer diameter of the 3-French sheath is 1.6 mm, and the cross-sectional area is approximately 70% of that of the 4-French sheath. These characteristics make the 3-French sheath advantageous for pressure hemostasis and prevention of vascular injury.

Advanced medical device technology plays a key role in establishing this access. That is, the development of devices, such as 3-French-compatible catheters, balloons, stents, and coils, and the improvement in image quality of echocardiography for vascular puncture, contribute significantly to successful catheterization with percutaneous carotid access.

Finally, the neonatal carotid artery is reportedly thicker than the femoral artery.[7, 10] As catheterizations for preterm low birth weight infants are expected to increase, percutaneous carotid access may provide a more feasible approach with the advantages of less invasiveness, shorter procedure time, and comparable or improved safety and improved aesthetics.

The limitations of this study include the single-center retrospective design and a small sample size. In addition, since the axillary approach has not yet been implemented in our hospital, we have not been able to compare the carotid approach with the axillary one. Additionally, we conducted clinical thromboembolism monitoring alone, without further objective testing such as magnetic resonance imaging studies, which would definitively exclude clinically silent or subtle thromboembolic events.

In conclusion, the percutaneous carotid access approach using the 3-French sheath introducer could provide a less invasive cardiac catheterization, with equal or improved safety, than the conventional surgical cutdown access approach.

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Conflicts of Interest

None.

Disclosures

None.

Ethical Standards

This study was approved by the Institutional Review Board at Shizuoka Children's Hospital.

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