

Transcatheter Closure of Congenital Coronary Artery Fistulas with a Giant Coronary Artery Aneurysm in Children: Experiences from a Single Center

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Abstract

Background: Transcatheter closure of congenital coronary artery fistulas (CCAFs) is an alternative therapy to surgery; however, data regarding transcatheter closure for CCAF with a giant coronary artery aneurysm (CAA) in pediatric patients are still limited due to the rarity of the disease. We aimed to evaluate the efficacy and safety of transcatheter closure for CCAF with a giant CAA in a pediatric population at a single center.

Methods: Medical records of pediatric patients (<18 years old) who underwent transcatheter closure of CCAF with a giant CAA between April 2007 and September 2016 at Guangdong Cardiovascular Institute (Guangdong, China) were reviewed.

Results: Twelve patients (median age, 6.1 years; range, 1.9–11.0 years) underwent successful transcatheter closure procedures. One patient underwent closure at both the entry and exit points of the CAA, three patients underwent closure at the exit point of the CAA, and eight patients underwent closure at the entry point of the CAA. After a mean follow-up of 7.2 years (range, 0.5–9.8 years), one patient (with closure at the exit point of the CAA) underwent transcatheter re-intervention because of a significant residual shunt. She eventually underwent a surgical procedure due to aneurysm dilation after the second intervention. One patient experienced thrombus formation within the CAA after the procedure. Among those with closure at the entry point of the CAA, a mild-to-moderate residual shunt was detected in three patients.

Conclusions: Transcatheter closure appears to be a safe and effective alternative therapy for CCAF with a giant CAA in the pediatric population. Closure at the entry point of the CAA, and closure at both the entry and exit points when feasible, may reduce the risk of postinterventional complications.

Key words: Aneurysm; Congenital Heart Disease; Coronary Artery Fistula; Pediatric; Percutaneous Closure

INTRODUCTION

Congenital coronary artery fistulas (CCAFs), defined as a communication between a coronary artery and a great vessel or a cardiac chamber,^[1] are a rare anomaly with a reported incidence of 0.1–0.2% among patients who undergo coronary artery angiography.^[2] Clinical complications of CCAF include atrial fibrillation, ventricular arrhythmias, congestive heart failure, infective endocarditis, coronary artery aneurysms (CAAs), and cardiac tamponade due to the spontaneous rupture of a CAA.^[3]

CAA is defined as a coronary dilatation that exceeds the diameter of the adjacent normal arterial segment or the patient's largest coronary artery by 1.5 times.^[4]

Aneurysms >20 mm in diameter can be called a giant CAA. CCAF combined with a giant CAA are a rare entity. Li *et al.*^[5] reported that a giant CAA was found in 5.9% of patients with a CCAF. The prognosis of CCAF with a giant CAA is poor. Therefore, early management is critical.

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Surgical procedures are traditionally viewed as the gold standard treatment for CCAF closure. In the recent years, transcatheter intervention has been considered an alternative to surgery, as it may reduce the risk of myocardial damage and avoid a thoracotomy and the use of cardiopulmonary bypass in some cases.^[4] However, only a few cases of successful catheter intervention for CCAFs with a giant CAA have been reported, and the long-term prognosis remains unclear. Herein, we reported our experience with transcatheter closure of CCAFs with a giant CAA in an exclusively pediatric population to better understand the prognosis and complications encountered in this population.

METHODS

Patients and ethical approval

Twelve patients (five boys, seven girls) under 18 years of age who were scheduled for transcatheter closure of CCAFs with a giant CAA at Guangdong Cardiovascular Institute (Guangdong, China) between April 2007 and September 2016 were included in the study. Patients with additional complex congenital heart diseases were excluded from the study. All patients were confirmed to have a CCAF with a giant CAA through transthoracic echocardiography (ECG) or contrast-enhanced cardiac computed tomography. A retrospective review of all available medical records before and after transcatheter closure was performed. Written informed consent was obtained from the parents of all patients. The study protocol was conducted in accordance with the *Helsinki Declaration* and was approved by the Institutional Review Board of our hospital.

Procedure

All patients underwent percutaneous procedures with general anesthesia and received an intravenous heparin bolus (100 IU/kg). Access was obtained through femoral arterial and/or venous catheters. After obtaining hemodynamic data, aortic root and selected coronary angiography were performed to determine the anatomy, type, origin, and drainage site of the CCAF, as well as the morphology of the CAA and distal coronary branches. The CCAF was classified as proximal- or distal-type, in accordance with a previous study.^[6] Attempted transcatheter occlusion of the CCAF was performed in suitable cases (absence of multiple fistulas, a single narrow drainage site, absence of large branch vessels, and safe accessibility to the coronary artery supplying the fistula). Guidewires, microcatheters, and coronary guidewires were used to access the fistula and create a delivery system. Occlusion devices were deployed through an arterio-venous loop (A-V loop), an arterio-arterial loop (A-A loop), a retrograde arterial approach, or an antegrade venous approach at the optimal occlusion site. Twelve-lead electrocardiography was monitored for 10–15 min after device deployment as an occlusion test. Selective coronary angiography was performed to assess the presence of a coronary branch occlusion and residual shunting immediately after deployment.

Devices

Occlusion devices were chosen based on size and the anatomic features of the optimal occlusion site. Utilized devices included the following: ventricular septal occluder (Lifetech Scientific, Shenzhen, China), atrial septal occluder (Lifetech Scientific), duct occluder (Lifetech Scientific), domestic vascular plug (Lifetech Scientific), Amplatzer duct occluder II (ADO II) (AGA Medical Corporation, Minnesota, USA), Amplatzer vascular plug I/plug II (AGA Medical Corporation, Minnesota, USA), and Cook coils (stainless steel coils or detachable, William Cook Europe, Bjaeverskov, Denmark).

Follow-up

A chest X-ray, ECG, and electrocardiography were performed on the 1st day after the procedure to evaluate device displacement or detachment, residual shunting, cardiac arrhythmia, and coronary ischemia. Follow-up data included clinical evaluation, ECG, and electrocardiography obtained at 1, 3, 6, and 12 months during the 1st year and annually thereafter.

Statistical analysis

Continuous variables are expressed as means and standard deviations. Categorical variables are expressed as ratios. Data analysis was conducted with SPSS software version 17.0 (SPSS Inc., Chicago, IL, USA). A $P < 0.05$ was considered statistically significant.

RESULTS

Clinical characteristics are summarized in Table 1. The median age at the time of procedure was 6.1 years (range, 1.9–11.0 years). The mean body weight was 17.16 ± 5.51 kg (range, 9.0–27.0 kg). Eleven patients (11/12) were asymptomatic; one patient (1/12) had chest congestion. A continuous systolic–diastolic murmur was detected in 11 patients (11/12), and a systolic murmur was detected in one patient (1/12). Electrocardiographic findings before the procedure included nonspecific ST- and T-wave changes in three patients (3/12), signs of left ventricular hypertrophy in four patients (4/12), and an incomplete right bundle branch block in three patients (3/12). On transthoracic ECG, both left atrium and left ventricle (LV) dilation were detected in two patients (2/12), LV dilation was detected in four patients (4/12), and right atrium (RA) dilation was detected in two patients (2/12). Left-to-right shunting was estimated using pulmonary-to-systemic blood flow ratio (Qp:Qs) measurements gathered during cardiac catheterization. Available Qp:Qs ratios among the patients ($n = 9$) revealed an average shunt ratio of $(2.1 \pm 0.7):1$ with a range of 1.2:1 to 3.0:1.

CCAF characteristics, CAA size, procedural data, and medication use are presented in Table 2. The CCAF arose from the left coronary artery (LCA) in five patients and arose from the right coronary artery (RCA) in seven patients. All except one CCAF drained into the right side of the heart. The fistula origin was proximal in all the 12 patients.

Table 1: Clinical characteristics of the twelve patients who underwent transcatheter closure of CCAF with a giant CAA

Patient number	Age (years)	Weight (kg)	Gender	Recorded symptoms	Murmurs	Electrocardiographic findings	Chamber dilation in echocardiography	Qp:Qs	Follow-up (years)
1	7.0	16.5	Female	Asymptomatic	Continuous	Normal	None	–	0.4
2	6.1	16.0	Female	Asymptomatic	Continuous	Signs of left ventricular hypertrophy	LA and LV dilation	2.2:1	1.2
3	11	27.0	Male	Asymptomatic	Continuous	Signs of left ventricular hypertrophy	LA and LV dilation	2.7:1	1.4
4	8.9	22.0	Female	Asymptomatic	Continuous	Normal	RA dilation	1.5:1	1.7
5	2.9	13.0	Female	Asymptomatic	Continuous	Normal	None	1.2:1	6.2
6	1.9	9.0	Female	Asymptomatic	Continuous	IRBBB	RA dilation	2.0:1	8.3
7	4.1	16.0	Male	Asymptomatic	Continuous	IRBBB and nonspecific ST-T changes	RA dilation	2.1:1	7.1
8	2.3	10.0	Male	Asymptomatic	Continuous	Signs of left ventricular hypertrophy	LV dilation	–	7.4
9	3.2	15.0	Male	Asymptomatic	Systolic	Normal	None	1.2:1	7.5
10	10.7	25.0	Female	Asymptomatic	Continuous	Signs of left ventricular hypertrophy and nonspecific ST-T changes	LV dilation	2.9:1	8.1
11	6.8	20.0	Male	Chest congestion	Continuous	Nonspecific ST-T changes	RA dilation	3.0:1	9.3
12	4.5	16.0	Female	Asymptomatic	Continuous	IRBBB	None	–	9.8

CCAF: Congenital coronary artery fistula; CAA: Coronary artery aneurysm; Qp:Qs: Pulmonary-to-systemic blood ratio; IRBBB: Incomplete right bundle branch block; LA: Left atrium; LV: Left ventricle; RA: Right atrium; -: Not available.

Table 2: Procedural data in successful closure of the twelve patients

Patient number	Origin site	Drainage site	Type of CCAF	CAA diameter (mm)	Approach	Devices	Device size	Proximal/distal occlusion site of CAA	Aspirin/clopidogrel
1	LCA	LV	Proximal	35.0	A-A loop	AVP II ADO II	12 mm, 4/4 mm	Proximal and distal	+/+
2	LCA	RA	Proximal	20.0	A-V loop	AVP II	12 mm	Proximal	+/+
3	LCA	RA	Proximal	25.0	A-V loop	AVP II	16 mm	Proximal	+/+
4	RCA	RA	Proximal	25.2	A-V loop	AVP II	12 mm	Proximal	+/+
5	RCA	RA	Proximal	20.0	A-V loop	Vascular Plug	8 mm	Proximal	+/0
6	LCA	RA	Proximal	22.0	Retrograde arterial	Coils	6.5–5, 6.5–5, 5–5 coil loops	Distal	+/0
7	RCA	RV	Proximal	35.0	A-V loop	Duct occluder	6/8 mm	Proximal	+/0
8	RCA	RA	Proximal	20.6	Retrograde arterial	AVP I	16 mm	Proximal	+/0
9	LCA	RA	Proximal	34.8	A-V loop	Coils	6.5–5 coil loops	Distal	+/0
10	RCA	RV	Proximal	36.4	A-V loop	Duct occluder	14/16 mm	Distal	+/0
11	RCA	RA	Proximal	37.1	A-V loop	ASD occluder	6 mm	Proximal	+/0
12	RCA	RV	Proximal	35.0	Retrograde arterial	Muscular VSD occluder	7 mm	Proximal	+/0

CCAF: Congenital coronary artery fistula; CAA: Coronary artery aneurysm; LCA: Left coronary artery; RCA: Right coronary artery; LV: Left ventricle; RV: Right ventricle; RA: Right atrium; AVP: Amplatzer vascular plug; ADO: Amplatzer duct occluder; ASD: Atrial septal defect; VSD: Ventricular septal defect; +: Present; 0: Absent; A-A loop: Arterio-arterial loop; A-V loop: Arterio-venous loop.

Transcatheter closure procedures were successfully performed in all cases [Table 2]. A-V or A-A loops were created in ten cases (10/12) and the retrograde arterial approach was used in two cases (2/12). Coils were deployed in two procedures, an Amplatzer vascular plug II (AVP II) was deployed in three procedures, an AVP I was deployed in one procedure, a domestic vascular plug was deployed in one procedure, a duct occluder was deployed in one procedure, an atrial septal occluder was deployed in one procedure, a muscular ventricular septal occluder was deployed in one procedure, and both an AVP II and an ADO II were used in one procedure. On repeated coronary angiography, three

patients had a trivial residual shunt and two had a mild residual shunt immediately after occlusion. All patients received antiplatelet therapy (0.4–2.0 years), eight patients received aspirin, and four patients received aspirin combined with clopidogrel. All the 12 patients were available for follow-up (median, 7.2 years; range, 0.5–9.8 years).

Closure at both the entry and exit points of the coronary artery aneurysm

Patient one underwent the closure procedure at both the entry and exit points of the CAA (1/12). She had a fistula originating from a branch of the intraventricular septum and

draining into the LV with an aneurysm of 32 mm × 35 mm in diameter. The diameters at the exit and entry points of the CAA were 3.5 mm and 7.2 mm, respectively. A primary A-A loop was created with the help of a 2.5-Fr microcatheter (Finecross®, TERUMO, Japan), a 0.014-inch floppy guidewire (Runthrough®, TERUMO, Japan), and a 0.010-inch hydrophilic guidewire (ASAHI Intecc, Japan). The system was then exchanged with a 0.032-inch guidewire and a 5-Fr diagnostic catheter, to create an actual A-A loop. A 6-Fr sheath was delivered through the aneurysm to the fistula drainage site. Occlusion devices were deployed with a 4/4 mm ADO II at the exit point and a 12 mm AVP II at the entry point of the CAA [Figure 1]. Her ECG showed a junctional escape rhythm and aberrant ventricular conduction without apparent ST-T changes at 24 h postprocedure. Her ECG was normal without residual shunting or wall motion abnormality. She was treated with aspirin (5 mg/kg), clopidogrel (1 mg/kg), creatine phosphate sodium, and coenzyme Q. Follow-up ECG at 1 and 3 months showed normal sinus rhythm. Follow-up ECG at 3 months showed a reduction in the size of the CAA, while the LCA was still dilated [Figure 2].

Closure at the exit point of the coronary artery aneurysm

Patients 6, 9, and 10 underwent closure at the exit point of the CAA (3/12). Patient 6 had a LCA-to-RA fistula and underwent a second catheter closure at the same occlusion site with coils 1.5 years after the first intervention, mainly due to significant recanalization through the coils. Follow-up ECG revealed that the coils were well located with a trivial residual shunt; however, the diameter of aneurysm increased to 24 mm × 28 mm 1 year after the second intervention. She eventually underwent fistula

ligation and aneurysmectomy to prevent a possible aneurysmal rupture.

Patient 10 had a RCA-to-RV fistula with a giant CAA. Fistula closure was performed distally at the exit point of the CAA using a duct occluder. Thrombosis was detected within the aneurysm on ECG at the 1-month follow-up [Figure 3]. The patient was asymptomatic and there were no ST-T changes in the ECG. She was treated with antiplatelet therapy (oral aspirin, 3 mg/kg) for 2 years and has remained without symptoms of myocardial ischemia or infarction during the follow-up period.

Patient 9 had a LCA-to-RA fistula, and complete occlusion with coils at the exit point of the CAA was achieved, without any complications during 7.5 years of follow-up.

Closure at the entry point of the coronary artery aneurysm

The remaining eight patients underwent closure at the entry point of the CAA ($n = 8, 8/12$). All of them have remained asymptomatic, without any clinical evidence of aneurysm dilation or thrombus formation after closure. Although a residual shunt was observed in three patients (3/12), no re-intervention or surgical procedures were required. Patients 2 and 4 underwent closure with an AVP II and experienced mild residual flow on follow-up [Figure 4]. In addition, patient 8 underwent closure with an AVP I and experienced moderate residual flow [Figure 4].

DISCUSSION

Given the rarity of CCAFs with a giant CAA, a standard treatment protocol has not been established. Adult cases with successful surgical procedures have been reported.^[7-9] Among these cases, surgical treatment was the most widely used strategy for symptomatic patients, and it was performed to prevent complications such as extension, rupture, thrombosis, and coronary embolization.^[5] In the recent years, with improvements in techniques, devices, and delivery systems, transcatheter CCAF closure has been applied in suitable pediatric cases, and extensive experience has been gained.^[10-12] In the American Heart Association guidelines, transcatheter occlusion is indicated for pediatric patients with symptomatic CCAFs, as well as those with moderate or large CCAFs, without clinical symptoms.^[13] In addition, previous studies have reported that the structural prerequisite

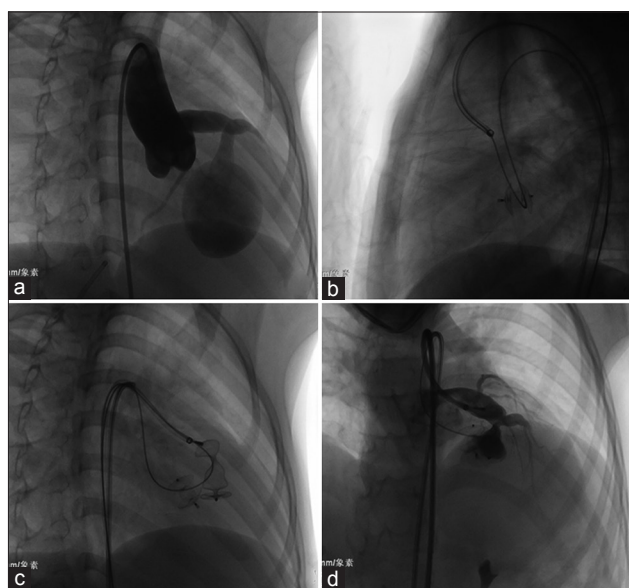


Figure 1: Transcatheter closure of a LCA to LV fistula with a giant CAA (patient 1). (a) Angiography showing a left coronary artery-to-left ventricle fistula with a giant coronary artery aneurysm. (b) A 4/4 mm Amplatzer duct occluder II deployed at the exit point of coronary artery aneurysm. (c) A 12 mm Amplatzer vascular plug II deployed at the entry point of coronary artery aneurysm. (d) Angiography showing no residual shunt after closure.

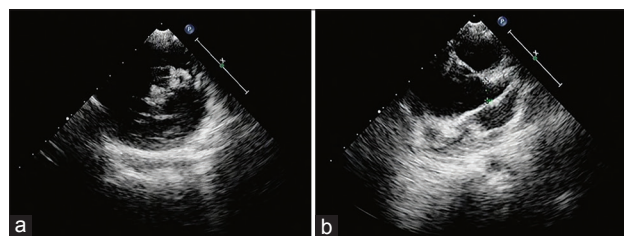


Figure 2: Echocardiographic follow-up results of patient 1. (a) Electrocardiogram showing a reduction in the size of coronary artery aneurysm 3 months after closure procedure. (b) Left coronary artery was still dilated after closure procedure.

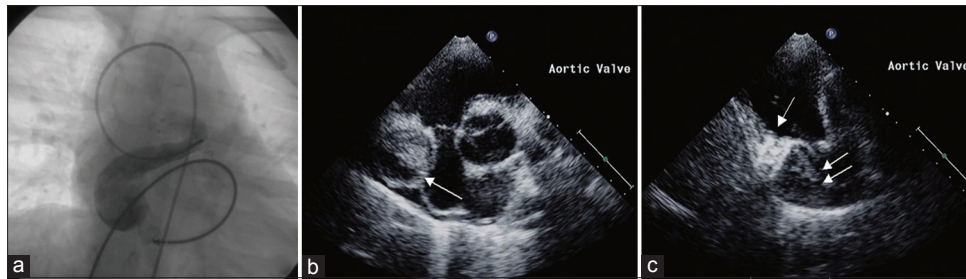


Figure 3: Transcatheter closure and echocardiographic follow-up results of a RCA to RV fistula with a giant CAA (patient 10). (a) Closure at the exit point of coronary artery aneurysm with a duct occluder. (b) Thrombus formation (arrow) within the aneurysm 1 month after closure procedure. (c) The occluder (arrow) and the thrombus (double arrow) at the dilated residual blind end.

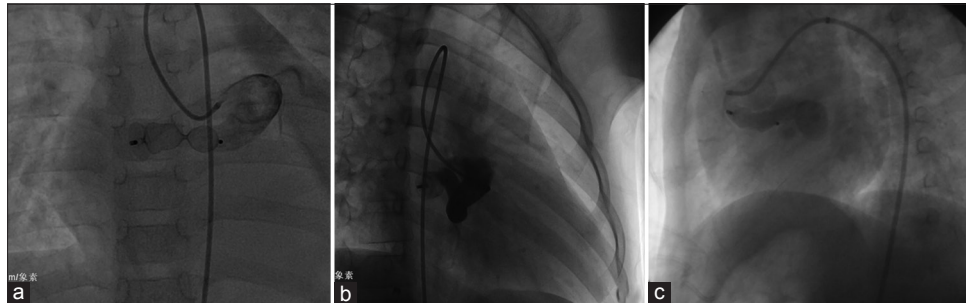


Figure 4: Closure at the entry point of CAA in patients with residual shunt during follow-up. (a) Closure of a left coronary artery-to-right atrium fistula with a 12 mm Amplatzer vascular plug II (patient 2). (b) Closure of a right coronary artery-to-right atrium fistula with a 12 mm Amplatzer vascular plug II (patient 4). (c) Closure of a right coronary artery-to-right atrium fistula with a 16 mm Amplatzer vascular plug I (patient 8).

for the successful transcatheter closure of a CCAF is a single, narrow, restrictive drainage site, without multiple fistulas or excessive tortuosity.^[11,14] However, data are still limited regarding CCAFs with a giant CAA in a pediatric population. To the best of our knowledge, this is the first single-center report of transcatheter closure for CCAFs with a giant CAA in children.

In a study by Gowda *et al.*,^[15] transcatheter closure for proximal-type CCAFs was recommended to be as close to the coronary origin as possible, and closure of the distal end at the same time, when feasible, was suggested to be responsible for the absence of thrombosis. Although closure at the fistulous opening has been suggested for distal-type CCAFs, the procedure remains a clinical and technical challenge. Latson^[6] firstly suggested that large, distal-type CCAFs may be at a higher risk of coronary thrombosis after closure. Furthermore, a study by Gowda *et al.*^[6] indicated that large, distal-type CCAFs are at risk for coronary events postclosure, irrespective of the age of patients. Given that controversy still exists regarding whether to intervene in patients with medium-to-large distal-type CCAFs, such patients were not included in the present study.

In the present study, aneurysm dilation was detected after closure at the exit point of the CAA in a case involving a large proximal LCA-to-RA fistula (patient 6). After the second intervention, progression in aneurysm dilation at the same distal site of the CAA eventually led to surgical treatment, preventing a potential aneurysm rupture. Similarly, Promphan *et al.*^[17] reported progressive aneurysmal dilation 3 years after closure at the exit point of the CAA

in a case involving a large proximal RCA-to-RA fistula. In contrast to our case, a second transcatheter occlusion was performed at the entry point of the CAA; follow-up cardiac computed tomography revealed almost complete aneurysm disappearance after 7 months. The mechanism underlying aneurysmal enlargement remains unclear, but may be due to a high expansion force transmitted from the aorta, or the unusual development of the native coronary artery branches.^[17] For large proximal CCAFs with a CAA, transcatheter closure of both the entry and exit points, to exclude the aneurysm, has been recommended.^[17,18] Our experience with a similar case suggests that closure at the exit point of the CAA may increase the risk of aneurysm dilation, and is not recommended for this type of CCAF.

In the case of patient 1, which involved a large proximal LCA-to-LV fistula, transcatheter closure by the bilateral isolation of the CAA was successfully performed, as recommended in previous studies.^[17,18] During the procedure, an A-A loop was created with the application of a microcatheter and coronary guidewire system. The small diameter of microcatheter and coronary guidewire system, and the ability to run through a tortuous fistula, enabled us to create a safe and efficient delivery approach, while simultaneously reducing the risk of coronary damage. Thus, our experience shows that the application of a microcatheter and coronary guidewire system is feasible in transcatheter closure, especially in situations involving a tortuous fistula and small drainage site.

Among those who underwent closure at the exit point of the CAA, patient 10 had a proximal RCA-to-RV fistula

and experienced a thrombus formation within the dilated aneurysm at 1 month of follow-up. Although the patient received antiplatelet therapy for 2 years, and no adverse coronary events have occurred during the past 8 years, the patient is still not free from the risk of myocardial infarction. Thrombosis and the development of adverse coronary events after surgical or transcatheter closure of a CCAF have been reported.^[6,19] Thrombosis and thrombotic embolization are possible due to flow stasis within the blind pouch of the dilated conduit coronary artery after CCAF closure, increasing the risk of thrombosis, the subsequent proximal propagation of the thrombus, and thrombotic obstruction of the associated coronary arteries.^[15,20] Freund *et al.*^[18] reported a case involving the successful transcatheter closure of a CAA with a proximal LCA-to-RA fistula. The authors suggested that a more proximal closure of the CCAF should be performed to reduce the size of the dilated blind pouch of the coronary artery.^[18] Some authors have even suggested closing the CCAF at the narrowest site, just distal to any angiographically observed coronary artery branches, to avoid the formation of blind fistula pouches.^[19] In agreement with previous studies,^[15,18,19] the results of the present study suggest that closure at the exit point of the CAA is not a favorable strategy in the transcatheter closure of proximal-type CCAFs, as a large, blind fistula pouch may carry a greater risk of thrombus formation after closure.

Some may speculate whether closure at the entry point only, rather than closure at both the exit and entry points of the CAA, is sufficient. In the present study, none of the patients who underwent closure at the entry point of the CAA experienced thrombosis or aneurysm dilation. This may be due to a shorter proximal residual dilated coronary artery and the prevention of a large residual aneurysm proximal to the blind pouch. Although the risk of proximal coronary branch obstruction could not be excluded in the proximal closure strategy, the present results indicate that closure at the entry point of the CAA could reduce the risk of thrombus formation and aneurysm dilation, and may be a sufficient transcatheter closure option for this type of CCAF.

Among patients who underwent closure at the entry point of the CAA, the rate of residual shunting was 37.5%, but no re-intervention was required. The rates for residual shunting and re-intervention are variable among published reports.^[3,12,21] Ponthier *et al.*^[3] reported a residual shunt rate of up to 31% after transcatheter closure and a rate of 50% after surgical ligation over a 10-year follow-up period. Freedom from re-intervention was reported to be 89% in pediatric patients at 6 years.^[3] In a study by Mottin *et al.*,^[12] 8 out of 38 patients (21%), who had a complete transcatheter occlusion, experienced fistula recanalization at 2 years of follow-up. In addition, four out of eight patients (50%) required a second intervention, including one surgical procedure and three transcatheter re-interventions. In our series, the three cases with residual shunting were all occluded with AVPs. AVPs are built with nitinol mesh

containing different number of layers.^[22] The plug with fibrin deposition may be less effective than other devices that use polyester fabrics.^[23] This feature of AVPs may partly explain the reason for our higher residual shunt rate compared to that in previous studies. Despite the relatively high recanalization rate, the follow-up in the patients who underwent closure at the entry point of the CAA was uneventful, without any major complications. Overall, the present results demonstrate that transcatheter closure at the entry point of the CAA is feasible and could be an effective alternative therapy for pediatric patients.

Some limitations of the present study should be noted. First, the study was retrospective in nature and involved a small number of patients from a single center, rendering the results susceptible to certain biases. Second, not all occlusion devices were available during the first several years of the study, which may have had adverse effects on the performance and follow-up results. Third, the anatomic and functional evaluations of the coronary arteries were limited and incomplete during the follow-up period; thus, more detailed anatomic and functional studies of the coronary arteries are warranted in future studies. Fourth, the study population was strictly selected; thus, the results should be extrapolated with caution.

In conclusion, the results of the present study demonstrate that transcatheter closure is a safe and effective alternative therapy for CCAF with a giant CAA in pediatric patients. Closure at the entry point of the CAA, and closure at both the entry and exit points of the CAA when feasible, may reduce the risk of postinterventional complications. Future studies with larger sample sizes and more detailed anatomic and functional studies of the coronary arteries following transcatheter closure procedures are warranted.

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Conflicts of interest

There are no conflicts of interest.

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