Outcome of coronary artery bypass grafting performed in young children

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Objectives: The long-term patency rate of coronary artery bypass grafting for which arterial grafts are used is known to be high in the pediatric population. However, this issue remains uncertain in children under 3 years of age. Here, we report the outcome in this specific population.

Methods: From July 1988 to July 2007, 18 children less than 3 years of age (age at operation, 0.1–35 months; median, 4 months) underwent 20 coronary artery bypass graft operations using an arterial graft. Indications for bypass grafting were coronary artery complications related to the arterial switch operation for transposition of the great arteries in 12 patients (coronary obstruction in 8 patients, perioperative coronary anomalies precluding coronary transfer in 4 patients), congenital anomalies of the coronary arteries in 4 patients, and Kawasaki disease in 2 patients.

Results: After a mean follow-up of 55 months (range, 1–176 months; median, 41 months), patency of 19 bypass grafts was assessed. One was occluded and 2 have necessitated a percutaneous procedure. Two patients died suddenly (1 with an occluded graft and 1 with a patent graft and hypertrophic cardiomyopathy) 3.5 and 4.6 months, respectively, after bypass grafting.

Conclusions: Coronary artery bypass grafting should be considered as a possible alternative for coronary revascularization in young children. Although our series shows quite a good patency rate, this procedure remains a technical challenge and requires careful follow-up. (*J Thorac Cardiovasc Surg* 2010;139:349-53)

Long-term outcome of coronary artery bypass grafting (CABG) performed in children has been mostly reported in patients with coronary complications after Kawasaki disease.¹⁻⁵ Two large Japanese studies reported a high patency rate in children older than 10 years; however, this rate was less satisfactory in younger children.^{3,5} Coronary complications have been extensively described after the arterial switch operation (ASO) for transposition of the great arteries (TGA) as well as late after repair of congenital anomalies of coronary arteries. Short series describe the outcome of coronary revascularization in these settings,⁶⁻⁸ but little is known about the outcome of CABG in very young children. We report herein our experience with CABG in this specific population.

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METHODS

We retrospectively analyzed all the patients less than 3 years of age who underwent CABG with an arterial graft between July 1988 and July 2007. The following data were collected before CABG: age, previous surgical procedure, type of coronary obstruction (occlusion or stenosis), ischemic events preceding surgery, and left ventricular ejection fraction (LVEF). We collected follow-up data in 5 pediatric cardiology centers and evaluated cardiac events: myocardial ischemia (on treadmill test or myocardial scintigraphy when performed), death, cardiac transplantation, patency of CABG by imaging, LVEF, and need for subsequent coronary interventions. Post-operative status of the CABG (using angiography or computed tomographic scan) was classified as patent or occluded. Stenotic CABG was considered as patent.

RESULTS

Population

Twenty CABG operations with arterial grafts were performed in 18 children. Age at operation ranged from 0.1 to 35 months (mean 12 months, median 4 months).

Indications for CABG and Preoperative Status (Table 1)

Four patients underwent CABG during the ASO for TGA because of coronary artery transfer difficulties or because of intramural course with congenital coronary artery stenosis. Eight patients had revascularization for ischemia or myocardial infarction related to post-ASO coronary lesion. Of these 8 patients, 6 had ischemia on the electrocardiogram with left ventricular dysfunction in 2 and cardiac failure in 1. The 2

Abbreviations and Acronyms

ASO	= arterial switch operation
CABG	= coronary artery bypass grafting
LVEF	= left ventricular ejection fraction
RCA	= right coronary artery
TGA	= transposition of the great arteries

other patients had an unexpected coronary stenosis diagnosed by coronary angiography with signs of ischemia on scintigraphy.

Indication for CABG was congenital coronary artery anomaly in 4 patients with myocardial infarction and cardiac failure in 3 (2 with anomalous origin of the left coronary artery arising from the pulmonary artery and 1 with ostial atresia of the left coronary) and ischemia on scintigraphy in 1 patient. This last patient, with Noonan syndrome (No. 16), had a modified Konno operation for hypertrophic cardiomyopathy. During this procedure, the right coronary artery (RCA) was found to be stenotic with an intramural and inter-aortopulmonary course, and a surgical angioplasty was performed. One month later, severe stenosis of the RCA was found on coronary angiography with myocardial ischemia on perfusion imaging studies, treated with a CABG.

Finally, 4 CABGs were performed in 2 patients with Kawasaki disease. Indications were myocardial infarction and ischemia with left ventricular dysfunction.

Surgical Procedure

Twenty CABGs were performed in 18 children: 16 children underwent 1 CABG and the 2 patients with Kawasaki disease had 2 CABGs on the right and the left coronary arteries (Table 1). The internal thoracic artery was used in all patients but one who had RCA revascularization with a right subclavian artery free graft. In most cases, continuous 9-0 Prolene polypropylene sutures (Ethicon, Inc, Somerville, NJ) were used. The entire length of the internal thoracic artery, whose diameter is quite large and adapted to that of the coronary, is needed to reach the proximal or the midsegment of the left anterior descending coronary artery. There was no operative death. All patients received aspirin after CABG.

Follow-up (Table 2)

Mean follow-up was 54 months (range, 1–175 months; median, 41 months). Control studies of CABG were performed in 17 of 18 patients: by catheterization in 12 patients, by computed tomographic angiogram in 4, and by both in 1 patient. Two patients died suddenly. The first patient (no. 2) had CABG on the RCA during ASO. Early postoperative angiographic monitoring of the CABG showed an involution of the graft by a competitive flow from the native coronary

artery, and it was the only one that was considered as occluded. There was, however, no evidence of myocardial ischemia either at echocardiography or at electrocardiography during the follow-up. He died suddenly 4 months postoperatively. The second patient (no. 16) is the one who underwent CABG for stenosis after surgical angioplasty of the RCA with an intramural course. An early angiographic study showed a patent CABG but death occurred suddenly 3 months later.

One patient with Kawasaki disease (no. 17) underwent heart transplantation 1 year after CABG for severe ischemic cardiomyopathy. Before transplantation, CABG monitoring showed a stenosis at the site of the anastomosis on one of the two grafts.

The remaining 15 patients were alive and asymptomatic at last follow-up. Preoperative cardiac failure had resolved after CABG. LVEF was greater than 50% and the electrocardiogram showed normal findings in all; however, myocardial ischemia on myocardial perfusion imaging studies was found in 5 patients: 2 had a CABG stenosis and 3 had patent CABGs. Of the 2 patients with stenosis and myocardial ischemia on scintigraphy, 1 patient (no. 15) had a successful dilatation of the CABG stenosis without residual myocardial ischemia on treadmill test at last follow-up. The second patient (no. 9) with moderate CABG stenosis was treated with β -blockers, and a successful percutaneous stenting of the lesion of the native coronary artery causing CABG occlusion was performed. The residual ischemia disappeared a few months later. Of the 3 patients without CABG stenosis, 1 (no. 3) was treated with β -blockers with a minimal residual myocardial perfusion defect at scintigraphy 6 years later. In the 2 others (nos. 4 and 11), moderate residual ischemia at scintigraphy remained at the last follow-up.

DISCUSSION

The largest clinical experience of CABG in children was gained in Kawasaki disease. However, the need for coronary artery revascularization has extended recently to new indications, namely, late coronary obstruction after either coronary transfer during ASO for TGA or after coronary reimplantation for isolated coronary artery anomalies. CABG⁶⁻¹⁵ or direct angioplasty¹⁶⁻²⁰ has been used in these conditions. The technique used for coronary artery revascularization depends on various factors: coronary artery anatomy, previous surgery, LVEF, and surgical experience. Large studies in Kawasaki disease report a lower patency rate of CABG in children less than 10 years of age than in older children.^{3,5} In Kawasaki disease and particularly in younger children, the inflammatory process and/or active coronary artery remodeling might influence CABG patency.^{21,22} In congenital or postoperatively acquired coronary artery obstructions, there is no alteration of coronary artery wall except at the site of the obstruction. In most cases of coronary artery

TABLE 1. Preoperative and peroperative data of the population

	Patient No.	Age	Prior surgery	Type of coronary artery obstruction	CABG type
<i>CABG related to ASO</i>					
Peroperative (ASO)	1	0.1 mo	None	Intramural LAD, wound of the LAD	LITA to LAD
	2	0.3 mo	None	Technical problem with RCA implantation	RITA to RCA
	3	0.4 mo	None	ostial atresia of LAD	LITA to LAD
	4	2.5 mo	None	Technical problem with RCA implantation	Right subclavian artery free graft on RCA
Coronary artery obstruction	5	0.4 mo	ASO	Critical stenosis of LAD	LITA to LAD
	6	2.1 mo	ASO	Critical stenosis of LMCA	LITA to LAD
	7	2.8 mo	ASO	Critical stenosis of LMCA	LITA to LAD
	8	3.7 mo	ASO	Critical stenosis of LAD	LITA to LAD
	9	4.7 mo	ASO	Occlusion of LAD	LITA to LAD
	10	11.2 mo	ASO	Critical stenosis of LAD	LITA to LAD
	11	1.7 y	ASO	Occlusion of LCA	LITA to LAD
	12	2.9 y	ASO	Occlusion of LAD	LITA to LAD
<i>Congenital coronary anomalies</i>					
ALCAPA	13	2.5 mo	Coronary reimplantation	Critical stenosis of LMCA	LITA to LAD
	14	10.9 mo	Coronary reimplantation	Occlusion of LMCA	LITA to LAD
Ostial atresia	15	2.3 y	None	Ostial atresia of LMCA	LITA to LAD
Interarterial RCA	16	2.6 y	Surgical angioplasty	Critical stenosis of RCA	RITA to RCA
<i>Kawasaki disease</i>	17	1.9 y	None	Bilateral giant aneurysms. Occlusion of RAD and critical stenosis of LAD	LITA to LAD RITA to RCA
	18	2.5 y	None	Bilateral giant aneurysms. Occlusion of LAD	LITA to LAD RITA to RCA

ALCAPA, Anomalous origin of the left coronary artery arising from the pulmonary artery; ASO, arterial switch operation; CABG, coronary artery bypass graft(ing); LAD, left anterior descending coronary artery; LITA, left internal thoracic artery; LMCA, left main coronary artery; RCA, right coronary artery; RITA, right internal thoracic artery.

obstruction after coronary artery surgical transfer, the preferred technique for coronary artery revascularization was surgical angioplasty of main coronary arteries as reported by one of the centers taking part in this study.¹⁶⁻¹⁸ However, in the 18 cases reported here, CABG was used either because coronary artery anatomy precluded angioplasty of the ostium or because the coronary artery lesion extended beyond the first segment. We chose to report only on patients between 1 day and 3 years of age because of the technical difficulties suspected to be related to the size of the coronary artery and also because most coronary artery obstructions, either congenital or postoperative, are diagnosed in this age range.

As expected, 16 of 18 patients who underwent CABG had acquired or congenital coronary artery obstruction and only 2 had very severe Kawasaki disease with multiple coronary obstructions and bilateral giant aneurysms. Excluding these 2 patients with Kawasaki disease, two indications for coronary artery revascularization using CABG could be identified in our series. The first is CABG performed as a salvage procedure during coronary artery transfer (4 ASOs and 1 ostial atresia) because the anatomy of the coronary artery precluded coronary artery transfer or surgical an-

gioplasty. Urgent coronary artery revascularization appears to be the most valuable solution in the setting of intraoperative or early postoperative ischemic events owing to coronary artery dysfunction. This indication has been reported previously, and short-term follow-up is satisfactory.⁸⁻¹⁵ The second indication is coronary artery revascularization for coronary obstruction after surgical transfer or reimplantation. Different series reported coronary artery revascularization for coronary obstruction after ASO or coronary artery reimplantation in congenital anomalies of coronary arteries. Both coronary artery angioplasty¹⁶⁻²⁰ and CABG⁶⁻⁸ have been used in these patients. Only a small proportion of children whose cases were reported in these series were less than 3 years of age. Finally, in Kawasaki disease, CABG is the only surgical technique available inasmuch as coronary stenoses are diffuse and associated with aneurysms.

Patency of the CABG was assessed by catheterization or computed tomographic angiography.²³ One of the 19 monitored CABGs was occluded at follow-up. This proportion is better than the patency rate reported in children less than 10 years of age who had arterial CABGs in Kawasaki disease, and it is the same as that of those up to 10 years of age.^{3,5} Flow competition between the bypass graft and the

TABLE 2. Outcome of CABG and cardiac events

Patient no.	Graft control	Cardiac events	Coronary intervention	Follow-up
1	Patent			11.7 y
2	Occluded	Sudden death		4.6 mo
3	Patent	Transient ischemia		5.9 y
4	Patent	Moderate ischemia		14.6 y
5	Patent			1.3 y
6	Stenotic			6.6 y
7	Patent			3.9 mo
8	Patent			1.4 y
9	Stenotic	Ischemia	Catheter intervention	1 y
10	Patent			3.3 y
11	Patent	Moderate ischemia		7.2 mo
12	NC			3.5 y
13	Patent			3.8 y
14	Patent			1.5 y
15	Stenotic	Ischemia	Catheter intervention	11.3 y
16	Patent	Sudden death		4 mo
17	Patent Stenotic	Cardiac transplantation		1.1 y
18	Patent Patent			11.5 y

NC, Not controlled.

native coronary artery is responsible for the occlusion of the CABG. This mechanism has been reported as being a major risk factor for graft occlusion in adults.²⁴ In addition, 1 of our patients died suddenly although his CABG was considered patent. However, this event may not be related to CABG obstruction because the patient had hypertrophic cardiomyopathy, which is by itself a risk factor for sudden death.

On the other hand, 4 of the 19 monitored CABGs were stenotic, with myocardial ischemia at scintigraphy in 3 patients (while taking into account patient 17). Three other patients had persistent moderate myocardial ischemia without CABG stenosis, which disappeared in 1 patient. It is often difficult to know whether persistent ischemia should be attributed to stenosis of a CABG or not. In the case of Kawasaki disease (patient 17), the important myocardial infarction before revascularization could explain at least in part residual myocardial ischemia. Furthermore, some reports have related myocardial perfusion anomalies without coronary obstruction after ASO to bypass damage.²⁵ Myocardial perfusion defect may also be associated with altered coronary flow reserve or with endothelial dysfunction when surgical angioplasty was performed previously.^{26,27}

Considering a subgroup of patients under 1 year of age, underlying coronary diseases are more homogeneous than for the whole series of patients (ie, TGA in 10 patients and anomalous origin of the left coronary artery arising from the pulmonary artery in 2). Rates of coronary complications are comparable, including one occluded graft and one catheter intervention. In patients with post-ASO coronary lesion,

other types of coronary artery revascularization could be proposed when possible (namely, surgical angioplasty or percutaneous dilatation),²⁸ indications depending on local anatomy of the lesion and surgical experience.

In conclusion, CABG should be considered as a possible alternative for coronary revascularization in young children. Although our series shows quite a good patency rate, this procedure requires careful follow-up, especially in case of flow competition between the bypass graft and the native coronary artery.

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