Original Article

Subclavian Artery Reconstruction in Patients Undergoing Coronary Artery Bypass Grafting

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The presence of occlusive disease of the subclavian artery (SCA) proximal to the origin of the internal thoracic artery (ITA) influences the operative strategy and the outcome of coronary artery bypass grafting (CABG). Of 780 patients who underwent CABG, concomitant SCA occlusive lesions were reconstructed in 13 patients (nine males, four females). The affected SCAs were left-sided in 11 patients, and right-sided and bilateral in one, each. An aortoaxillary bypass utilizing an 8-mm PTFE graft was constructed in nine patients and a carotid-subclavian (C-S) transposition in two, simultaneously with CABG. Percutaneous balloon angioplasty with a stent was performed in two patients prior to CABG.

With follow-up periods ranging from 4 to 8.4 years (mean, 6.3 years), aortoaxillary bypass grafts were patent in all patients. Other reconstructive procedures, including a C-S transposition and balloon angioplasty, were performed safely and effectively in off-pump CABG patients. In six patients, the left internal thoracic artery (LITA) could be used as a graft to the coronary artery after SCA reconstruction.

Aortoaxillary bypass using an 8-mm PTFE graft is a safe and effective way for simultaneous subclavian reconstruction in patients undergoing CABG. Mid-term patency of the graft is satisfactory. The LITA can be used as a graft to the coronary arteries in selected patients. Preoperative brachial angiography is mandatory in these patients. (Ann Thorac Cardiovasc Surg 2003; 9: 57–61)

Key words: coronary artery bypass grafting (CABG), subclavian artery (SCA), aortoaxillary bypass, internal thoracic artery (ITA)

Introduction

The internal thoracic artery (ITA) is the primary graft of choice for coronary artery bypass grafting (CABG) because of its proven excellent long-term patency. When subclavian artery (SCA) occlusive disease proximal to the origin of the ITA exists, the ITA cannot be used as a graft to the coronary arteries. If the occlusive lesion is not identified correctly before CABG or if it progresses after the procedure, it may result in reversal of the blood flow through the ITA (coronary-subclavian steal)[1,2] leading to myocardial ischemia. Therefore, the occlusive disease in the proximal segment of the SCA influences the outcome of the patients undergoing CABG. However, there are only a few reports in the literature on this issue.[3,4]

We previously reported our initial experience of the simultaneous SCA reconstructive procedure, i.e., aortoaxillary bypass[5] in patients undergoing CABG. Since then, we have aggressively reconstructed SCA occlusive lesions in these patients to utilize the ITA as a pedicled graft for coronary arteries.

As a simultaneous procedure in the open heart surgery, the proximal axillary artery is very accessible. It does not

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require manipulation of the carotid artery. The proximal axillary artery can be exposed very easily without any fear of possible complications such as injuries to the phrenic nerve, the recurrent laryngeal nerve, the vagus nerve, the cervical sympathetic chain, and the thoracic duct, which are always encountered in the vicinity of the SCA.

In this report we describe the mid-term results of the aortoaxillary bypass procedure and discuss related problems.

Patients and Methods

From March 1993 to May 2001, among 780 patients who underwent CABG at our institute, 13 (1.7%; nine males, four females, aged from 51 to 77 years) underwent concomitant SCA reconstruction.

The presence of an SCA occlusive lesion was suspected when a blood pressure (BP) difference of more than 30 mmHg in the upper arms was present. The diagnosis was confirmed by an additional angiogram taken after the diagnostic coronary angiography in all patients.

Affected SCAs were left-sided in 11 patients, and right-sided and bilateral in one patient, each. The symptoms of the SCA occlusion included those of vertebro-basilar (V-B) insufficiency in seven patients and upper limb ischemia in three. The other three patients only exhibited BP difference in the upper arms (Table 1).

Table 1. Subclavian artery lesion and symptoms

Pt.	Age	Gender	SCA lesion	Symptoms
1	70	M	Lt. occlusion	V-B insufficiency
2	68	M	Rt. stenosis	Upper limb ischemia
3	64	F	Lt. occlusion	V-B insufficiency
4	64	F	Bilat. stenosis	BP difference
5	69	F	Lt. occlusion	Upper limb ischemia
6	69	M	Lt. occlusion	V-B insufficiency
7	66	M	Lt. occlusion	V-B insufficiency
8	51	M	Lt. occlusion	V-B insufficiency
9	69	M	Lt. stenosis	Upper limb ischemia
10	64	M	Lt. stenosis	BP difference
11	77	F	Lt. stenosis	BP difference
12	61	M	Lt. occlusion	V-B insufficiency
13	77	M	Lt. occlusion	V-B insufficiency

SCA: subclavian artery, lt.: left, rt.: right, bilat.: bilateral, V-B: vertebro-basilar, BP: blood pressure

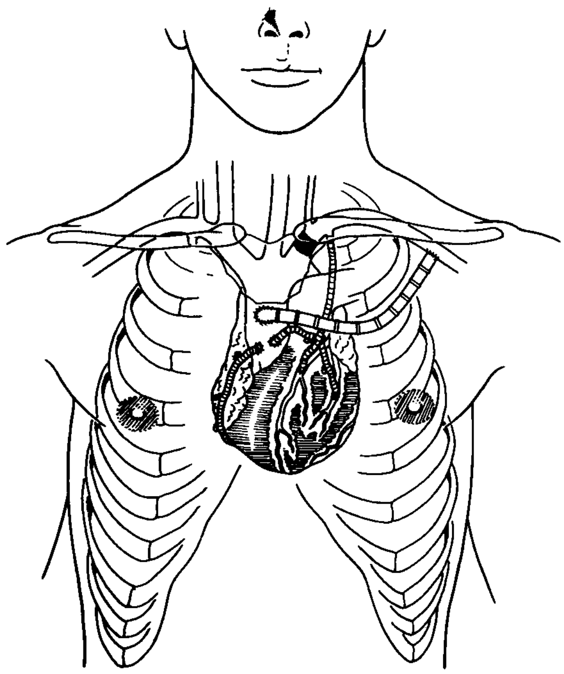

Fig. 1. Schematic drawing of the aortoaxillary bypass. An 8-mm ring-reinforced PTFE graft is anastomosed to the ascending aorta. The graft is led to the subclavicular region through the first or second interspace and is anastomosed to the proximal segment of the axillary artery.

SCA reconstruction

An aortoaxillary bypass using an 8-mm polytetrafluoroethylene (PTFE) graft was performed in nine patients (Fig. 1). Details of the procedure have been described previously.[5] Briefly, a 6- or 7-cm transverse incision was made one fingerbreadth below the clavicle to expose the proximal part of the axillary artery. During a single aortic cross-clamp period, after completion of all the distal anastomosis, a 10-mm transverse incision was made on the anterior aortic wall. An 8-mm ring-reinforced PTFE graft was attached to the aorta perpendicularly. The graft was led to the axillary artery with forceps through the first or second intercostal space extrapleurally and anastomosed to the inferior surface of the artery. On passing the graft through the intercostal space, the fascia and muscles were manipulated digitally to loosen the hole to prevent pinching of the graft.

Carotid-subclavian (C-S) transposition,[6] in which the left SCA is attached directly to the side of the left common carotid artery, was performed in two patients. These procedures were performed simultaneously to CABG. In the other two patients with left SCA stenosis, percutaneous balloon angioplasty with a stent was performed prior to CABG (Table 2).

CABG and the use of the ITAs

Single to quadruple CABG was performed in this group of patients. In the last three patients, an off-pump CABG (OPCAB) through a median sternotomy was performed (Table 2).

In seven patients in whom the left SCA was affected (patients 4, 5, 7, 9, 11-13), the LITA was used as a graft to the left anterior descending (LAD) or other coronary arteries after reconstruction of the SCA (Table 2). In these patients, preoperative retrograde SCA angiography was performed via the left brachial artery to confirm the quality of the LITA from its origin to the distal segment. Free flow of the LITA was evaluated after reconstruction of the SCA. In patients 4, 5, 7 and 9, we constructed the aortoaxillary bypass prior to cardiopulmonary bypass with a side-clamp on the ascending aorta.

In patients whose LITA was not grafted to the LAD, the RITA was used as a graft to the LAD.

Statistical analysis

Nonparametric, nonrisk-adjusted estimates of graft-related event-free rates were obtained by Kaplan-Meier's method.

Results

There were no operative deaths. No postoperative complications were encountered in patients of this series. Symptoms of SCA occlusion, either V-B insufficiency or upper limb ischemia, disappeared postoperatively in all patients.

Aortoaxillary bypass

Patency of the SCA or the aortoaxillary bypass graft was confirmed by either the absence of pressure difference in the upper arms or postoperative angiography. All patients were followed up at our outpatient clinic.

All patients were evaluated by direct angiography or

Table 2. CABG and SCA reconstruction

Pt.	SCA reconstruction	CABG	LITA	RITA
1	Ao-lt. axillary bypass	×3	(–)	LAD
2	Ao-rt. axillary bypass	×3	LAD	(–)
3	Ao-lt. axillary bypass	×3	(–)	LAD
4	Ao-bilat. axillary bypass	×4	LAD	(–)
5	Ao-lt. axillary bypass	×1	LAD	(–)
6	Ao-lt. axillary bypass	×2	(–)	LAD
7	Ao-lt. axillary bypass	×2	LAD	(–)
8	Ao-lt. axillary bypass	×4	(–)	LAD
9	Ao-lt. axillary bypass	×2	OM	LAD
10	Angioplasty	×4	Free	LAD, IM, PL
11	Angioplasty	×3*	LAD	(–)
12	Lt. C-S transposition	×4*	IM	LAD
13	Lt. C-S transposition	×3*	Diag.	LAD

CABG: coronary artery bypass grafting, SCA: subclavian artery, Ao: aorta, C-S: carotid-subclavian, lt.: left, rt.: right, bilat.: bilateral, LITA: left internal thoracic artery, RITA: right internal thoracic artery, LAD: left anterior descending, OM: obtuse marginal, IM: ramus intermedius, diag.: diagonal, PL: posterolateral branch, *: off-pump CABG

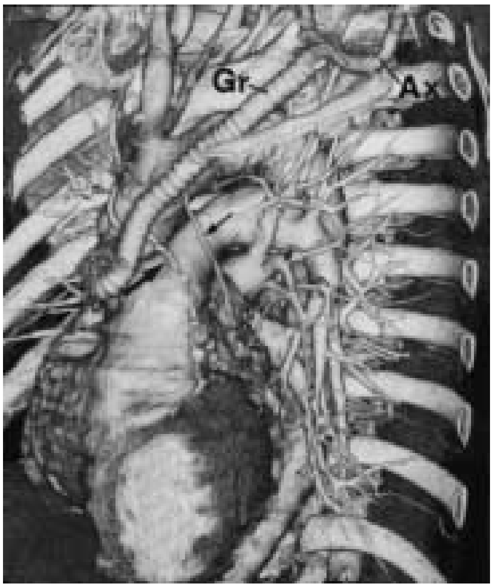

Fig. 2. Aortoaxillary bypass. Postoperative three-dimensional computed tomography (left anterior oblique [LAO] view) of patient 9 at 46 months. Gr: 8-mm ring-reinforced PTFE graft, Ax: proximal segment of the axillary artery. The LITA (small arrow) and RITA (large arrow) are clearly visualized.

three-dimensional computed tomography at 3 to 56 months postoperatively, revealing satisfactory patency of the grafts in all patients (Fig. 2). In the follow-up period, ranging from 4 to 8.4 years (mean, 6.3 years), one patient died of neoplastic disease at 98 months. He was asymptomatic up until 94 months postoperatively. The other eight patients did not exhibit an upper-arm pressure difference. The radial artery of the affected side was palpated well in all patients. Freedom from graft-related events in patients with aortoaxillary bypass was 100% (Fig. 3).

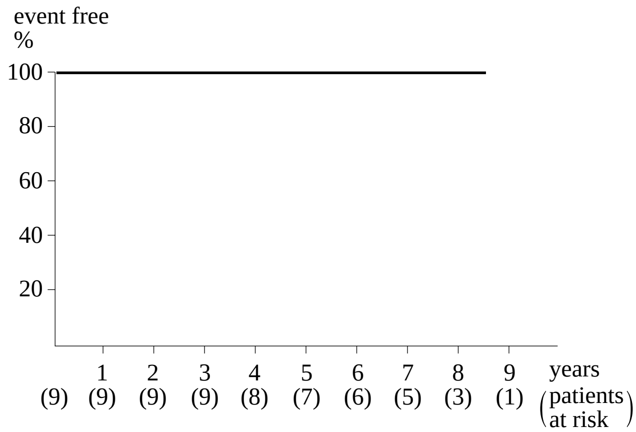

Fig. 3. Freedom from graft-related events in patients with aortoaxillary bypass.

C-S transposition and angioplasty

Angiography in two patients who underwent a C-S transposition, 3 and 14 months postoperatively, revealed excellent patency of the anastomosis. Patients who underwent angioplasty remained asymptomatic with no upper-arm pressure difference.

"Affected" LITAs as grafts to coronary arteries

Seven patients in whom the LITA was used as a graft to the coronary artery after SCA reconstruction were examined angiographically. The LITAs were widely patent in six patients, while the LITA to the diagonal branch was occluded in a patient with a C-S transposition. The occlusion was attributed to difficulty in anastomosing the LITA to the poor run-off coronary artery. However, no patients developed myocardial infarction or angina during the follow-up period.

Comment

Since the ITA is the primary graft of choice for CABG, special attention should be paid to SCA occlusive lesions in patients who undergo CABG. The presence of an occlusive lesion from the brachiocephalic artery to the proximal segment of the SCA prevents the use of the ITA as a graft to the coronary artery. Furthermore, an unrecognized pre-existing SCA lesion or the progression of atherosclerosis in the artery may lead to flow reversal of the ITA with upper extremity activity (coronary-subclavian steal), in which the blood flow is directed towards the SCA.[1,2)]

As a blood pressure difference of more than 20 mmHg between the upper-arms is highly suggestive of SCA stenosis, routine measurement of bilateral upper-arm pressure has been advocated. Ultrasonic duplex scanning with exercise is reported as a more reliable method of screening for SCA occlusion.[4)] At our institute, when a patient is considered to be a candidate for CABG, cardiologists routinely perform semi-selective ITA angiography by injecting a bolus of contrast medium at the origin of the bilateral SCAs as well as the ITAs. This procedure is useful for detecting not only the SCA occlusion but also any lesions of the brachiocephalic artery.

At the present time, an optimal approach for SCA reconstruction has not been established yet. Reports on both transthoracic direct revascularization and extrathoracic bypasses (C-S bypass) have shown excellent results.[6-8)] Acceptable patency rates after SCA angioplasty with stenting or other interventional treatments have been reported.[9,10)] The interventional approach may be an alternative SCA reconstruction to a bypass procedure for patients with non-occluded stenotic SCA lesion or for elderly patients with various risk factors, which necessitate the use of OPCAB.

As a simultaneous operation, we performed an aortoaxillary bypass for SCA occlusion in nine patients who underwent CABG. With a mean follow-up period of 6.3 years, the mid-term patency of the aortoaxillary bypass graft proved to be acceptable. The results may be attributed to obtaining an inflow from the ascending aorta, which provides a higher driving pressure than the potentially diseased brachiocephalic vessels. When simultaneous SCA reconstruction is considered along with CABG, aortoaxillary bypass is a reliable option in such a special condition.

When an occlusive lesion of the left SCA exists, the LITA cannot be used as a pedicled graft. Although alternative grafts such as a free ITA or the radial artery are available, lack of a graft of excellent patency may endanger the long-term fate of patients undergoing CABG.

One of the issues to be clarified is the use of the LITA as a bypass graft to the coronary artery after reconstruction of the left SCA. Under these circumstances, the benefit of using the pedicled ITA as a graft for CABG is greatly influenced by the patency of the SCA bypass graft. A recent report revealed that direct revascularization of the SCA by bypass provides protection from development of coronary-subclavian steal in patients who undergo simultaneous CABG using the ITA.[4] Furthermore, reports on coronary-subclavian steal being successfully treated with C-S bypass indicate that the LITA that receives blood through the bypass graft can afford to perfuse the coronary artery sufficiently.[11,12]

In our initial experience, we abandoned the use of the LITA because the long-term outcome of an aortoaxillary bypass graft had not yet been established. As the number of cases have been accumulating, however, we have become convinced of the durability of the aortoaxillary bypass graft as well as its capability for providing adequate blood flow to the ITA which can be confirmed by postoperative angiograms.[13]

Nevertheless, some standards may be necessary to decide whether to use the ITA after reconstruction of the SCA. Free blood flow rate of the ITA after harvesting is commonly used to evaluate the adequacy of the flow through the graft. However, the shape of the ITAs in patients with chronically occluded SCA is varied.[14] It mainly depends on the degree of the collateral to the SCA as well as to the ITA itself. Therefore, a retrograde angiogram of the SCA via the brachial artery is a reliable tool for predicting the efficacy of the ITA as a graft.

OPCAB has become widely accepted and even multiple coronary revascularization can be achieved with the technique through a sternotomy. We performed C-S transposition in the last two patients who underwent OPCAB. When the aortic side clamping is best avoided in patients with diseased aorta, the extra-thoracic procedure may be indicated. However, in the trans-sternal OPCAB, aortoaxillary bypass is one of the SCA reconstructive procedures of choice as long as a side-clamp can be safely placed on the ascending aorta.

In conclusion, when the lesion is confined to the origin of the SCA and the distal segment of the SCA, including the ITA, is intact on the angiogram, the use of the pedicled ITA as a graft to the coronary artery can be validated after the SCA is reconstructed by some means. Aortoaxillary bypass using a PTFE graft is an effective and durable procedure for SCA reconstruction in patients undergoing trans-sternal CABG.

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