Tohoku J. Exp. Med., 2004, **204**, 53-62

Carotid-Subclavian Bypass in Occlusive Disease of Subclavian Artery: More Important Today than Before

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Cinar, B., Enc, Y., Kosem, M., Bakir, I., Goksel, O., Kurc, E., Cicek, S. and Eren, E. *Carotid-Subclavian Bypass in Occlusive Disease of Subclavian Artery: More Important Today than Before*. Tohoku J. Exp. Med., 2004, **204** (1), 53-62 ── After left internal mammary artery graft is anastomosed to the coronary artery, atherosclerotic occlusion of subclavian artery becomes more important, because the vascular segment between the origin of the subclavian artery and the coronary artery becomes a part of the coronary circulation functionally. The subclavian artery occlusion may be treated through percutaneous intervention including balloon angioplasty alone or with stent. But failure of initial treatment by percutaneous intervention is possible especially in some proximal and total occlusions. In those cases, surgical options include extraanatomic reconstruction, anatomic reconstruction with transthoracic approach or redo-coronary artery surgery in patients with coronary steal syndrome. In this retrospective study, the medical records of 66 patients underwent carotid-subclavian bypass under general or local anesthesia between January, 1990 and January, 2003 were reviewed to analyze the early and long-term results of carotid-subclavian bypass with polytetrafluoroethylene grafts. There were no intraoperative mortalities. There were only one peroperative cerebrovascular accident and one death due to myocardial ischemia early in the post-operative period. Over a mean follow up of 96 months (6 month-144 months), thirteen patients died due to various reasons and there were eleven late graft thrombosis. The primary patency rates at 1, 3, 5 and 10 years were 98%, 91%, 83% and 47%, and the overall survival rates at 1, 3, 5 and 10 years were 100%, 95%, 93% and 38%, respectively. Carotid-subclavian bypass with polytetrafluoroethylene grafts is a safe, effective and durable procedure. It can be easily applied even under regional anesthesia when percutaneous intervention is unsuccessful or impossible. ──── carotid; subclavian; coronary artery; bypass

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Received April 30, 2004; revision accepted for publication July 2, 2004.

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Subclavian steal syndrome (SSS) occurs when there is stenosis or occlusion of the subclavian artery proximal to the vertebral artery. This blockage reverses normal direction of blood flow in the vertebral artery, and is named as "steal", because it steals blood from the cerebral circulation. Blood is drawn from the contralateral vertebral, basilar or carotid artery regions into the low-pressure ipsilateral upper limb vessels. Subclavian steal syndrome is diagnosed with the symptoms of reversed vertebral artery flow causing cerebral ischemia with associated symptoms of vertebrobasilar hypoperfusion and/ or symptoms of brainstem or arm ischemia. This syndrome is still an important consideration in the differential diagnosis of cerebral and brachial ischemia (Fischer 1961).

On the other hand, the occlusive disease of subclavian artery nowadays seems to cause another subset of SSS that is the coronary-subclavian steal syndrome (CSS) which occurs in patients who have undergone coronary artery revascularisation with internal mammary artery (Branchereau et al. 1991; Appleby et al. 1996). After left internal mammary artery (IMA) graft is anastomosed to the coronary artery, the vascular segment between the origin of the subclavian artery and the coronary artery becomes part of the coronary circulation functionally. Thus, stenosis in each part of this segment can directly cause myocardial ischemia. The reason can also be an occlusion or high grade stenosis in the proximal subclavian artery. The blood flow in vertebral artery and/or left internal mammary artery is drawn back to the arm (Von Son et al. 1989; Stagg et al. 1994). Symptoms related to left upper limb and/ or cardiac ischemia may be present in these patients.

The aim of the treatment is to restore permanent antegrade blood flow to the vertebral and internal mammary artery, and thereby to eliminate cerebral and myocardial hypoperfusion. The traditional treatment of SSS has been surgery (Crowe and Iannone 1993; Delaney et al. 1994; Margues et al. 1997). However, there is a recent trend towards percutaneous transluminal angioplasty. Percutaneous catheter intervention may help avoid the morbidity of operative intervention and provide acceptable results (Leavitt et al. 1991; Sullivan et al. 1991). In the presence of proximal subclavian artery occlusion or total occlusion, percutaneous interventions are not always possible. In this situation, extraanatomic revascularisation with carotid subclavian bypass can be performed to prevent cerebral and/or myocardial ischemia. This extraanatomic bypass procedure is particularly significant for patients with CSS, because this procedure provides IMA patency and relieves recurrent myocardial ischemia without the risk of redo coronary artery reconstruction (Bryan et al. 1995; Paty et al. 2003).

Methods and Patients

In this retrospective study, the medical records of 66 patients undergoing carotid-subclavian bypass for symptomatic occlusive subclavian artery diseases were reviewed after the approval was obtained from the Siyami Ersek Cardiovascular and Thoracic Surgery Center Institutional Ethics Committee. Fifty four patients for SSS and twelve patients for CSS underwent surgery in which polytetrafluoroethylene (PTFE) grafts were used (Gorotex; W.L. Gore and Associates, Inc, Flagstaff, Ariz.) between January 1990 and January 2003 at our institution. The medical records were reviewed to establish the demographic data, risk factors, presenting clinical manifestation, the location of the subclavian disease and immediate postoperative results. Indications for surgery were classified as arm ischemia (claudication or rest pain), symptomatic subclavian steal or vertebrobasilar insufficiency (VBI) or myocardial ischemia.

All patients underwent noninvasive duplex ultrasonographic scanning and angiographic evaluations (four-vessel arch aortography with carotid and subclavian arteriography) before surgery. Following diagnosis, the patients were also assessed for operation by neurologists to rule out other causes of the symptoms. The appropriate anesthesia type for patients was determined by considering overall patient status as well as noninvasive and invasive evaluations and depended on the discretion of the personal preference of the surgeon.

Patients were positioned in dorsal decubitus position on an operating table and surgical exposure of the common carotid and subclavian arteries were obtained through an anterior supraclavicular incision under general or local anesthesia. The subclavian artery was identified and exposed for bypass. The identified portion of the subclavian artery was distal to IMA and medial to the brachial plexus. If additional cephalad exposure of the common carotid artery was required, the previous incision was extended cephalad along the lateral border of the sternocleidomastoid muscle or a separate longitudinal incision was made until bifurcation region. After exposure of arteries, intravenous heparin (30 U/kg) was given. Subclavian distal anastomosis was principally applied before carotid anastomosis under cross-clamp. Cross-clamp was released and the flow initially restored to the upper extremities to prevent embolisation of the coronary and vertebral arteries. The patients were managed in surgical intensive care unit for one day and in surgical ward for 3 days thereafter and discharged from hospital on the fourth day. All patients were followed by clinical examination, duplex scan, pulse volume recording and myocardial perfusion imaging. If necessary, further invasive evaluation should be performed to document bypass patency. Perioperative morbidity and mortality were defined as events occurring within 30 days of operation. After being discharged from hospital, the patients were periodically observed with serial clinical examination and noninvasive vascular testing. Determination of graft patency was made with color Doppler imaging, the presence of symptoms of patients, or in some cases, with magnetic resonance angiography when indicated. The cumulative patency, and overall survival rates were calculated with the life table method.

Results

The present study includes 54 SSS patients, and 12 CSS patients. The demographic characteristics of the patients are summarized in Table 1.

The lesions were observed at the left subclavian artery in 39 (72.5%) patients and at right subclavian artery in 15 (27.5%) patients with SSS. Thirty four (62.5%) patients with SSS had total occlusion whereas 20 (37.5%) had stenosis of the subclavian artery. In 12 patients with CSS, the lesions were stenosis in 3 (25%) and total occlu-

TABLE 1. *Demographic characteristics of the patients*

Demographic	S.S.S		C.S.S	
	No.	%	No.	%
Average Age (years)	60 (range, 42-70)		66 (range, 62-74)	
Men/woman	32/22	60/40	9/3	75/25
Smoking	35	65	10	83
Diabetes Mellitus	15	27	3	25
Hypertension	24	45	6	50
Coronary Disease	19	35	12	100
C.V.D	10	20	4	33
P.A.D	10	20	5	42
Carotid artery disease	30	55	6	50
Site of lesion: left/right	39/15	72/28	12	100 left
stenosis/occlusion	20/34	38/62	3/9	25/75

TABLE 2. *The symptoms of patients*

Symptoms	S.S.S		C.S.S	
	Number	%	Number	%
Dizzyness/vertigo	38	70	6	50
Syncope	20	37	2	15
Ataxia	7	12	6	50
Visual field disturbance	8	15	4	25
Hemiparesis	3	5	0	0
Claudication	14	27	2	15
Distal emboly	5	10	0	0
Digital necrosis	2	2	0	0
Myocardial ischemia	2	2	12	100

TABLE 3. *Type of anesthesia under which carotid-subclavian bypass applied*

	Type of anesthesia		
patients with	General	Local	Total
S.S.S	21 (39%)	33 (61%)	54
C.S.S	4 (25%)	8 (75%)	12
Total	25 (38%)	41 (62%)	66

sion of left proximal subclavian artery in 9 (75%) patients. The mean preoperative arm pressure gradient was 32.4 (range: 25-50) mm Hg in patients with subclavian artery disease. All the patients that underwent surgery for subclavian artery disease were symptomatic. Table 2 summarizes the predominant symptoms of the patients. The symptoms of cerebral ischemia were predominant in 43 patients (80%). However, symptoms of arm ischemia were predominant in only 11 patients (20%) with SSS. The most common symptom of cerebral ischemia was dizziness which was found in almost 70% of all cases. Loss of consciousness and/or previous syncope were present in 37% of the patients. However, intermittent claudication, being the most common symptom of ischemia of the upper extremities was found in 27% of all cases. The predominant symptoms in patients with CSS was the recurrent chest pain after aortocoronary bypass surgery (CABG). The mean duration between the initial CABG with the in situ IMA conduit and the recurrent chest pain due to symptomatic steal was 60 months (range: 24-116 months).

Thirty three (61%) patients with SSS underwent operation by local (infiltration and/or cervical blokage) anesthesia and 21 (39%) patients were operated under general anesthesia (Table 3). We preferred to use 6-8 mm polytetrafluoroethylene (PTFE) grafts. An 8 mm graft was placed in 36 patients and 6 mm conduit in 18 patients with SSS. Two patients required concomitant carotid endarterectomy (CEA) for high grade stenosis before the bypass procedure. Out of 12 patients with CSS, we used 8 mm graft in 9 and 6 mm graft in 3 patients and the operations were performed under general anesthesia in 4 (25%) and local anesthesia in 8 (75%) patients with CSS.

Early results. There were no intraoperative mortality in our patients that had been operated due to symptomatic SSS and CSS. Only one peroperative cerebrovascular accident was seen in patients with SSS during carotid-subclavian bypass procedure. Upon examination of the perioperative morbidity and mortality occurring within 30 days of operation, we noted only one death in patients with SSS due to myocardial ischemia on the second postoperative day of intensive care unit. Six (11%) morbidities in patients with subclavian artery disease were observed within this

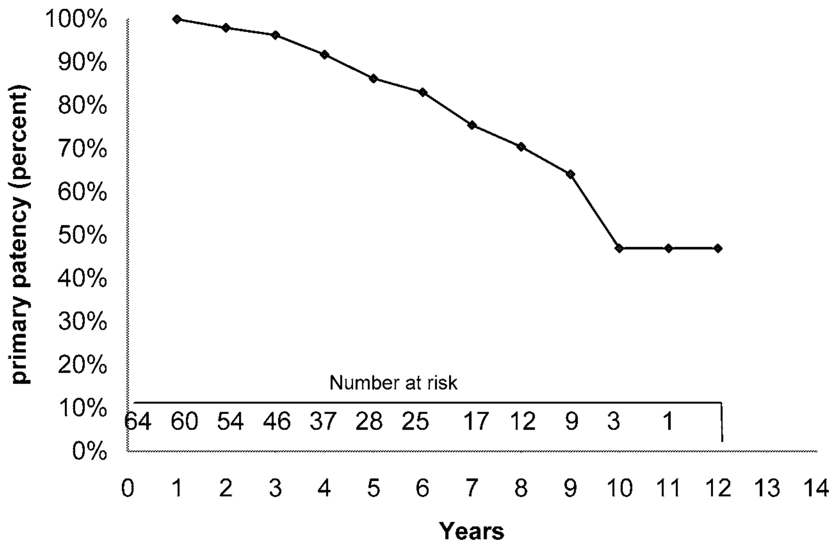

Fig. 1. Cumulative patecy rates of PTFE graft used at carotid-subclavian position.

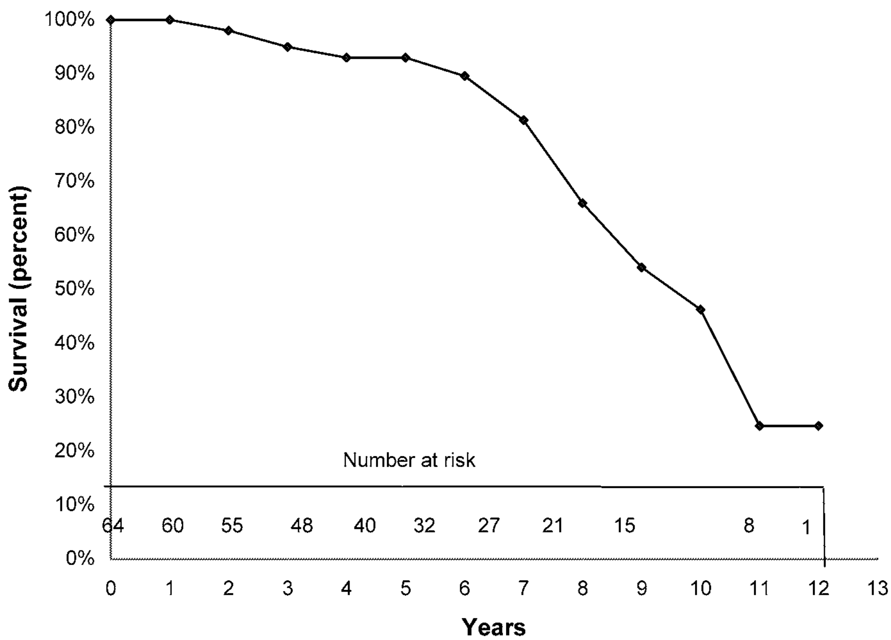

Fig. 2. Survival rates of patients with carotid-subclavian bypass.

period. Two patients with SSS and one patient with CSS underwent reoperation due to bleeding, one patient with SSS underwent brachial embolectomy due to embolisation of the distal arterial system and two patients with SSS underwent reoperation due to early (one in the second hour and one on the second day) graft thrombosis. The two grafts in patients with early graft thrombosis were excised and revised to carotid-axillary bypass. The mean preoperative arm pressure gradient was 32.4 mmHg with a mean postoperative pressure gradient of 5.4 mmHg (range: –4-10). Immediate relief of symptoms was achieved in 100% with an early graft success of 97%.

Late results. Over a mean follow up of 96 months (6 month-144 months) after operation, thirteen patients with SSS died: three patients due to cardiac, four due to cerebrovascular and six due to other reasons. The PTFE grafts were patent in seven and occluded in six patients when they died. There were eleven late graft thrombosis observed in patients with carotid-subclavian bypass. When we diagnosed the graft thrombosis, we discussed the management options with the patients. Eight patients with occluded graft refused surgical options and chose medical therapy after discussing the management options. Three patients chose to undergo revision of the carotid-subclavian bypass graft to carotid-axillary bypass with PTFE graft. However, two of them were occluded at 20 and 24 months and they died. Only one patient with second bypass graft was alive and patent at 38 months of operation. In total, five patients with occluded PTFE grafts were alive. The four patients that chose medical options were being followed up in our out patient clinics with medical therapy.

All the patients with CSS were alive nearly after 48 months mean follow-up period and there is no late complication and all the grafts are patent. The evaluation of these patients with dipyridamole-thallium scans showed the improvement in reversible defects noted preoperatively in the anterior and lateral myocardial segment supplied by IMA. We examined the cumulative patency, and overall survival rates of all PTFE grafts used in the same anatomic position irrespective of the predominant symptoms. We determined that immediate symptoms were relieved in 97% of patients. The primary patency rates at 1, 3, 5 and 10 years were 98%, 91%, 83% and 47% (Fig. 1) and the overall survival rates at 1, 3, 5 and 10 years were 100%, 95%, 93% and 38%, respectively (Fig. 2).

Discussion

After left internal mammary artery (IMA) graft is anastomosed to the coronary artery, the vascular segment between the origin of the subclavian artery and the coronary artery becomes functionally part of the coronary circulation. Thus, subclavian artery becomes a part of the two most important blood circulations in the body as long as IMA is used for coronary bypass surgey. As only 20% of bloodflow to the brain is supplied by the vertebral arteries and presence of alternative blood supply for vertebral artery like carotid arteries via circle of Willis and contralateral vertebral artery, the symptoms related to brain do not occur unless a pathology of these alternative pathways exist. Nevertheless, when subclavian artery becomes part of coronary circulation there is no alternative flow pathway. So, severe cardiac symptoms occur more and more frequently.

The most common location for atherosclerotic lesion causing reversal of blood flow is the proximal part of the left subclavian artery. A preponderance of 3 : 1 of symptomatic subclavian artery lesions on the left to the right was reported in the literature (Zimmerman 1993). In the present study, the lesions were seen at the left subclavian artery in 39 (72.5%) patients and at right subclavian artery in 15 (27.5%) patients with SSS while the lesion was left-sided in all patients with CSS. The symptoms of cerebral ischemia resulting from subclavian steal syndrome were thought to be exacerbated by arm exercise. In most reported series in the literature, augmentation of steal with arm exercise seldom reproduces the symptoms of posterior circulation insufficiency (Branchereau et al. 1991). It has been postulated that only one major blood supply to the intracranial circulation is required to prevent cerebral ischaemia (Hennerici et al. 1988). However, finding a complete circle of Willis is a relative rarity. Miller-Fischer, as cited in Lacey (Lacey 1996) reported a lack of adequate collateral channels in the anterior circulation in 44% and a small posterior communicating artery in 49% consecutive autopsy dissections. Therefore, a combination of extracranial vascular stenosis plus an incomplete intracranial network may result in reduced blood flow to either anterior or posterior cerebral regions.

The coronary-subclavian steal syndrome was first reported by Harjola an Valle in 1974 in a patient who underwent CABG with in situ IMA

(Paty et al. 2003). The incidence of CSS is low. Tyras and Barner described an angiographic incidence of steal in 2 of 450 cases (0.44%). This may also result from an occlusion or high grade stenosis in the proximal subclavian artery. The blood flow to the arm is then drawn from reverse flow in vertebral artery and/or left internal mammary artery (Von Son et al. 1989; Stagg et al. 1994). Symptoms related to left upper limb or cardiac ischemia may be present in these patients. In CSS, stenosis at the origin of grafted internal mammary artery is either stenosed before bypass surgery or becomes stenosed after surgery, allowing steal from the mammary artery (Fischer 1961; Fitz Gibbon and Keon 1995). The development of coronary steal may be early or late following CABG procedures. However, ost of CSS cases present within 3 years after bypass surgery (Fitz Gibbon and Keon 1995). Because of the lack of collateral flow and prior coronary artery disease in the native coronary artery, reversal of blood flow of IMA causes severe recurrent myocardial ischemia. The mean duration between the initial CABG with the in situ IMA conduit and the recurrence chest pain due to symptomatic steal in our cases was 60 months (range: 24-116 months).

In the diagnosis of subclavian artery disease, the difference in systolic blood pressure between arms is suggestive and is also one of the most important signs of SSS and CSS (Smith et al. 1994; Lacey 1996). Patients with symptoms of arm ischemia have a contralateral brachial pressure difference of 40 mmHg to 50 mmHg. Those with predominant cerebral symptoms usually have a difference between 20 mmHg to 40 mmHg, because of reversed blood flow to arm through the vertebral artery (Zimmerman 1993). In all of our series, the pressure difference between rignt and left extremities was higher than 40 mmHg. Nevertheless, the pressure differences were used as diagnostic tool only in 24 patients with SSS and 4 patients with CSS (42%). In others, the pressure differences were realized after the radiological evaluations of vertebral and carotid arteries or after coronary angiography. So, the pressure differences should be realized especially after late follow-up period in all patients with CABG. In the case of a suspected SSS upon clinical examination, Doppler ultrasonography has been demonstrated to be the most sensitive and specific instrument to conclude the diagnosis (Hennerici et al. 1988; Delaney et al. 1994; Walker et al. 1995). On the other hand, some authors believe that Doppler ultrasonography should be used as an initial screening instrument and if the ultrasonography finds a subclavian lesion, a confirming arteriogram should be used to view the full anatomy and concomitant lesions of carotid and/or vertebral arteries (Lacey 1996).

Because of the minimal risk of suffering an infarct, most surgeons agree that surgery is only indicated for those patients experiencing frequent and disabling symptoms of SSS (Mannick et al. 1962; Fields et al. 1972; Perler and Williams 1990; Ackerman et al. 1998). Conversely, this does not apply to patients with prior IMA graft surgery to the coronary artery in which the vascular segment between the origin of the subclavian artery and the coronary artery becomes part of the coronary circulation functionally. In the case of CSS revascularization is inevitable. The subclavian artery occlusion may be treated through percutaneous intervention including balloon angioplasty alone or with stent (Fitz Gibbon et al. 1995). Sullivan et al. (1991) treated 72 patients with innominate and subclavian artery lesion with angioplasty and primary stent for occlusive lesions. Thirty seven percent of patients in this group were treated for CSS. This intervention was immediately successful in 94% of subclavian lesions. One year patency rate was determined as 90% in these patients. However, failure of initial treatment by percutaneous intervention is possible especially in some proximal and total occlusions. In these cases, surgical options include extraanatomic reconstruction, anatomic reconstruction with transthoracic approach or redo-coronary artery surgery in patients with CSS. The morbidity of reoperative cardiac surgery may preclude its use in patients with CSS. So, the extrathoracic and extraanatomic bypass have emerged as the treatment of choice for symptomatic patients with proximal subclavian and carotid occlusive disease as a result of the high morbidity and mortality rates associated with transthoracic approaches (Raithel 1980; Thompson et al. 1980; Vogt et al. 1982). The extraanatomic bypass of carotid and subclavian artery was first introduced by Diethrich et al in 1967 to reduce the complication rates of transthoracic reconstruction (Diethrich 1967). After this report, many other reports have shown its excellent long-term results (Crawford et al. 1969; Fery et al. 1992). In a review of carotid-subclavian bypass with PTFE graft, AbuRahma et al. reported an overall 10-year primary patency of 92% (AbuRahma et al. 2000). Besides, carotid-subclavian bypass can be applied under regional anesthesia. This approach allows us to determine the neurological status of patient easily.

Another extraanatomic procedure, subclavian-carotid transposition is also an elegant procedure with excellent longterm durability (Cina et al. 2002). However, potential aggravation of coronary ischemia during interruption of vertebral and IMA blood flow makes it a less attractive treatment option in patients with CSS. Selection of the ideal conduit for Carotid-Subclavian reconstruction has been controversial, and accumulating evidence suggests that the choice of conduit does have a significant effect on long-term patency. Arterial transposition demonstrated superior results, with 100% 5-year actuarial patency. In another series with transposition, early (30-day) patency rates were reported as 100% and long-term patency was 95-100%, with somewhat lower results for vein grafts or prosthetic bypass grafts (Ziomek et al. 1986).

But arterial transposition should not be used in patients with CSS to prevent myocardial ischemia during procedure. So, we have two choices of graft material to use in carotid-subclavian position: prosthetic grafts and autologous saphenous grafts. The prosthetic conduits, polytetrafluoroethylene (PTFE) were generally preferred over vein for carotid-subclavian bypass because of lesser tension and lesser kinking of the graft, as well as a better conduit-artery size match (Fery et al. 1992).

We also preferred to use PTFE (6 or 8 mm) grafts. Forty one (62%) carotid-subclavian PTFE bypass procedures were applied under local (infiltration and/or cervical blokage) anesthesia and only 25 (38%) procedures were carried out under general anaesthesia. Meanwhile, the cost of procedures and hospitalization time were reduced.

There were no intraoperative mortalities. Only one peroperative cerebrovascular accident was seen among patients with carotid-subclavian bypass procedure. There was only one death due to myocardial ischemia in the early post operative period. Six (9%) morbidities that were three reoperations due to bleeding, one brachial embolectomy due to embolisation of the distal arterial system and two reoperations due to early graft thrombosis were observed within this period.

Over a mean follow up of 96 months after operation, thirteen patients died due to several reasons. There were eleven late graft thromboses. The primary patency rates at 1, 3, 5 and 10 years were 98%, 91%, 83% and 47% and the overall survival rates at 1, 3, 5 and 10 years were 100%, 95%, 93% and 38%, respectively. The patency rates of PTFE grafts significantly decreased after 5 year follow-up in our population. This decline was mostly due to atherosclerotic process and lack of adequate antithrombolytic and lipid-modifying agent usage. When the mean age of patients increased and HDL levels decreased as in our population, patency rates of PTFE grafts at carotid-subclavian position decreased significantly especially after 5 years follow-up. As atherosclerotic occlusion of subclavian artery becomes more and more important after left internal mammary artery graft surgery to the coronary artery, the insitu IMA usage should be avoided especially in older patients (age over 65 years) and in patients with the pressure difference between right and left extremities was higher than 20 mmHg.

When surgical revascularization is inevitable in subclavian occlusive diseases, carotid-subclavian bypass with PTFE grafts is a safe, effective and durable procedure. It can be easily applied to patients even under regional anesthesia when percutaneous intervention is unsuccessful or impossible.

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