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APPRAISAL OF REVASCULARIZATION OF UPPER EXTREMITY ARTERIAL OCCLUSIVE DISEASE

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Aim: *Symptomatic arterial occlusive disease of the upper extremities requiring revascularization to prevent limb loss is rare. The aim of this work is to review our experience with management of symptomatic, non-traumatic, non-embolic, upper extremity arterial occlusive disease.*

Patients and methods: *Forty one patients (44 limbs) were separated into 2 groups. Group 1 (29 patients, 32 limbs) with intrinsic arterial occlusive disease and group 2 (12 patients, 12 limbs) with arterial complications secondary to thoracic outlet syndrome (TOS). In group 1, seven innominate artery lesions were treated using transthoracic bypass grafts (n = 3) and extra-anatomic bypass grafts (n = 4). All subclavian artery lesions (n = 14) were treated using extra-anatomic bypass. Six of 11 limbs with axillary or brachial occlusions had bypass using saphenous vein, one underwent axillary endarterectomy, while 4 were treated conservatively.*

Results: *Immediate success rate was 100% with resolution of the ischemic symptoms. Early graft thrombosis in one patient was treated successfully with thrombectomy accounting for early patency rate of 96.4 %. Two more patients developed graft thrombosis at 5 and 12 months resulting in a mid-term patency rate of 92.8%. One patient underwent successful graft thrombectomy the other was treated conservatively and both had good outcome. Arterial complications of TOS in group 2 consisted of subclavian artery stenosis with post-stenotic dilatation and were caused by cervical ribs in 11 patients and fibrous band in one patient. Seven of these 12 patients had embolic occlusion of the brachial artery. All patients underwent excision of the cervical ribs or division of the fibrous band, excision of the diseased subclavian segment with interposition Dacron grafting, and in 7 patients concomitant brachial embolectomy was performed. All patients had resolution of their ischemic symptoms. There was no operative mortality in both groups.*

Conclusion: *The results of this study demonstrate that surgical revascularization for upper extremity arterial occlusive disease when indicated is safe, well tolerated, and yield a high rate of limb salvage.*

Key words: *arterial disease, atherosclerosis, revascularization, upper extremity, thoracic outlet syndrome,*

INTRODUCTION

Symptomatic arterial disease of the upper extremity is an uncommon problem and upper extremity ischemia that requires surgical intervention accounts for approximately 4% of all vascular surgical procedures.[1,2] Upper extremity pathology differs markedly from the lower extremity. Although atherosclerosis is a common finding, other etiologies include trauma, arteritis, fibromuscular dysplasia, thoracic outlet syndrome (TOS), collagen vascular disorders, and arterial injuries secondary to radiation therapy.[3-5] Obstructive symptoms are less common in the upper versus lower extremities due to rich collateral circulation around the shoulder and elbow and the small muscle mass of the upper extremity.[4,6] Surgical intervention is required less and limb loss is rare.[1]

Brachiocephlaic occlusive disease was initially treated with transthoracic surgical procedures, but because of their inherent increased morbidity and mortality (6%-20%), extrathoracic procedures have gained acceptance.[4,7] More recently, percutaneous transluminal balloon angioplasty (PTA) of these vessels is being performed with increasing frequency[7,8] This is in contrast to occlusive diseases affecting the axillary, brachial, radial, and ulnar arteries that are readily exposed and are treated successfully by direct revascularization.[2]

Published data on long-term results of revascularization of the upper extremity arteries are rare compared with those on lower extremity. In addition, factors such as the well developed collaterals in the upper extremity and the different disease pathology make direct extrapolation of principles from lower extremity revascularization experience not possible.[1,9] Moreover, since most reports are small and include different operative procedures besides bypass such as endarterectomy, direct repair, embolectomy, and balloon angioplasty and stenting in their outcome analysis, meaningful statements regarding long-term patency, preferred site of distal anastomosis, and optimal type of conduit are impossible to make.[9]

This study was conducted to evaluate our results with vascular reconstruction in patients who presented with symptomatic (non-embolic, non-traumatic) occlusive disease of the upper extremity arteries.

PATIENTS AND METHODS

This retrospective study comprises 41 patients with non-traumatic, non-embolic upper extremity ischemia treated during a period of 8 years between July 1996 and June 2004. Patients are divided into those with occlusive arterial disease (n = 29) and those with arterial complications of TOS (n = 12).

Group I. Arterial occlusive disease

Twenty nine patients (17 males) with an average age of 48.4 years (range 19 to 72 years) had 32 upper extremity arterial occlusive disease. The etiology of arterial disease was atherosclerosis in 18 patients (62.1%) and arteritis in 11 patients (37.9%). Risk factors and associated diseases are depicted in Table 1. Two of the nine patients with hypertension had renal artery stenosis diagnosed during angiography.

Aortography was performed in all patients. Seven patients had innominate artery lesions, of whom one had a concomitant left common carotid artery occlusion and another patient had long segment occlusion involving the subclavian and axillary arteries. Thirteen patients had 14 subclavian arteries occlusion (Figs. 1 & 4) with an associated distal brachial artery occlusion in one patient. Six patients had 7 axillary arteries occlusion (Figs. 2 & 3), while 3 patients had 4 isolated brachial artery occlusion (Figs. 5, 6 & 7). Preoperative symptoms are shown in Table 2.

Thirty-two arterial occlusive disease of the upper extremities in 29 patients were managed according to the location of the lesion, severity of ischemia, and associated risk factors. Surgical revascularization was performed using Dacron grafts in 20 limbs, saphenous vein graft in 7 limbs, and with endartrectomy in another limb. Bifurcated Y-shaped Dacron grafts were used in the 2 cases of aorto-subclvian and carotid bypass. Adjunctive distal thromboembolectomy of the brachial artery was performed in 2 limbs with acute ischemia. Four limbs with short segment occlusion of the axillary artery (n=3) or brachial artery (n=1) and with mild ischemic symptoms were managed conservatively. Summary of revascularization techniques are presented in Table 3.

Group 2. Thoracic outlet syndrome

Twelve patients (5 males) with an average age of 32.8 years (range 21 to 54 years) who had ischemia of their upper extremities were subjected to plain X-ray of the chest followed by 4 vessel angiography. Chest radiographs revealed cervical rib in 11 patients. Angiographic findings consisted of stenosis of the mid-subclavian artery with post-stenotic dilatation (Fig. 8). Embolic occlusion of the brachial artery was present in 7 cases with reconstitution of the distal brachial, radial and ulnar arteries.

The goal of surgical management was to eliminate the compressing element, reconstruct the diseased arterial segment, and clearance of distal embolization, or distal revascularization when indicated. Supraclavicular approach was used in all patients. Elimination of the compressing elements accomplished by excision of 11 cervical ribs and division of a fibrous band that extended between the neck of the first rib and its inner border. The stenosed segment of the subclavian artery and the post-stenotic dilatation were excised and an interposition 8-mm Dacron graft was used to bridge the defect. In three patients, division of the middle third of the clavicle was required to achieve adequate control of the subclavian-axillary arteries. Catheter thromboembolectomy via a brachial arteriotomy was performed in 7 patients, of whom 3 patients presented with acute ischemia and another patient required axillo-brachial saphenous vein bypass.

RESULTS

Group 1. Arterial occlusive disease

Twenty-eight limbs underwent revascularization with immediate success in all limbs (100%). All limbs had their radial and/or ulnar pulses returned after revascularization except in one limb with concomitant distal brachial artery occlusion, however, the limb benefited from the proximal revascularization with resolution of the preoperative symptoms. Five limbs with established gangrene of one or more of the fingers underwent minor digital amputations.

Early thrombosis (10 days post-revascularization) occurred in a carotid-axillary bypass resulting in an early success rate of 96.4% in this series. Graft thrombectomy was successfully performed with return of distal pulses.

Two patients had their axillo-axillary and carotid-

subclavian Dacron bypass grafts occluded at 5 and 12 months, respectively. This accounts for a mid-term success rate of 92.8%. Surgical intervention was only performed in the patient with axillo-axillary graft thrombosis because of the recurrence of symptoms. As was expected, one of the axillary anastomoses was the site of neointimal hyperplasia that resulted in the graft thrombosis. After graft thrombectomy, the graft was extended and anastomosis was performed to the axillary artery distal to the previous anastomosis.

Group 2. Thoracic outlet syndrome

Successful surgical treatment was achieved in all the 12 patients with TOS with immediate return of radial and/or ulnar pulses. One patient, however, suffered re-thrombosis of the brachial artery 2 days following thrombectomy but without recurrence of the ischemic symptoms. Minor amputation of gangrenous fingers established before surgical management was performed in 6 patients.

Table 1. Risk factors in patients with arterial occlusive disease of the upper extremity

Risk factor	*No. of patients (%)*
Hypertension	9 (31.0)
Diabetes mellitus	5 (17.2)
Smoking	7 (24.1)
Coronary artery disease	3 (10.3)
Lower extremity ischemia	1 (3.4)

Table 2. Preoperative symptoms

Symptoms	*No. of patients (%)*
Peripheral symptoms	
Coldness	4 (12.5)
Claudication	7 (21.8)
Rest pain	19 (59.4)
Necrosis	5 (15.6)
Vertebrobasilar symptoms	
Dizziness	2 (6.8)
Vertigo	3 (10.3)
Carotid symptoms	
Transient ischemic attacks	2 (6.8)

Table 3. Types of revascularization

Lesion (number of limbs)	*Revascularization technique (No.)*
Innominate artery (7)	*Aorto-right subclavian and left carotid bypass (1)*
	Aorto-right subclavian and right carotid bypass (1)
	*Aorto-brachial bypass (1)**
	Axillo-axillary bypass (1)
	Carotid-subclavian bypass (3)
Subclavian artery (14)	*Carotid-subclavian bypass (8)*
	Carotid-axillary bypass (1)
	Axillo-axillary bypass (4)
	Subclavian-axillary bypass (1)
Axillary (7) & brachial arteries (4)	*Subclavian-brachial bypass (2)**
	*Axillo-brachial bypass (3)**
	*Axillary-radial bypass (1)**
	Axillary endarterectomy (1)
	Conservative (4)

** Arterial bypass was performed using saphenous vein graft*

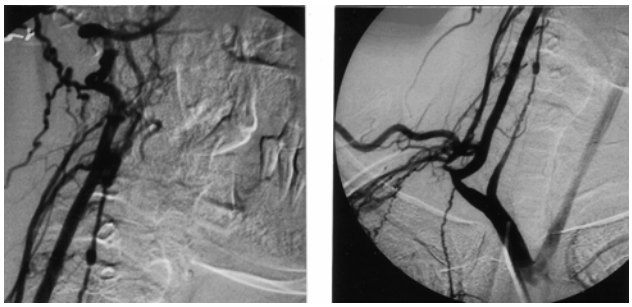

Fig 1. Angiograms showing right subclavian artery occlusion. The proximal end of the occlusion is at the origin of the subclavian artery (right film) and the distal end is at the distal axillary artery (left film).

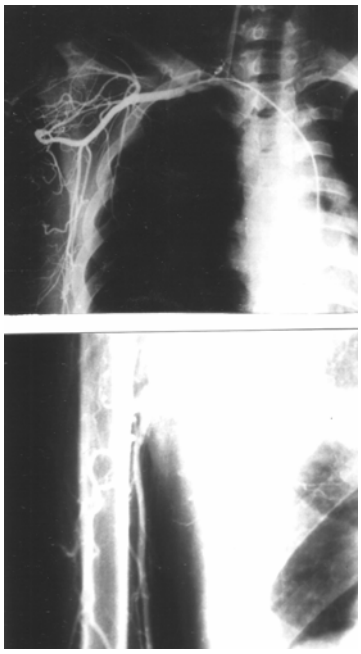

Fig 2. Angiogram showing right axillary artery occlusion with proximal brachial artery runoff.

Fig 3. Angiogram showing right axillary artery occlusion with mid-brachial artery runoff.

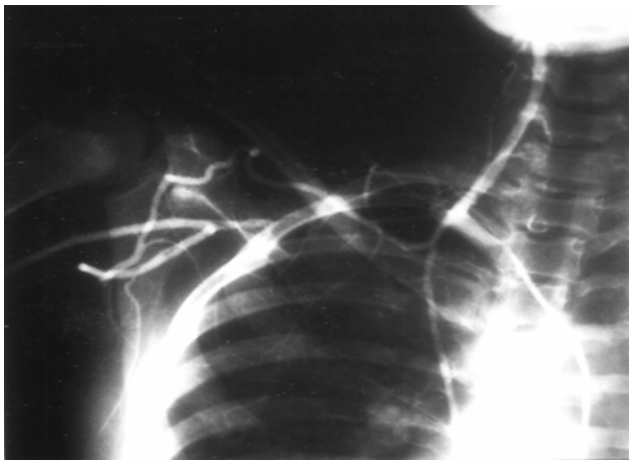

Fig 4. Angiogram showing right subclavian artery occlusion distal to the origin of the vertebral and internal mammary arteries with axillary artery runoff.

Fig 5. Angiogram showing short-segment proximal left brachial artery occlusion.

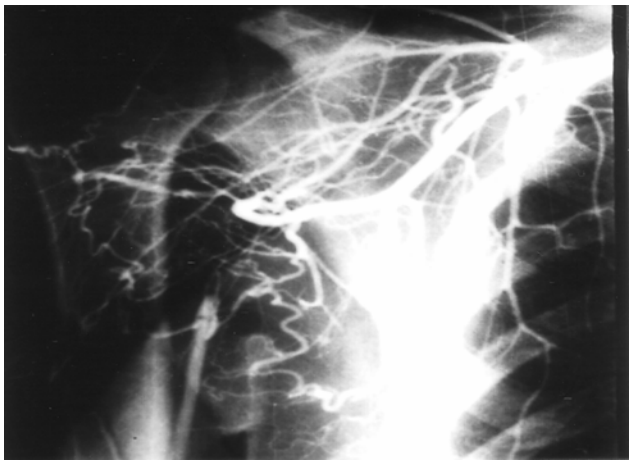

Fig 6. Angiogram showing short-segment proximal right brachial artery occlusion.

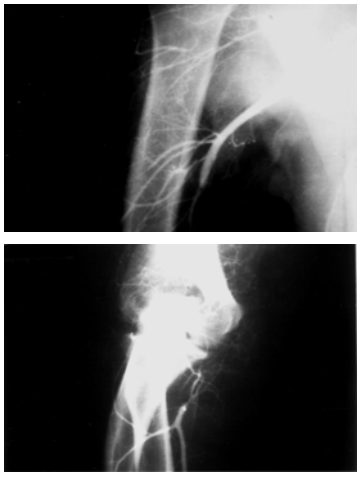

Fig 7. Long-segment right brachial artery occlusion (upper films) with runoff proximal to radial-ulnar bifurcation (lower film).

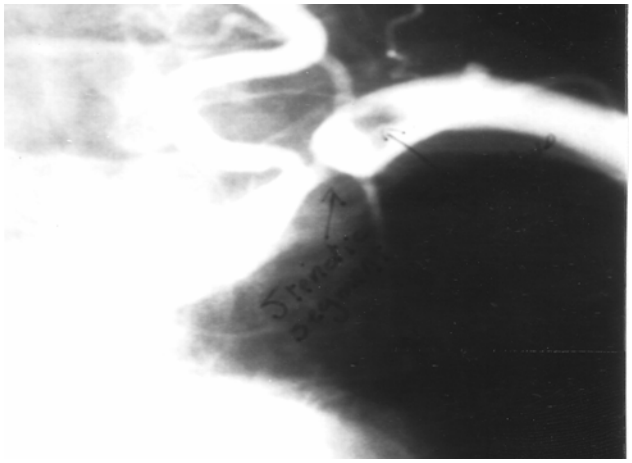

Fig 8. Angiogram showing stenosis of the left subclavian artery and post-stenotic dilatation harboring a thrombus due to cervical fibrous band.

DISCUSSION

Arterial reconstructive surgery for upper limb ischemia of non-traumatic non-embolic origin is uncommon in comparison to that of the lower extremities and long-term follow-ups are rare.[10] Treatment of symptomatic occlusive arterial disease of the upper extremity depends on the site and extent of occlusion and associated risk factors.

Arterial occlusive disease of the innominate and subclavian arteries requiring reconstruction may be managed by transthoracic anatomic, extra-anatomic cervical or endovascular repair.[7,11-13] The extra-anatomic techniques have been advocated to avoid the higher morbidity and mortality rates of transthoracic approaches.[4,11,14,15] The opponents of extra-anatomic approaches argue that the routes of extra-anatomic bypasses performed for innominate artery disease crossing the trachea or sternum makes these tunnels prone to skin erosion and infection. Further, the routes complicate tracheostomy, coronary artery bypass grafting, or subsequent arch reconstructions should any of these become necessary. Moreover, atheroembolic lesions require direct repair rather than extra-anatomic reconstruction if the atheroembolic source is to be removed from the circulation. Finally, multiple great vessel occlusive lesions are better treated by direct arch reconstruction because the aorta offers an excellent source of inflow and diseased arch vessels do not.[7,12] On the other hand, a previous mediastinotomy performed for myocardial revascularization or the presence of severe pulmonary disease substantially increases the risk of thoracic approach.

Direct reconstruction may be accomplished by aortic origin grafting or by innominate artery endarterectomy. Each method has its proponents, and each gives excellent results and is equally effective in properly selected patients.[7] Berguer et al reviewed their experience with 100 consecutive transthoracic reconstructions of the innominate and common carotid arteries and reported operative mortality of 6.4% and a cumulative patency rates at 5 and 10 years of 94% and 88%, respectively.[12] A similar experience was reported by Kieffer et al with 5.4% operative mortality in 148 patients with innominate artery reconstruction and primary patency rates of 98.4% and 96.3% at 5 and 10 years, respectively.[13]

If the ipsilateral common carotid artery is healthy, a reconstruction based on that vessel is the preferred method of revascularization. Carotid-subclavian artery bypass using prosthetic material has been the most commonly performed operation.[16] Carotid-subclavian bypass led to excellent long-term patency rates (95% at 10 years) and can provide durable relief of symptoms with minimal mortality rate (0-1.9%).[16-18] Law et al have reported that PTFE grafts had a patency of 95%, followed by Dacron grafts at 84% and saphenous vein grafts at 65%, but these differences were not statistically significant.[19]

Several authors, however, favors subclavian artery transposition which avoids the use of prosthetics with its associated risk of infection (1.5%) and also the need for a second anastomosis.[20,-23] This procedure does require more dissection of the subclavian artery proximal to the vertebral and internal mammary arteries so that prograde flow into these two important branches may be maintained. This dissection increases the incidence of complications such as Horner's syndrome, hoarseness and bleeding.[11] The contraindications to transposition are proximal origin of the vertebral artery, the extension of the atherosclerotic process well beyond the origin of the vertebral artery, and the presence of a left internal mammary artery graft to the coronary arteries.[7]

Both reconstructions cannot be used with the involved subclavian artery segment exceeding 6 to 7 cm in length. Furthermore, a major problem for these operations is the simultaneous and frequent (32%) presence of ipsilateral carotid artery stenosis.[11,24] Axillo-axillary bypass grafting is an excellent alternative to transthoracic anatomic reconstructions for innominate lesion, long stenosis of the subclavian artery, and short subclavian artery stenosis associated with ipsilateral carotid artery lesions.[11,14,25] It should also be selected in patients with concomitant ipsilateral carotid artery stenosis when symptoms persist after its correction to avoid the use of a diseased artery that may undergo restensosis that limits the patency rates of this reconstruction. Mingoli et al reported excellent long-term results with axillo-axillary bypass grafting with postoperative mortality of 1.6% and 10-year patency rates of 84.3%.[11] Chang et al reported similar experience with axillo-axillary bypass in 39 patients with a 10 –year primary and secondary patency rates were 88% and 91%, respectively.[14] The complications related to the subcutaneous course and length of axillo-axillary bypass were not encountered in the Mingoli study of 63 bypass grafting, nor by Chang et al with 39 bypasses, and were extremely rare in the Stipa study of 237 bypass grafting with 2.1% skin erosions and 0.4% infection.[11,14,26] Mingoli et al recommended also that a careful search for coronary artery disease and its treatment before the construction of an axillo-axillary bypass graft and that the treatment of coronary artery disease, developed during the follow-up period, should consist of PTA and stent positioning or the adoption of minimally invasive coronary artery bypass graft surgery.[11] The low mortality rates associated with extra-anatomic bypasses were also reported by Owens et al in their review of the results of different extrathoracic revascularization of the supra-aortic trunks. The authors reported operative mortality rate of 2.2% in 44 patients who underwent 47 extrathoracic bypass procedures.[15] Another study compared the immediate and long-term results of three different extrathoracic arterial reconstruction procedures, carotid-subclavian bypass, subclavian-carotid transposition, and subclavian-subclavian or axillo-axillary crossover bypass, for subclavian obstructive disease.[21] There were no differences in morbidity rate and there was no mortality. The cumulative patency of subclavian-carotid transposition was significantly better with 100% at 2, 5 and 10 years postoperatively compared to Carotid-subclavian bypass (75.6%, 62.6% and 52.2%, respectively) and crossover bypass (76.5%, 63.7% and 63.7%, respectively).

We reserved the trans-thoracic reconstruction only for young patients with multi-vessel occlusive disease and good surgical risk, particularly the presence of carotid artery lesion which precludes its use as an inflow artery. In this series, a young patient with long segment occlusion of the subclavian-axillary arteries and concomitant carotid artery occlusion underwent aorto-brachial bypass with saphenous vein graft. Otherwise we treated isolated innominate and all subclavian occlusive disease with extra-anatomic bypass. It has been our strategy to use carotid-subclavian bypass if the carotid arteries are not diseased, otherwise axillo-axillary bypass was used. We have not utilized subclavian-carotid transposition because of the good results of the carotid-subclavian bypass and the need for extensive proximal dissection and control of the subclavian artery in these patients with high risk. We as well others have extended the bypass grafting to the brachial artery for long lesions with good long-term patency.[27]

Percutaneous transluminal balloon angioplasty (PTA) of the great vessels, especially the subclavian artery, is being performed with increasing frequency. It is an attractive

option in high-risk patients for whom sternotomy is less than an appealing alternative. Angioplasty with or without stenting is probably an appropriate option for patients with localized disease (<4 cm in length) of the great vessels, most often without concomitant lesions, but it also has a high rate of recurrence (patency rate from 80% at 2 years to 54% at 5 years), which often necessitates repeated dilatation (7, 28, 29, 30, 31). Berguer et al argued, however, that long-term patency goals are less relevant in this population of patients in which 50% will not survive a decade.[12] Martinez et al reported 17 patients undergoing stenting for occlusion of the subclavian arteries. There was a 94% procedural success rate and an 81% cumulative patency rate at 6 months.[30]

Chronic occlusive diseases of the axillary, brachial, radial and ulnar arteries are rarely encountered compared with those of the innominate and subclavian arteries. Surgical treatment of chronic lesions requires bypassing of the occluded arterial segment. Collateral artery bypass is an option when the main arteries are affected by the disease such as in arteritis. A patent but diseased artery should be avoided as a target for reconstruction.[32]

Autogenous saphenous vein is the conduit of choice.[9,33,34] Upper extremity veins may be used as alternatives in the absence of an adequate saphenous vein. The use of in situ cephalic and basilica vein grafting has been reported.[35-37] Prosthetic material should be used only in rare instances when an adequate autogenous vein is not available.[1,2] In one of the largest series of upper extremity revascularization, Mesh et al reviewed their 15-year experience with 74 patients who underwent 95 arterial bypass operations. The authors reported no operative mortality, a single major amputation, and an overall patency rate of 61.2% at 5 years. They also found that patency rates of autogenous conduit are superior at all sites compared with prosthesis (70.9% vs. 37.7%) and all far distal forearm prosthetic bypass grafts failed within 1 year.[9] We used saphenous vein as the conduit of choice for revascularization of the brachial and radial outflow arteries.

Surgical treatment of arterial complications of TOS must often be performed on an emergency or semi-emergency basis, not only in the presence of acute or subacute ischemia of the upper extremity but also every time a mural thrombus has been recognized, because severe embolic complications are unpredictable and may rapidly become difficult to manage. The three anatomic component of the disease process must be treated simultaneously: arterial compression, subclavian-axillary arterial lesions, and distal emboli, if present.[38,39] The supraclavicular approach offers complete exposure of the subclavian artery, a cervical rib, and muscular or fibrous bands. When arterial lesions extend to the axillary artery, additional exposure is obtained through a deltopectoral or infraclavicular incision, leaving the clavicle undisturbed.[38,40,41]

Surgical techniques must be tailored to the arterial lesions. Resection is necessary in the presence of a subclavian-axillary aneurysm. Excessive arterial length is usually obtained after resection of the cervical and first thoracic ribs; this allows end-to-end anastomosis in most cases.[41] With a lengthy arterial dilatation, a short segment of graft, preferable autogenous vein, may have to be interposed to bridge the arterial defect. A mild fusiform post-stenotic dilatation, because it is difficult to diagnose intimal disease or mural thrombus in the absence of clinical or radiologic manifestations, should be opened longitudinally along its entire length and closed with a continuous tailoring suture after an intimal lesion has been ruled out or treated by either intimectomy or limited segmental resection.[38,41]

Distal embolization is often a major problem because emboli are usually multiple, diffuse, and of different ages. Recent emboli can easily be cleared by thromboembolectomy. Old emboli are adherent to the arterial wall and unsuccessful attempts at disobliteration may result in extensive thrombosis. A distal bypass using autogenous vein may be performed in an attempt to revascularize one of the forearm arteries, usually the interosseous one, otherwise upper dorsal sympathectomy is performed.[38,41]

In conclusion, surgical revascularization for upper extremity arterial occlusive disease is safe, well tolerated, and yield high rates of limb salvage. The technique of revascularization must be tailored to the arterial lesion and associated risk factors. Conservative treatment is indicated in patients with mild symptoms as development of the rich collateral circulation will usually results in termination of ischemic symptoms.

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