Arterial Surgery for Arm Ischemia

A Survey of 136 Patients

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A series of 136 patients with upper extremity ischemia requiring operative correction is presented. Causes of the ischemia included trauma, atherosclerosis, embolism, iatrogenic causes, radiation injury, and cervical rib syndrome. Operations included primary repair, various bypass grafts and embolectomy. Illustrative case reports are used to emphasize important points. The subclavin, axillary and brachial arteries have been considered separately. In general, ischemia of the arm caused by a discrete lesion is amenable to surgical correction with an excellent chance of success.

ISCHEMIA OF THE UPPER extremity requiring operative intervention is relatively uncommon. Atherosclerotic occlusive disease involves the arm infrequently, and the rich collateral circulation tends to be protective. Nonetheless, there are patients who do have significant ischemia of the upper extremity, often due to trauma. The purpose of this paper is to present a series of 136 consecutive such patients admitted to the University Hospital from 1961 to the present, and the operations employed will be emphasized. The arm ischemia in these patients was produced by a wide variety of causes.

Clinical Material

There were 20 patients with subclavian artery disorders, 30 patients with axillary artery disorders, 81 with brachial arterial disorders, and only five listed with radial or ulnar disorders. However, patients with hand ischemia who did not have an operation were not included, and a considerable number of patients fell into this category. The types of lesions which had produced arm ischemia included atherosclerosis, trauma, embolism, cervical rib problems, congenital atresia of the subclavian artery, Blalock-Taussig operation with interruption of the subclavian artery, arteritis, radiation injury, and other miscellaneous conditions.

The various types of lesions and the operations employed for relief of the ischemia will be presented in series with respect to the subclavian artery, the axillary artery, the brachial artery, and the radial and ulnar arteries and more distant vessels.

Subclavian and Innominate Artery Disorders

Twenty patients had disease involving the subclavian or the innominate artery, atherosclerosis being the most common cause. Each patient had symptoms of arm ischemia ranging from intermittent claudication to rest pain. Nine of the 20 patients also complained of vertigo, syncope or blurred vision, and these exhibited subclavian steal on the arteriograms. The various causes of subclavian artery occlusion producing steal are atherosclerosis, congenital atresia of the subclavian artery, Blalock-Taussig operation, bullet embolism from left ventricle, arteritis, and trauma and aneurysm.

Case 1. (Subclavian steal relieved with axillo-axillary bypass). This 68-year-old white man presented with a six-year history of intermittent bilateral transient blindness. Physical examination revealed a decreased left radial pulse and bilaterial carotid bruits. Arteriography disclosed total occlusion of the left subclavian artery at its origin, total occlusion of the right internal carotid at its origin, high-grade stenosis of the left internal carotid, and left subclavian steal.

It was felt that the subclavian steal should be corrected to reverse the flow in the left vertebral artery prior to having a carotid endarterectomy. This was accomplished by performing an axillo-axillary bypass with a saphenous vein graft (Fig. 1). The radial pulses and arm blood pressures were equal postoperatively, and he subsequently underwent carotid endarterectomy without difficulty.

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FIG. 1. Axillo-axillary reversed saphenous vein bypass for revascularization of proximally occluded left subclavian artery associated with symptomatic subclavian steal (arrow). Postoperatively the arm blood pressures were equal and the neurologic symptoms were abolished (Case 1).

Comment

The subclavian steal syndrome was first described by Contorni in 1961 and represents a combination of angiographic findings in which there is 1) innominate or subclavian stenosis or occlusion, 2) retrograde vertebral flow, 3) patency of both vertebral arteries and the basilar artery.[3] The most common symptom is vertigo, although the spectrum of symptoms includes ischemic arm symptoms such as claudication and paresthesias, as well as vertebrobasilar symptoms such as diploplia, ataxia, and syncope. A minority of patients with the radiographic syndrome are asymptomatic.[5,19]

Upper extremity gangrene or stroke resulting from subclavian artery disease is uncommon, though it is not rare to find some necrosis of the fifth, or the fourth and fifth, fingers of the hand in elderly persons who have occlusion of the subclavian artery (Fig. 9).

Our philosophy of management of subclavian artery occlusive disease has been progressively modified since 1961. During the earlier years of this series the ischemia was corrected principally with aortosubclavian bypass (Fig. 2). Seven patients had this type of bypass, with one postoperative death due to respiratory insufficiency. Another patient underwent subclavian endarterectomy. However, during the more recent years we have usually employed an extra-anatomic bypass such as carotid-subclavian or subclavian-subclavian bypass. The carotid-subclavian bypass is performed with either a prosthetic graft or preferably a saphenous vein graft, using a temporary shunt in the carotid in most patients.[20] The early concern that the carotid-subclavian bypass would cause carotid steal with neurologic symptoms has been allayed by extensive and satisfactory clinical and laboratory experience.[4,8,23] The advantages of this procedure over the aortosubclavian bypass are that it does not require a thoracotomy and also that it avoids the risk of intrathoracic infection. Moreover, carotid-subclavian bypass has proved to be as effective and durable as aortosubclavian bypass.[2,5]

In those patients with ipsilateral carotid disease or innominate disease we have employed the subclavian-subclavian or axillo-axillary bypass where appropriate.[14,17,21] This procedure shares with the carotid-subclavian bypass the advantage of reduced physiological insult, compared with the aortosubclavian bypass. A retrograde femorosubclavian graft may be employed for the correction of arm ischemia, though we have not used this bypass ourselves as yet.[16]

There was only one instance in which subclavian injury causes serious distal ischemia, though there were other trauma patients in whom subclavian artery interruption occurred without major distal ischemia. In one patient a bullet embolized from the left ventricle to produce complete occlusion of the left subclavian artery with subclavian steal. Of course, the pulsatile flow may continue through a subclavian artery which is

simply the site of a subclavian traumatic false aneurysm without interruption or thrombosis of the artery. There follows an instance of a patient in whom the subclavian artery had been interrupted in all elements except its adventitia and the pleura of the upper thorax on the left, without extensive bleeding but with complete occlusion of the vessel due to contusion, disruption of the intima and media, and thrombosis.

Case 2. (Blunt trauma with multiple injuries). This 22-year-old white male was admitted to University Hospital having been involved in a motor vehicle accident some two to three hours previously. He had had no detectable blood pressure when seen at an outlying hospital where he was initially resuscitated.

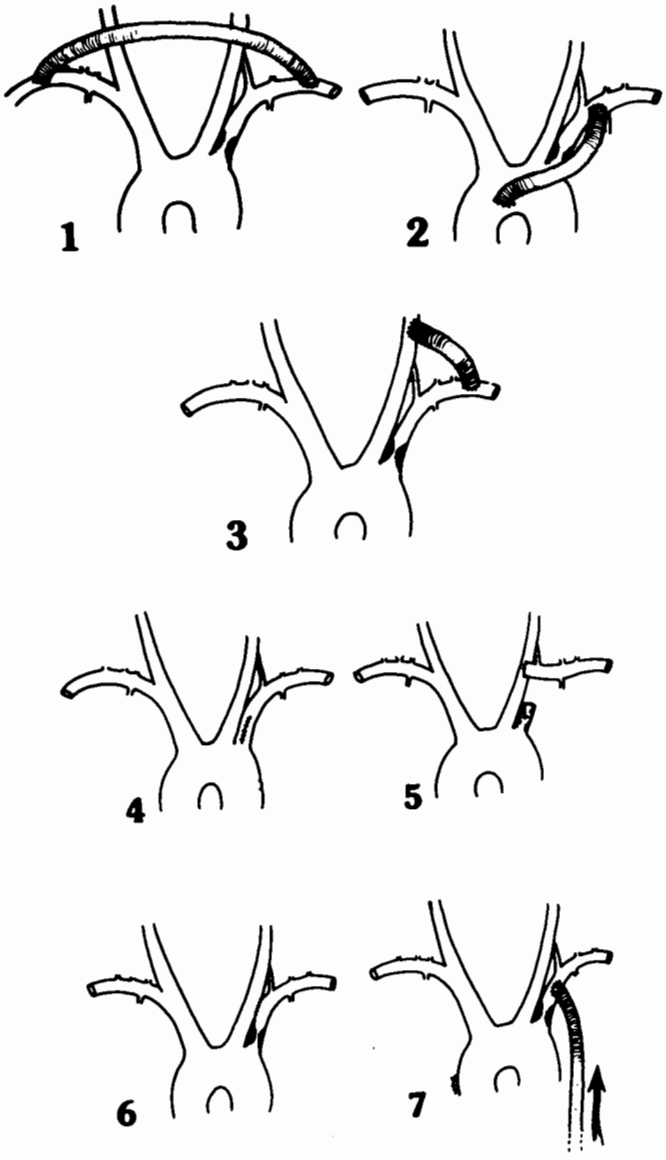


FIG. 2. Operations for relief of proximal subclavian artery occlusion. (1) Axilloaxillary bypass. (2) Aortosubclavian bypass. (3) Carotid-subclavian bypass, the most commonly used method. (4) Subclavian endarterectomy. (5) Carotid-subclavian anastomosis, end-to-side. (6) Carotid-subclavian anastomosis, side-to-side. (7) Femorosubclavian or femoro-axillary bypass. Either reversed saphenous vein or fabric graft may be used but we prefer the vein.

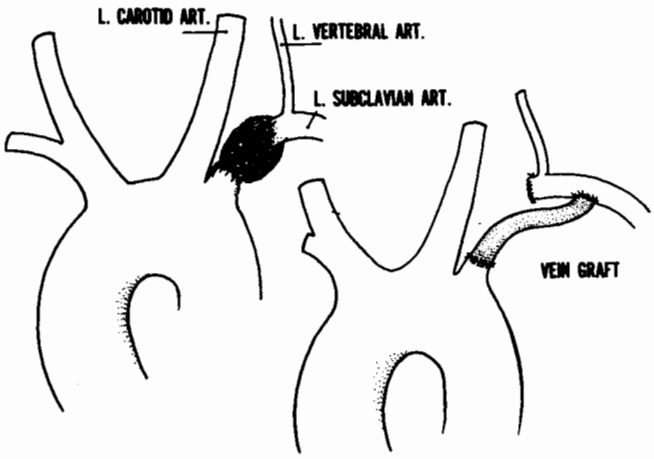


FIG. 3. (Left) False aneurysm of left subclavian artery secondary to MVA blunt trauma. (Right) Correction with reversed saphenous vein graft (Case 2).

On arrival at UMC he was noted to be severely obtunded mentally and requiring assisted ventilation via an endotracheal tube. Further examination revealed reactive pupils, a pulsatile hematoma in the left supraclavicular space, no palpable pulses in the left arm with cyanotic nail beds, and no response to pain. His left hand, although cyanotic, was warm and viable. Peritoneal lavage fluid was grossly bloody. Aortogram revealed injury and occlusion of the left subclavian artery (Fig. 3).

He first underwent emergency exploratory laparotomy and was found to have a large retroperitoneal hematoma and a long liver laceration which was controlled. He was further stabilized and 24 hours later was taken back to surgery where, through an anterior thoracotomy, the injured segment of the left subclavian was oversewn and flow reconstituted via saphenous vein bypass graft. He developed a good pulse in the left arm.

His hospital course from this point on was stormy. On the fifth postoperative day he required re-exploration of the abdomen for massive secondary liver hemorrhage, and he subsequently developed a severe respiratory distress syndrome. He died 12 weeks later from respiratory complications secondary to his severe head injuries.

Comment

The subclavian artery is less frequently injured than is the brachial artery or the arteries in the leg.[11] Furthermore, serious ischemia following subclavian injury is uncommon because of the rich network of collateral circulation about the shoulder. However, regardless of the absence of serious distal ischemia, it is important to repair injuries to the brachial or the subclavian artery promptly, first, because of the continuing potential for serious blood loss and, secondly but equally important, the fact that a false aneurysm of an artery may gradually expand to compress adjacent nerves and produce neurologic deficits. Inasmuch as a subclavian injury may be present regardless of a palpable distal pulse, arteriograms are very important in delineating the

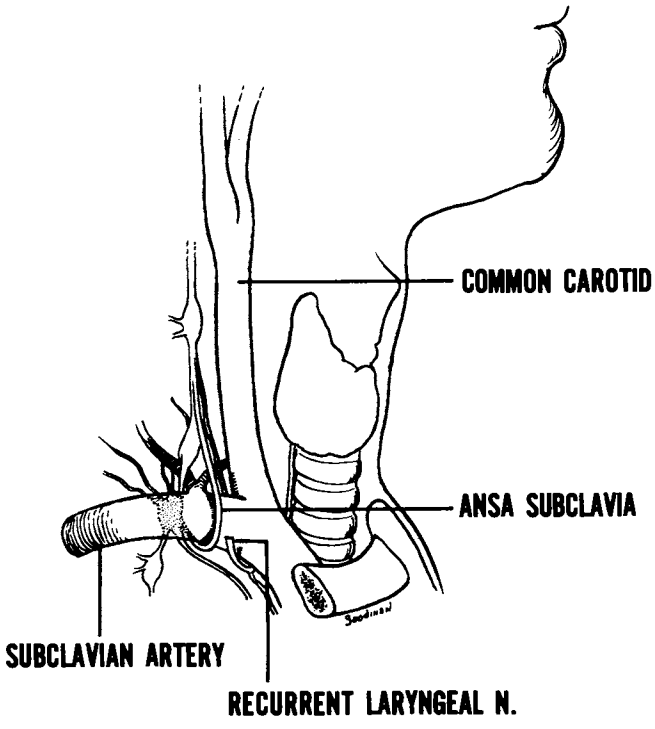


FIG. 4. Injury to the ansa subclavia may result in a temporary or prolonged ipsilateral Horner's syndrome. The recurrent laryngeal nerve loops around the right subclavian artery in the neck and runs adjacent to the left subclavian artery as it courses from the aorta to the thoracic inlet.

presence and nature of a subclavian injury. Moreover, the arteriographic identification of the site of the subclavian artery injury will assist in planning the appropriate incision. Lesions of the proximal left subclavian artery are best approached through a left thoracotomy incision. The innominate and the proximal thirds of the right subclavian artery can be approached through a partial median sternotomy or a "trap door" incision, if in fact the injury cannot be reached through a simple neck incision. The distal and middle thirds of the subclavian artery on either side can be approached through a supraclavicular incision, with excision or division of the clavicle when required. Occasionally it may be advisable simply to ligate the subclavian artery if distal ischemia is not serious, since the presence of infection may render this mandatory; but in the absence of infection and with patency of the vessels distally, revascularization is almost routinely successful. If the vessel must be ligated because of extreme circumstances, one can return later and insert an appropriate graft for restoration of subclavian artery continuity if indicated.

Obtaining proximal and distal control of a subclavian injury can be particularly challenging because of the extensive collateral circulation about the shoulder. At times control of the injury can best be accomplished by compressing the artery on each side of the injury, and then inflating Fogarty catheters proximal and distal to the injury. This maneuver will stop bleeding, allow precise assessment of the situation, and permit placement of sutures, with removal of the catheters just as the last sutures are being tied down. The ansa subclavia and the recurrent laryngeal nerves are to be protected (Fig. 4).

Miscellaneous Other Subclavian Artery Lesions

Among the various other lesions of the subclavian artery which produced distal ischemia were congenital atresia of the right subclavian artery proximal to the origin of the vertebral artery, a cervical rib with thrombosis within the compressed subclavian artery and with distal embolism, aneurysm of the subclavian artery, arteritis, and the use of the subclavian artery for the Blalock-Taussig operation.

Case 3. (Left cervical rib with axillo-subclavian artery thrombosis and distal embolism). This 30-year-old white woman developed pain in the left hand 10 days prior to admission to University Hospital. There was no history of trauma, diabetes, smoking or heart disease. Arteriograms from the referring physician revealed occlusion of the brachial artery on the left.

Physical examination revealed the left hand to be cool with cyanotic nail beds. The radial and ulnar pulses on the left were absent. Radial artery pressure on the left was 70 mmHg with a right brachial pressure of 130 mmHg.

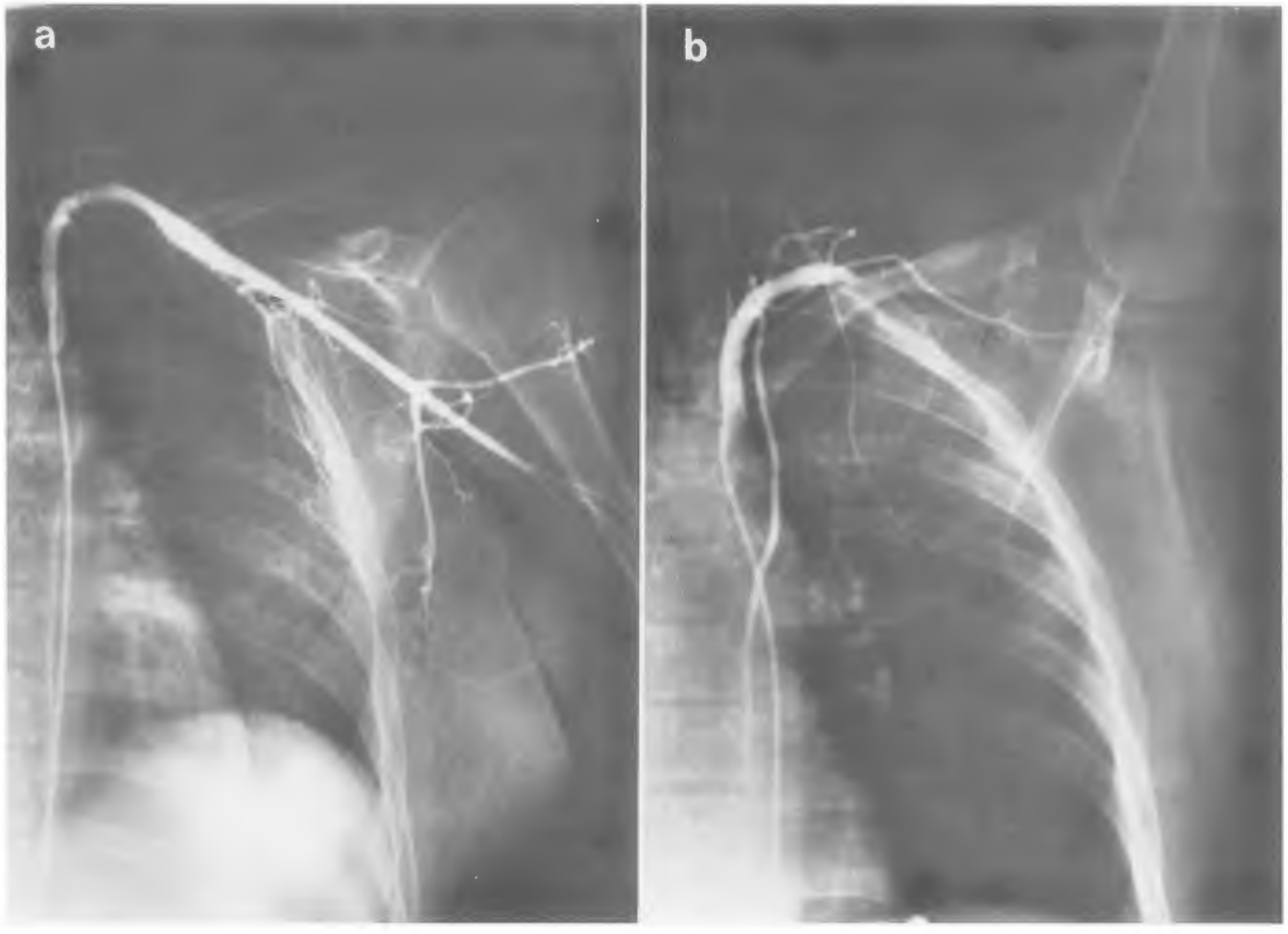
Chest x-ray disclosed a cervical rib bilaterally, and arteriograms showed narrowing of a 3–4 cm segment of left subclavian artery adjacent to the cervical rib with dilatation distal to this narrowing. Elevation of the arm above the head produced almost complete subclavian artery occlusion, with return of pulsations when the arm was lowered to the side (Fig. 5). There was also occlusion of the left brachial artery at the midportion with collateral reconstitution of the radial, ulnar, and interosseus arteries.

The patient underwent resection of the left cervical and first ribs and fogarterization of the brachial artery, with vein patch angioplasty at the arteriotomy site. Postoperatively there was a good radial pulse with a warm, painless, noncyanotic hand.

Comment

Poststenotic dilatation of the axillary artery distal to a cervical rib may eventually result in true aneurysm formation (Fig. 6). Thrombus may form and embolize to more distal divisions of the arterial tree and produce severe ischemia, and thus an offending cervical rib should be dealt with promptly.

The various forms of thoracic outlet syndrome, including cervical rib, usually cause paresthesias, aching and weakness of the upper extremity from brachial plexus compression. Symptoms of arterial insufficiency such as coldness, pallor, or peripheral embolism are



FIGS. 5a and b. Arteriograms of left subclavian artery in patient with cervical rib, poststenotic dilatation of the artery with thrombus formation, and distal embolism producing marked ischemia. (a, *left*) Arteriogram discloses dilatation just distal to the cervical and first ribs. More distally, emboli had produced major obstruction in the brachial artery and its branches. (b, *right*) Elevation of the left arm above the head produced complete cut-off of flow through the subclavian artery at the level of the first rib (Case 3).

uncommon but do occur. Treatment usually consists of removing the first rib and the cervical rib if present. In recent years we have used the transaxillary approach almost exclusively.

Use of the subclavian artery to construct the Blalock-Taussig shunt for correction of tetralogy of Fallot is a well recognized but uncommon cause of subclavian steal syndrome and arm ischemia. In an article describing a review of the angiograms of 114 children with Blalock-Taussig shunts, Folger and Shah identified subclavian steal in 12, of whom seven had symptoms of vertebrobasilar insufficiency.[7] Occasionally gangrene of the arm can result from the Blalock-Taussig procedure, particularly if anatomic considerations dictate extensive dissection with ligation of many collaterals. Total correction of the tetralogy has generally relieved the symptoms of subclavian steal.[18]

Congenital atresia of the subclavian artery results from failure of development of the fourth aortic arch. Although subclavian atresia is frequently associated with a right aortic arch or coarctation of the aorta, our case had neither. If the symptoms from congenital subclavian atresia are sufficiently disabling, the standard bypass operations for subclavian steal can be used.[15]

Endarteritis or Takayasu's disease is an uncommon disorder which primarily affects the branches of the aortic arch. Pathologically this disease consists of a transmural inflammation of the arterial wall, followed by thickening, replacement with fibrous tissue, and obliteration of the lumen. The initial symptoms usually consist of fever, malaise, arthralgia and weight loss. As the disease progresses, tenderness develops in the neck and shoulder girdle over the affected vessels. As the arterial lumen is obliterated, symptoms of distal ischemia develop. Steroids have been used in treatment

with variable response. Surgical treatment has been used for correction of distal ischemia of aortic, carotid, or subclavian occlusion with limited success.

Axillary Artery Disorders

Axillobrachial occlusion was caused by trauma, embolism and atherosclerosis. Trauma was the most common cause of ischemia secondary to occlusion of the axillary and brachial arteries. A total of 88 patients had traumatic lesions of these two arteries, which included 41 gunshot wounds, 23 lacerations, and seven instances of blunt trauma. These injuries were managed by end-to-end anastomosis in 35 patients, vein graft in 24 patients, lateral repair in eight patients, and fasciotomy on only two occasions. The following patient is illustrative of the management of patients with gunshot wounds.

Case 4. (Axillary artery gunshot injury with occlusion. Repair with vein graft). This 18-year-old black boy was admitted to University Hospital after receiving a gunshot wound to the right shoulder eight hours prior to admission. Physical examination revealed an entrance wound 3 cm below the right clavicle, just medial to the axillary fold. There was a large hematoma in the axilla and no pulses could be felt in the right arm. Arteriogram revealed a complete block of the axillary artery in its distal third.

The patient was taken to surgery for exploration of the injury. He was found to have a rent in the axillary artery about one-half inch in length. The damaged portion of the vessel was resected and the artery was reconstructed using a segment of reversed saphenous vein. Good distal pulsations were achieved and he recovered uneventfully.

Comment

Angiography was usually performed on suspected axillary artery injuries, first, for diagnosis and, second, to define the nature of the lesion and to indicate the most appropriate anatomic approach. In the management of brachial artery injuries, arteriography was usually reserved for those patients in whom the diagnosis of arterial injury was in doubt. Operative management included proximal and distal control, debridement of the injured artery, Fogarty catheterization for thrombectomy, and reestablishment of continuity. In most instances a primary anastomosis was possible, but occasionally a saphenous vein graft was required. Lateral repair was performed when feasible. Completion operative arteriography was obtained whenever there was no doubt as to the satisfactory nature of the anastomosis even in the presence of a good distal pulse.

Brachial Artery Disorders

Brachial artery lesions were caused principally by trauma, but atherosclerosis, embolism and radiation injury were also met in some patients.

Acute Brachial Artery Thrombosis

Brachial artery thrombosis following cardiac catheterization was a significant cause of trauma causing upper extremity ischemia. There were 15 such injuries which required operative intervention. In 13 of these patients thrombectomy, debridement, and lateral repair yielded a satisfactory result. One patient required debridement and interposition of a vein graft. One other patient required an extra-anatomic saphenous vein graft to bypass an infected false aneurysm of the brachial artery.

Case 5. (Cardiac catheterization injury with infection). Ligation of brachial artery and extra-anatomic vein bypass). This 30-year-old white man had had aortic valve replacement secondary to bacterial endocarditis. Shortly after repeat cardiac catheterization he developed a false aneurysm of the right brachial artery. This was explored and the defect in the artery closed primarily. In the postoperative period he developed high fever and bleeding from the operative site. Blood cultures grew *Staphylococcus aureus* and he was begun on appropriate antibiotics. The right antecubital fossa was re-explored, and the brachial artery was ligated at the site of the false aneurysm to control recurrent hemorrhage. However, the right hand was now severely ischemic and clearly would not survive without revascularization. Therefore, a vein graft was performed between the brachial artery proximally and the radial artery below, through clean tissue planes (Fig. 7).

The hand was satisfactorily revascularized, the patient recovered uneventfully, and has remained well for one year.

Comment

The general principles of management of an infected false aneurysm were observed in this case. Then the false aneurysm "ruptured" repeatedly with subsequent external hemorrhage, the vessel was ligated through clean tissue on both sides of the false aneurysm and thereafter the distal circulation was evaluated. When there was no detectable flow with a Doppler instrument, and since the hand was obviously severely ischemic, arterial reconstruction was mandatory. An autogenous saphenous vein graft was brought from the brachial artery, well above the site of ligation of the brachial artery to the radial artery below, through uncontaminated tissue planes. The postoperative anteriogram is shown in Figure 7. Specific antibiotic therapy was employed and the site of ligation of the brachial artery healed without event.

Case 6. (Brachial artery compression by bone fragments—fasciotomy). Fasciotomy was not often necessary in our series, but it was useful when required. This 4-year-old girl was admitted to University Hospital with a completely displaced left humeral supracondylar fracture. Closed reduction was achieved and a cast applied. However, a few hours later the radial pulse disappeared. The brachial artery was then explored at the elbow and fasciotomy was performed. Open reduction of the fracture was carried out with a good long-term result.

Comment

Arterial spasm sufficient to cause signs and symptoms of ischemia is uncommon but may follow blunt trauma with or without an associated fracture. However, before a diagnosis of spasm is accepted, arterial compression of thrombosis due to intimal injury should be excluded. Spasm should always be confirmed by arteriography or surgical exploration. An erroneous diagnosis of spasm may result in irretrievable ischemia and gangrene.

Fasciotomy is a valuable adjunctive measure in the management of arterial injuries. Compartmental edema or contusion can cause impairment of venous drainage and pressure injury to nerves and muscles.

Embolism

In contrast to the subclavian artery, embolism affected particularly the more distal arteries including the axillary (four patients), branchial artery (12 patients), and the radial and ulnar arteries (one patient). The emboli were removed by use of a transverse arteriotomy and the Fogarty catheter. The causes of embolism were, most frequently, lesions of the left side of the heart.[12] However, in one instance, as noted above, thrombosis in the axillary artery was due to a cervical rib, producing distal embolization. Unfortunately, two patients with brachial artery embolism required amputation above the elbow. Each of these two patients presented at our hospital with severe ischemia of greater than 24 hours duration.

Chronic Axillobrachial Occlusive Disease with Distal Ischemia

Chronic surgically correctable upper extremity ischemia is much less common than is acute ischemia. There were five cases of chronic upper extremity ischemia in our series that were secondary to brachial or axillary lesions. Axillobrachial bypass using reversed saphenous vein graft was successfully performed in two cases. In two instances old arterial trauma was responsible for the chronic arm ischemia, which again was corrected with vein graft bypass. One of these thrombosed in the postoperative period, but the other patient has continued to have a good result from a brachial to ulnar bypass.

Case 7. (Ischemia due to old trauma). This 26-year-old black male received a shotgun wound of the left upper arm on April 16, 1978. He was referred to University Hospital and was found at arteriography to have a brachial artery injury as well as a humeral fracture. Both the radial and ulnar pulses were present but weak. He underwent exploration and repair of this arterial injury on the night of admission. Reconstruction was performed using a segment of reserved saphenous vein. Other wounds were also debrided. A fasciotomy was performed four days later. Immediately after operation the distal pulses were palpable, but these gradually weakened until on discharge they were present only by Doppler flow probe, though his hand appeared to be well perfused.

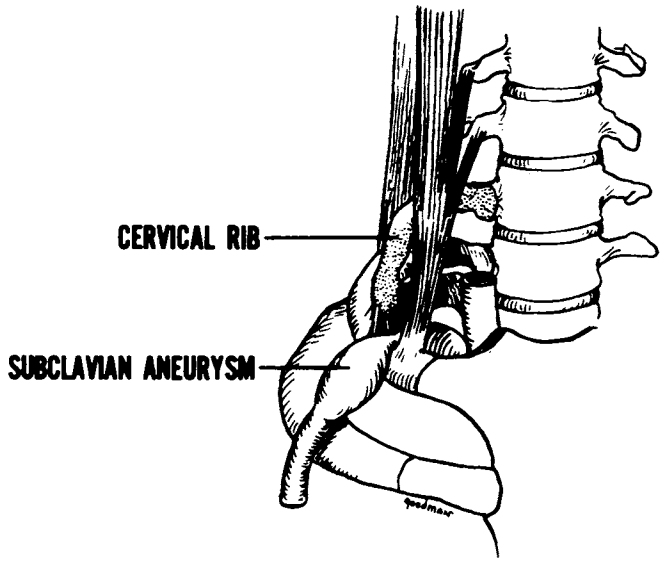


FIG. 6. Anatomical features of cervical rib compression with poststenotic dilatation and eventual aneurysm formation. A special hazard of this condition is that repeated embolism may occlude more and more vessels distally and may produce irretrievable ischemia with gangrene.

Over the ensuing four months he developed progressive pain in the left hand as well as evidence of tissue necrosis at the tips of the fingers. A repeat arteriogram was performed which showed occlusion of the brachial artery with reconstitution of the ulnar but not the radial artery.

He was subsequently re-explored and the area of obstruction bypassed with a reversed saphenous vein graft. The bypass was from the proximal brachial artery to the ulnar artery. A good ulnar pulse at the wrist was immediately present. The patient's symptoms were relieved and he has had no further problems.

Case 8. (Arterial thrombosis associated with radiation injury). A 56-year-old black man was admitted to University Hospital complaining of pain, weakness, and coolness of his right arm and hand. Past history revealed that he had undergone resection of a sarcoma from his right biceps 25 years prior to admission and received postoperative irradiation to his right arm.

Physical examination showed marked atrophy of the musculature and chronic edema. No brachial, radial or ulnar pulse was palpable in the right arm. Doppler pressure was 80 mmHg systolic in the brachial artery and 50 mmHg systolic in the radial artery. Left arm blood pressure was 120/70. Arteriogram revealed occlusion of the right brachial artery just distal to the take-off of the circumflex humeral artery (Fig. 8).

Surgical correction was achieved with an axillobrachial reversed saphenous vein graft. Postoperatively he has done well and has excellent pulses in the right arm. Postoperative Doppler studies show a brachial systolic pressure of 124 mmHg compared to 120 mmHg in the left arm and a radial pressure of 120 mmHg compared to 120 mmHg in the left wrist.

Comment

The cardiovascular system is relatively resistant to radiation injury, but this appears to be a valid situation

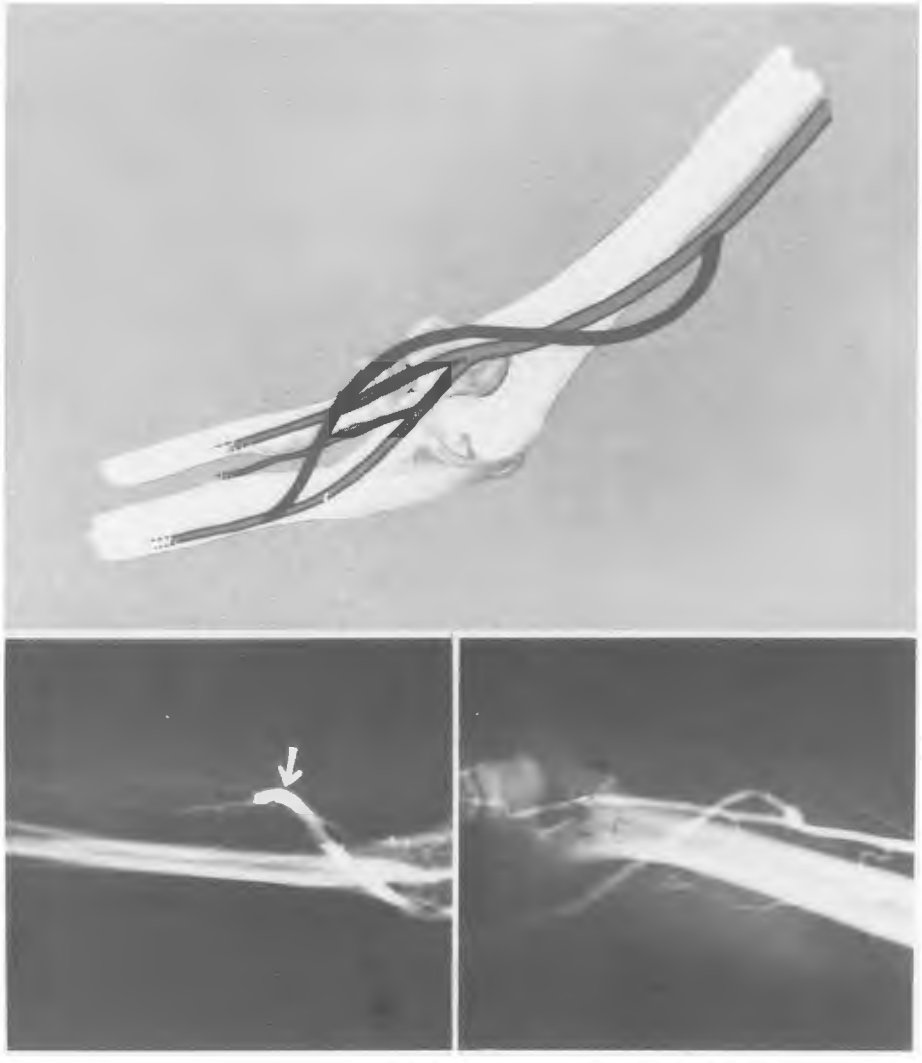


FIG. 7. Extra-anatomic reversed saphenous vein bypass, employed in the management of an infected brachial false aneurysm which followed cardiac catheterization (Case 5).

in which radiation to a sarcoma did produce injury and thrombosis of the brachial artery many years later, though entrapment by scar tissue may have been a factor.

Radial, Ulnar, and More Distal Artery Disorders

Forearm and hand ischemia secondary to trauma or other injury to the radial, ulnar, or more distal arteries was recorded in five instances (Fig. 9). Nonetheless, the authors are certain that the incidence of this hand ischemia was far greater than that indicated by the computer survey, probably because the injuries were not appropriately classified or recorded on the patient's chart at the time of discharge. The causes of injury to these vessels include trauma with or without fractures, intra-arterial cannulas for measuring blood pressure, inadvertent arterial injections, and miscellaneous other small vessel diseases.

This segment of our report of operations for arm ischemia can best be summarized by a few statements. First, the traumatic false aneurysms of these vessels were managed by formal lateral repair of a false aneurysm, by resection of a segment of the vessel with primary end-to-end anastomosis, or by interposition vein graft where indicated. The common policy objective was to preserve both the ulnar and the radial artery in all patients. If thrombosis had been associated with the use of arterial cannulas or arterial infection, a Fogarty catheter was employed to remove all clots to the extent possible. If an arterial cannula was required for the continuous monitoring of arterial blood pressure or for the availability for frequent arterial blood gas measurements, close attention was paid to the condition of the hand. The cannula was moved to another site when any evidence of significant ischemia occurred such as a cold, painful, numb or paralyzed hand.

Case 9. (Hand ischemia caused by arterial cannula and vasopressor drugs). This patient was admitted to University Hospital for evaluation of severe atherosclerotic heart disease at age 64. After thorough evalution, he underwent coronary artery bypass. His postoperative course was very stormy, requiring a long stay in the intensive care unit. During this part of his postoperative care he had radial artery lines placed for blood pressure and arterial blood gas monitoring. In addition, he required epinephrine and dopamine infusions for approximately ten days to support the cardiac output. Although he recovered and went home in fair general condition, he developed dry gangrene of distal phalanges of the index and middle fingers of both hands. This was felt to be the result of the arterial lines and possibly the long-term epinephrine infusion.

FIG. 9. Gangrene of the tip of the fifth finger due to atherosclerotic occlusion of left subclavian artery at its origin from the aorta. Such finger necrosis may be caused by arterial occlusion at any point from the aorta to the small vessels of the finger itself.

Sympathectomy

Our policy has been to use sympathectomy very sparingly in the management of arm or hand ischemia. It has occasionally been used for the management of causalgia, though in such instances ischemia was not a problem. However, if the hand was seriously ischemic, we have employed stellate ganglion blocks to identify whether or not subsequent sympathectomy might be useful in improving blood flow to the hand.

FIG. 8. Occlusion of the brachial artery secondary to massive radiation therapy for a soft-tissue sarcoma. Corrected with saphenous vein bypass (Case 8).

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Discussion

Dr. Charles Rob (Greenville, North Carolina): I'd like to discuss the question of carotid-subclavian bypass for proximal subclavian occlusion. We all, when we started doing these, felt that we might get steal syndromes and cerebral ischemia as a result of this. Those of us who have used this now know that such syndromes do not occur clinically.

Some years ago, with a Polish colleague, we published a paper on what happens to the carotid–subclavian flow after a carotid–subclavian bypass, and we made measurements of the flow in animals and patients, and it is of interet that if you measure the blood flow in the common carotid artery proximal to such a bypass, it rises an average of 48% after the bypass is opened. If you measure the blood flow of the internal carotid distal to such a bypass, it fluctuates slightly, but in general it remains unchanged. And if you measure the flow in the subclavian artery distal to such a bypass, it rises on the average 48%.

So, in fact, experimentally and clinically, we do not steal blood from the head when we put in a carotid–subclavian bypass. We just increase the outflow, and increase the flow through the common carotid artery.

Dr. Jesse E. Thompson (Dallas, Texas): Dr. Hardy and his colleagues have given us an all-inclusive survey of lesions responsible for arm ischemia.

He has described the symptomatic patient with proximal subclavian artery occlusion, and he points out that when these patients have symptoms, they need to be operated on. The techniques which he has described are quite appropriate and are really very successful.

Curiously enough, however, the majority of patients with atherosclerotic occlusions of the proximal portion of the subclavian artery do not require operation, since they are asymptomatic, even in the presence of a demonstrable subclavian steal on the x-rays. When the collateral circulation breaks down, and symptoms supervene or embolization from an atherosclerotic plaque occurs—something that we have come to recognize more recently—then operation becomes necessary; but an atherosclerotic occlusion on the x-ray alone is not necessarily an indication for a bypass operation.

Dr. Hardy mentioned arterial damage from radiation therapy. This is a rare cause of arm ischemia, but it can be very challenging. My colleagues and I have recently seen a patient with severe ischemia stemming from a left radical mastectomy, followed by radiation therapy, complicated by infection. Time does not permit elaboration of the details, but my colleague, Dr. Talkington, saved her left arm and relieved her causalgia by means of a dorsal sympathectomy and a long bypass graft using Goretex, starting at her innominate artery, passing across her neck, and down the arm to her left ulnar artery, a graft which has now been patent for well over a year.

Now a word about iatrogenic injuries. Dr. Hardy mentioned the injuries encountered with coronary angiograms. The incidence of brachial artery injuries from this procedure is in the range of 3–4%; so that in institutions where a great many of these are being performed there are a number of cases that require thrombectomy with a Fogarty catheter, and then repair of the artery.

Another area for iatrogenic injury is the arterial monitoring line. The worst problems that we have seen have come from the brachial lines rather than from radial lines. One of our patients actually lost a thumb from thrombosis of the artery around a brachial monitoring catheter. And as a result of this experience, we prefer the radial line at the wrist, and get the catheter out as soon as possible, rather than use the brachial line, which some of our anesthesiologists advocate.

Over the years we have continued to employ dorsal sympathectomy as an adjunct in patients with upper extremity ischemia, especially when large vessel reconstruction is not feasibile. In fact, we have been more prone to use sympathectomy with occlusive lesions than in patients with the classic Raynaud's disease, or other syndromes related to autoimmune phenomena. I would like to ask Dr. Hardy if he would comment on the use of sympathectomy in these two latter situations.

Dr. Alton Ochsner, Jr. (New Orleans, Louisiana): I would just like to suggest that the proximal axillary artery is a better alternative to the use of the subclavian artery, and it can be used any time that you ordinarily would use the subclavian artery, except when you want to transplant the vertebral to the subclavian.

For seven years, I've used the proximal axillary artery, and in 24 patients have been pleased with it. It's been universally successful in relieving symptoms with no complications, including no Horner's syndrome, Dr. Hardy.

And I feel that any operation that's easier for the physician has got to be better for the patient.

The proximal axillary artery is easily exposed beneath the clavicle in a muscle-splitting incision of the pectoralis major muscle. It seems to be thicker than the subclavian, and holds its sutures better.

(slide) The first slide is actually a picture following closure, but it shows beneath the clavicle the type of incision that can be used to approach this artery, splitting the muscle of the pectoralis major.

(slide) The second slide in this patient shows the bypass from the axillary artery on your right to the carotid artery on your left. This patient had both an occlusion of the proximal carotid artery and stenosis of the internal carotid artery, and the distal end, on the left, is used as a patch graft to cover the endarterectomized segment. I would recommend using the axillary artery in place of the subclavian.

Dr. Frank E. Schmidt (New Orleans, Louisiana): Dr. Robert Hewitt and I recently reviewed our experience with severe upper limb ischemia, (slide) and over the ten years ending in 1978 we had 31 cases. "Severe ischemia" was defined as the presence of gangrene, rest pain, or truly disabling intermittent claudication. Note that one-third of our patients had ischemia on the basis of emboli, approximately one-fifth on the basis of arteriosclerotic occlusive disease, with obstructive symptoms, and one third due to trauma.

(slide) There are three points which we would like to emphasize. The first is that half of the patients who presented with ischemia due to emboli had emboli on the basis of lesions in proximal arteries,