Civilian Vascular Injuries:

A Critical Appraisal of Three Decades of Management

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THE salvage of life and limb following acute vascular injuries during the past three decades has been largely attributed to principles of diagnosis and therapy evolved from cumulative military experience. In civilian practice diagnostic problems continue to exist largely due to differing patient populations, mechanisms of injury and inadequate exposure to a large enough number of occurrences by any single person. This report presents a critical appraisal of acute arterial injuries treated at the Tulane Division of the Charity Hospital of Louisiana during the past 30 years.

Clinical Material

This report is based upon the study of 226 patients with arterial injuries treated from 1942 through 1969. This experience included 48 patients treated during the period from 1942 through 1957 and 178 treated from 1958 through 1969. Ages for the 226 patients ranged from 11 to 68 years and averaged 31 years.

Distribution and Types of Injury

One hundred and seventy-three patients sustained injuries to major arteries, and 53 had injuries to minor arteries, defined as the following: radial, ulnar or one tibial artery. Distribution of the 226 arterial injuries is depicted in Figure 1. Figure 2 demonstrates the comparative frequency of various arteries injured.

Penetrating arterial injuries occurred in 204 patients (90.2%) and blunt trauma caused injury in 22 patients (9.8%). Types of injury for the 226 patients are summarized in Table 1. Penetration, perforation, transection or lateral laceration were the usual forms of injury among patients with penetrating wounds. Fracture of the intima with disruption and thrombosis was the usual mechanism of arterial injury following blunt trauma and was only rarely seen in penetrating trauma.

Among penetrating injuries of major arteries 43.6 per cent were due to puncture wounds or lacerations, and 56.4 per cent were due to gunshots of low velocity. Distribution of penetrating injuries was similar to that of the entire series. Distribution of arterial injuries due to blunt trauma is shown in Table 2.

Acute arteriovenous fistulas occurred in eight patients (3.5%) of the entire series, but all were observed between 1958 and 1969 so that the incidence of acute arteriovenous fistulas among patients with injuries to major arteries treated during the period from 1958 through 1969 was 5.6 per cent. Locations of the eight acute fistulas are depicted in Figure 3.

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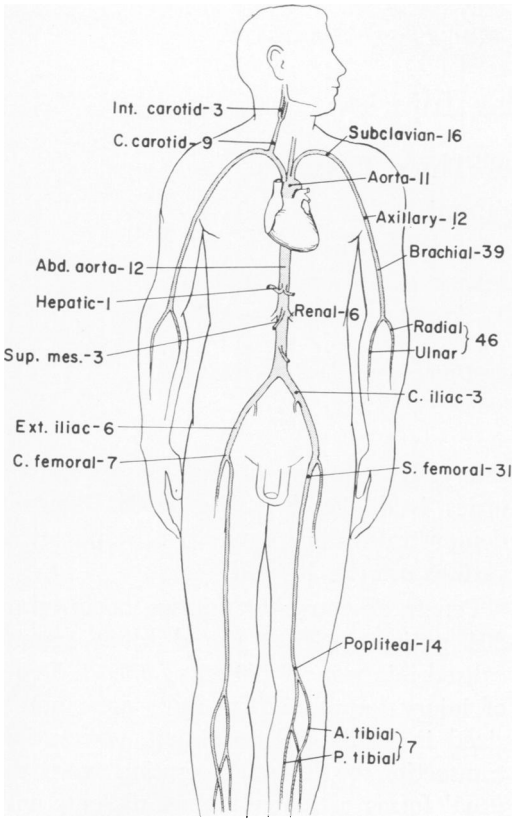

FIG. 1. Distribution of 226 acute arterial injuries.

Clinical Findings and Diagnosis

The time from injury to operation varied enormously from a few minutes up to 30 hours. Average delay for injuries to arteries of the extremities and neck was approximately 5 hours. Delay was least among survivors of abdominal aortic injuries, average 36 minutes. Fifty per cent of the 226 patients were admitted in shock due to blood loss as defined by systolic blood pressure of less than 80 mm. Hg. Fifty-seven per cent of patients with major arterial injuries, and 32 per cent of patients with injuries to a radial, ulnar or tibial artery were in shock upon admission.

Among the 128 patients with injuries to major arteries of extremities, 35 (27.3%) had palpable pulses distal to the injury. This finding was similar for patients with injuries to the upper and lower extremities, 17 (25.3%) and 18 (29.5%), respectively. Notable ischemia distal to the injury was observed in 24.1 per cent of patients with arterial injuries of the extremities.

Among major arterial injuries of the neck and extremities active arterial bleeding was noted in 13.5 per cent of patients. A murmur and often a thrill could be detected over the site of injury in 8.4 per cent. Among injured extremities edema was present in 4.5 per cent.

Among 10 patients with injuries to the carotid arteries, five had no neurological deficits. Six were in shock, three were comatose and one was hemiparetic.

Patients with injuries to major arteries within the chest had obvious signs of intrathoracic bleeding as evidenced by shock, hemothorax or hematoma demonstrated by chest roentgenogram. Abdominal arterial injuries were invariably accompanied by signs of peritoneal irritation and other obvious signs of intra-abdominal injury.

Arteriograms were performed in 30.5 per

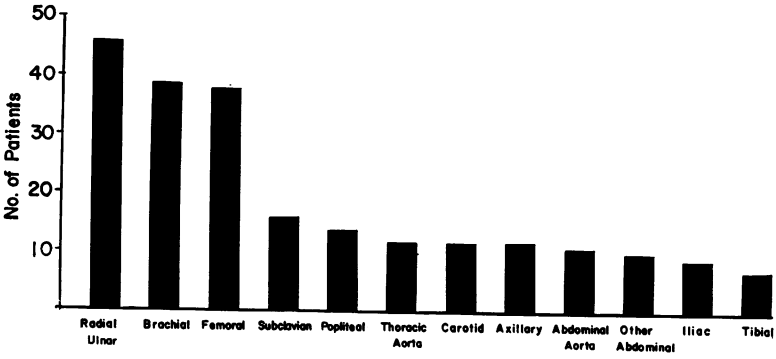

FIG. 2. Frequency of various arteries injured.

cent of patients with major wounds of the extremities or neck, and 94.4 per cent demonstrated arterial injuries (Fig. 4). Obvious arterial injury as evidenced by active bleeding, hematoma, murmur or diminution or absence of peripheral pulses was the usual indication for operating upon patients without an arteriogram. In the two instances where arteriography failed to demonstrate an injury clinical findings prompted exploration.

Arteriography was particularly useful in the evaluation of patients following blunt trauma. Acute traumatic dissection of the thoracic aorta (Fig. 5) and acute traumatic dissection of the abdominal aorta (Fig. 6) may be demonstrated by arteriography. Figure 7 is an example of arteriographic demonstration of occlusion of a renal artery following blunt abdominal trauma.

Associated Injuries

Among the 226 patients, 41.1 per cent were found to have injuries to adjacent veins although the incidence may actually be somewhat higher. Ten per cent of patients with arterial injuries of the neck or limbs had associated nerve deficits resulting in decreased motor function. Long bone fractures occurred in 8.3 per cent of patients with extremity injuries and were most common among patients with injuries to the popliteal arteries (25%). Among patients with major arterial wounds of the limbs or neck 13.5 per cent also had a wound of the chest or abdomen.

Among the most seriously injured patients were 12 with wounds of the abdominal aorta. Associated injuries among these patients included: inferior vena cava, four; left renal vein, four; pancreas, five; duodenum, three; spleen, two; liver, five; stomach, six; colon, two; kidney, one; and superior mesenteric artery, two.

Multiple abdominal injuries occurred among three patients with injury to the superior mesenteric artery and one of five patients with renal artery injuries. Multiple injuries of the abdomen were also common

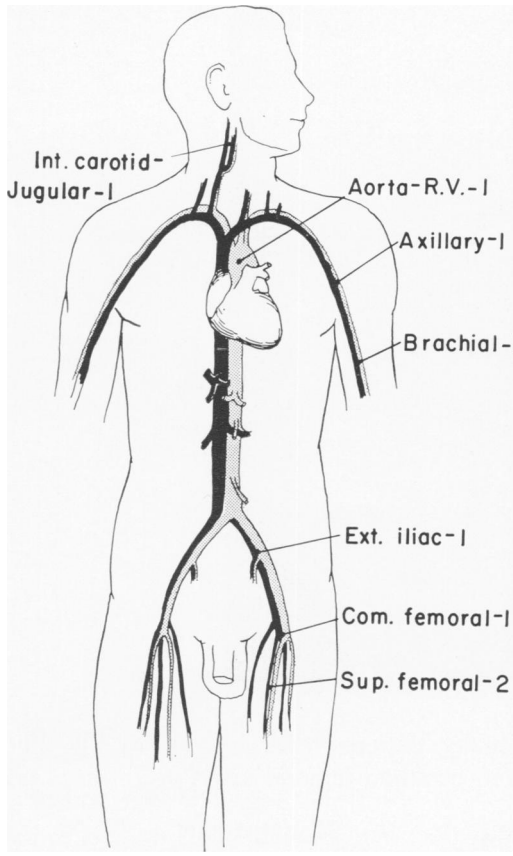

FIG. 3. Distribution of the eight acute arteriovenous fistulas.

TABLE 1. *Types of Arterial Injury*

	No	Per Cent
Penetration or perforation	77	33.9
Transection	59	26.0
Laceration	56	25.2
Fracture of intima; thrombosis	24	10.6
Arteriovenous fistula	8	3.5
False aneurysm	2	0.8
Total	226	

TABLE 2. *Arteries Injured by Blunt Trauma, 22 Patients*

Extremities	12
Renal arteries	5
Thoracic aorta	4
Abdominal aorta	1

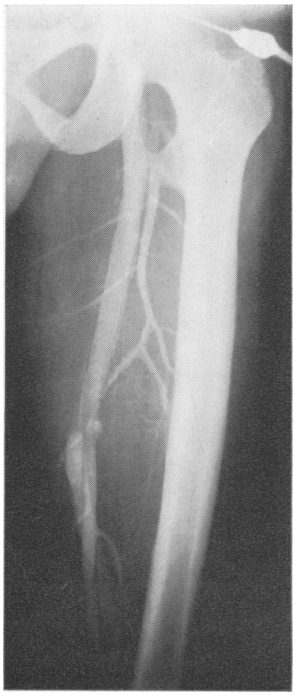

FIG. 4. Femoral arteriogram demonstrating acute arteriovenous fistula of superficial femoral artery and vein following stab wound.

among patients with injuries to the iliac and common femoral arteries.

Management

Arterial reconstruction was possible in 83.2 per cent of the 226 patients. Among the patients with injury to major veins, 50 per cent had repair of the vein. Types of arterial repair performed are listed in Table 3. Direct suture or resection and primary anastomosis was possible in 70 per cent of reconstructions. Recognition of the importance of avoiding undue tension on the repair has resulted in the more frequent use of autogenous vein grafts. Cephalic vein or other suitable arm veins are preferred for reconstruction of arteries of the upper extremity while saphenous vein grafts are used in the legs. Prosthetic grafts have been reserved for use where vein grafts are too small to serve as a conduit. The best application of patch angioplasty is for small arteries when a portion of the wall remains intact.

Incisions in the fascia to decompress muscle were performed in 9.3 per cent of patients with arterial injuries of extremities either during initial or subsequent operation. Fasciotomies were required in 50 per cent of patients with popliteal arterial injuries. Increasing experience has resulted in more frequent use of fasciotomies initially in patients with prolonged periods of ischemia especially in popliteal and superficial femoral artery injuries.

The diagnosis of a penetrating wound of the abdominal aorta is usually not made until operation. Shock is not invariably present in patients who survive abdominal aortic injury, since the aortic wound is most often tamponaded to some degree. Discovery of a retroperitoneal hematoma is the usual sign alerting to the possibility of a penetrating aortic injury. Prior to dissection of a retroperitoneal hematoma, certain conditions must be satisfied. Necessary blood and dependable routes of administration, aortic vascular clamps, arterial suture, adequate assistance and proper lighting are prerequisites to exposing the aorta and vena cava. Once controlled, most penetrating aortic injuries can be usually repaired by simple suture.

An unusual abdominal aortic injury occurred in a 67-year-old man following an automobile accident. Disruption of the intima just distal to the inferior mesenteric artery resulted in dissection, thrombosis and occlusion of the distal aorta, requiring a decron aorto-femoral bypass. A large laceration of the duodenum was also present, and he did not survive.[6]

Three patients sustained renal artery thrombosis following blunt trauma. Since

TABLE 3. *Arterial Repairs Performed*

	No.	Per Cent
Suture	82	43.2
Resection and suture	53	28.4
Vein graft	30	16.0
Prosthetic graft	14	7.6
Patch angioplasty	9	4.8
Total	188	

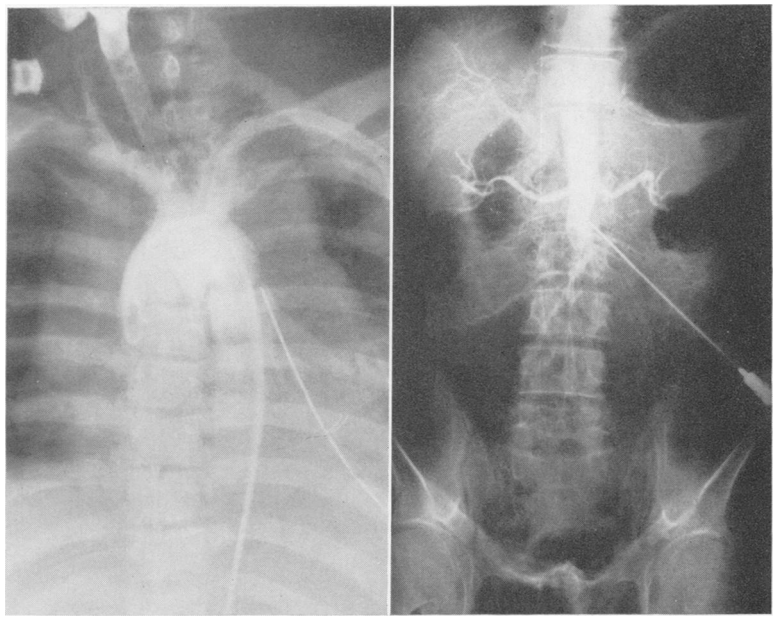

FIG. 5 (left). Retrograde aortogram demonstrating traumatic dissection of thoracic aorta, blunt trauma.

FIG. 6 (right). Translumbar aortogram demonstrating traumatic dissection of abdominal aorta, blunt trauma.[6]

the diagnosis is usually made only after irreversible renal ischemia, management is usually by nephrectomy as was done in two instances. One patient with bilateral renal artery thrombosis and renal failure required a renal allograft but died following rejection and renal failure approximately 1 year later (Fig. 8).

Suspected injury to the thoracic aorta or its branches should indicate prompt immediate thoracotomy. Figure 9 demonstrates a chest roentgenogram and femoral arteriogram in a patient with a bullet embolus lodged in the common femoral artery following a gunshot wound of the thoracic aorta. Small injuries of the thoracic aorta may be controlled easily and quickly, but certain injuries such as traumatic dissection of the thoracic aorta secondary to blunt trauma may require the use of partial heart bypass with an oxygenator or use of left heart bypass without an oxygenator.

Results

Among the 226 patients there were 24 deaths (Table 4), a case fatality rate of 10.6 per cent. Five of 12 patients with injuries to the thoracic aorta died. Four deaths were due to incorrect diagnoses and all occurred during the first decade of this study. One death occurred following operation in a patient who also had massive injury to the chest and a large liver fracture. Among 12 patients with wounds of the abdominal aorta there were six survivors, three of whom also had wounds of the inferior vena cava or renal veins (Fig. 10). Death was usually due to massive hemorrhage and hypovolemic shock and associated with presence of other severe intra-abdominal injury.

Among 12 patients with injuries to the carotid arteries there was one death; one patient was admitted in coma. Seven patients were asymptomatic following repair.

TABLE 4. *Deaths Due to Arterial Injuries, 24 Patients*

	Deaths
Abdominal aorta	6
Thoracic aorta	5
Subclavian artery	4
Iliac artery	4
Superficial femoral	2
Superior mesenteric	1
Renal	1
Carotid	1

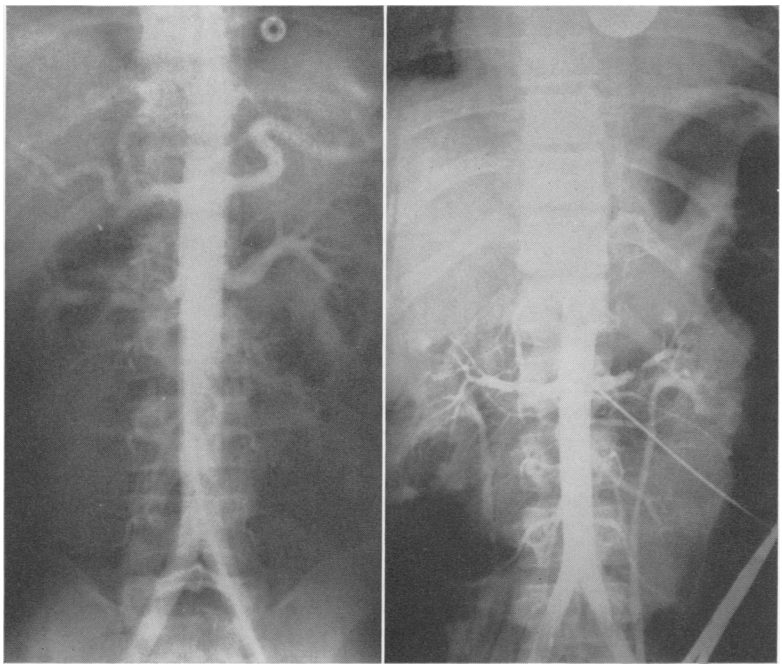

FIG. 7 (left). Retrograde aortogram demonstrating occlusion of right renal artery, blunt trauma.[3]

FIG. 8 (right). Translumbar aortogram demonstrating bilateral renal artery occlusion, blunt trauma.[3]

Two patients remained hemiparetic, one following repair and one following ligation. One remained aphasic and one had loss of proprioception. No patients were worse following operation.

For the 181 patients with injuries to arteries of the extremities the case fatality rate was 5.5 per cent and the amputation rate was 7.1 per cent. Pulses were palpable immediately postoperatively in 80 per cent of patients with repair of arterial injuries in extremities. Table 5 lists the case fatality rate and amputation rate for each artery.

TABLE 5. *Results for Arterial Injuries of Extremities, 181 Patients*

	Amputations		Deaths	
	No.	%	No.	%
Subclavian	1	6.2	4	25.0
Axillary	1	8.3	0	0.0
Brachial	1	2.5	0	0.0
Radial; ulnar	0	0.0	0	0.0
Iliac; common femoral	0	0.0	4	25.0
Superficial femoral	3	9.6	2	6.4
Popliteal	6	42.8	0	0.0
Anterior, posterior tibial	1	14.3	0	0.0
Total	13		10	

Among patients with salvage of their injured limbs, 20.4 per cent experienced decreased function due to apparent motor nerve or muscle abnormality for a prolonged or permanent period. Chronic pain was a complaint in 10.2 per cent of patients with salvaged extremities.

Infections occurred in the site of injury in approximately 5 per cent of patients, but all occurred in extremity wounds and most were in patients who required amputation. Most infections were related to wounds resulting in ischemic muscle.

A distressing complication was the development of marked edema within a few hours of restoration of arterial flow to a previously ischemic limb. Despite an apparently successful repair accompanied by incisions in the fascia to decompress muscle, progressive edema and subsequent necrosis was sometimes observed. Some degree of edema following restoration of arterial flow in an injured extremity was seen in 41 patients (Table 6). Table 7 lists cer-

tain factors generally believed to be important in development of edema after arterial repair. However, delay in treatment, incidence of vein injury, and presence of shock were not significantly different from the group which did not develop edema. Severe ischemia was noted on admission in nearly 40 per cent of those patients as compared to an incidence of 24.1 per cent among patients not developing edema.

During the period included in this study the occurrence of chronic arteriovenous fistulas and false aneurysms has declined notably. Figure 11 depicts the decrease in chronic arteriovenous fistulas and false aneurysms admitted to Charity Hospital from 1958–1969, the last decade covered by this report.

Comment

Currently accepted principles regarding management of acute vascular injuries are largely based upon military experience.[1, 7, 8, 12, 14] The expected results of ligation of major arteries were summarized in classic reports of vascular injuries in World War II, and results of suture repair were clearly shown to be superior to ligation.[1] Other important factors were recognized to influence the ultimate result following arterial injury and included: 1) time-lag, 2) practical difficulties such as experience of surgeons, 3) associated injuries, 4) site of wound, 5) type of arterial lesion, and 6) infection. The phenomenon of edema following restoration of arterial flow was precisely documented, and the value of incisions in the fascia to decompress muscle was recognized.

The problem of repair of large defects in injured arteries was not solved until the Korean War when sutured vein grafts were used for patients with acute injury.[7, 8, 14] Improved results were also related to a reduction in time-lag.

Improved results in Vietnam are largely attributable to two factors, a further reduction in time-lag due to efficient and almost routine evacuation by helicopter and the availability of surgeons experienced in vascular surgery.[12] The frequent severity of injuries due to high velocity weapons has, however, had an adverse effect.

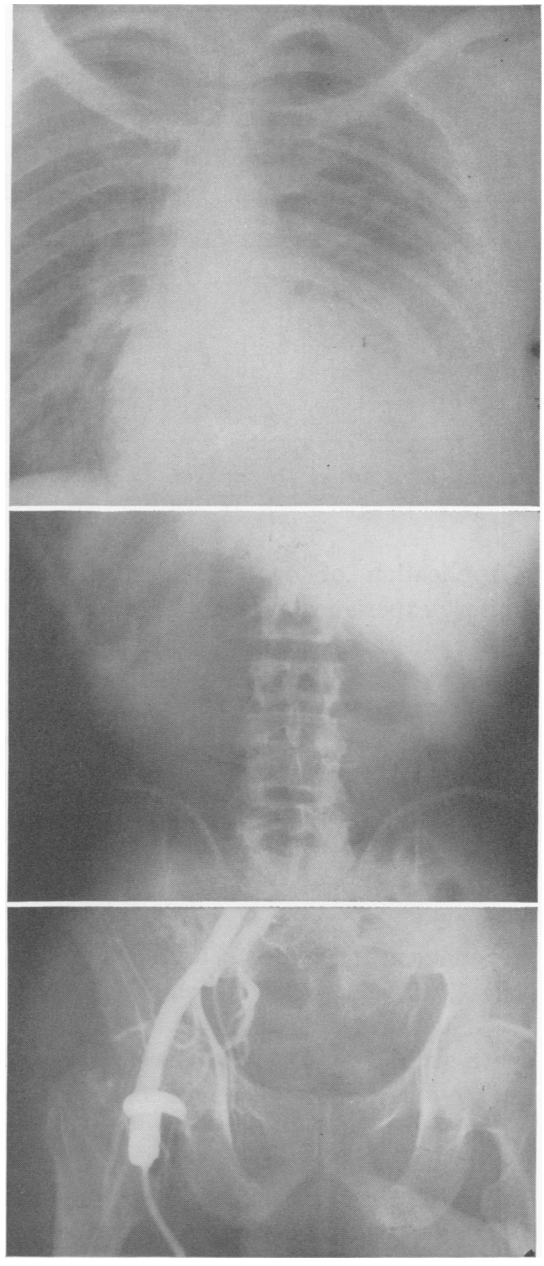

FIG. 9. Chest roentgenogram and femoral arteriogram in patient with bullet embolus to common femoral artery following gunshot of thoracic aorta.

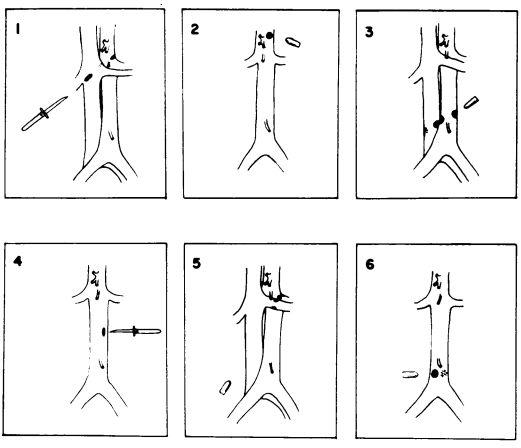

FIG. 10. Diagrams of six survivors of penetrating abdominal injuries.

Application of concepts derived from military experience in treatment of patients with civilian injuries has improved results notably.[2, 9-11, 15] Certain problems still contribute to death and loss of limb and are primarily related to frequency of arterial injuries due to blunt trauma, presence of multiple injuries and delay in treatment. The present study suggests that early recognition and prompt repair are the most important considerations in the successful management of patients with acute arterial injuries once they reach the hospital. Since immediate repair is advocated for all acute arterial injuries, the development of serious delayed complications including arteriovenous fistulas and false aneurysms should be largely prevented.

Careful examination may often result in diagnosis of unsuspected arterial injury. Notable ischemia distal to the arterial injury was observed in only 24 per cent of patients with limb wounds, and nearly 30 per cent had palpable pulses beyond the injury. Acute arteriovenous fistulas are often accompanied by the presence of distal pulses and apparently adequate blood flow to the part, and the frequency of this type of injury has recently been emphasized.[4] In the present series, the incidence of acute arteriovenous fistulas among major arterial injuries since 1958 was 5.6 per cent.

Arteriography may be helpful in the diagnosis and localization of certain injuries and may provide information relating to the operative approach. Arteriography is important in the evaluation of most patients with suspected arterial injuries resulting from civilan trauma when the patient's condition and the presence of active bleeding do not contraindicate it. This concept differs from the usual military experience where the nature of the wound and the lack of time do not make arteriography routinely desirable. Arteriography may be especially helpful in the evaluation of the patient following operation.

The severity of the injury often determines the type of arterial repair and to an extent the ultimate result. Seventy per cent of injuries in this series were repaired by suture or resection and suture; only 16 per cent were repaired with vein grafts. Use of vein grafts is much more frequent among current military vascular injuries[13] and particularly so where high velocity wounds comprise a large percentage of the in-

TABLE 6. *Edema Following Repair of 128 Major Arterial Injuries of Extremities*

Arteries Repaired	No.	No. with Edema
Subclavian	16	3
Axillary	12	2
Brachial	39	10
Iliac; common femoral	16	9
Superficial femoral	31	11
Popliteal	14	6
Total	128	41

TABLE 7. *Factors Possibly Contributing to Edema after Repair of Major Arterial Injuries of Extremities, 41 Patients*

Shock	17
Ischemia, severe	16
Vein injured	21

juries.[5] Recognition of the importance of preventing tension on the arterial repair has resulted in increasing use of vein grafts even among civilian injuries.

Veins were also repaired in 50 per cent of patients with concomitant arterial and venous injury. Although the subsequent patency of repaired veins could not be accurately evaluated, our present policy is to repair injured major veins by primary suture whenever practical. Adequacy of venous return may be a major consideration when other factors contributing to edema are already present. No patients in this series were observed to have pulmonary embolism following repair of a major vein.

Death following acute arterial injury most commonly follows wounds of major large arteries (thoracic aorta, abdominal aorta, subclavian or iliac arteries) often in combination with other serious thoracic or abdominal injuries. Location of the injury in arterial injuries to extremities is an important consideration. The observation that injuries to the popliteal and tibial arteries are followed by the highest incidence of amputation is consistent with findings of others whether reporting on ligation or arterial repair.[1, 12] Arterial injuries accompanied by fractures are associated with a higher degree of failure, and this is particularly so for popliteal injuries.

The observation that only half of patients who develop edema after repair of major arterial injuries of extremities had major venous injury is not surprising. Ischemic damage to the vascular system and muscle is believed to contribute to the development of edema following restoration of arterial flow. Prolonged ischemia prior to arterial repair appears to be the most important factor in this distressing phenomenon.

Improved results among patients with civilian arterial injuries will largely depend upon reduction in delay between time of injury and ultimate restoration of arterial flow. The successful treatment of associated injuries, especially in patients sustaining blunt trauma, is another important consideration.

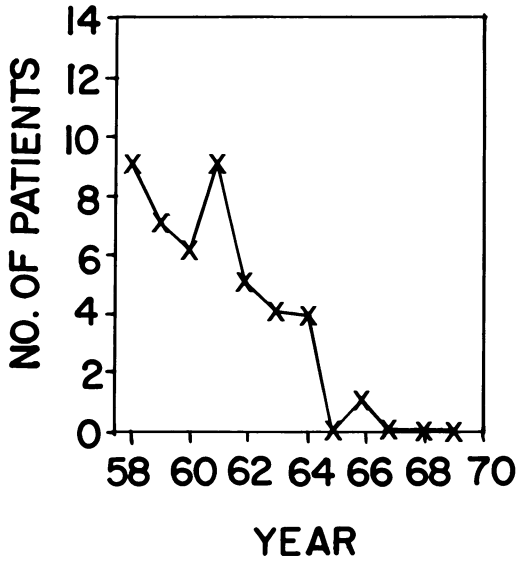

FIG. 11. Graph depicting number of patients with chronic arteriovenous fistulas and false aneurysms admitted to Charity Hospital, 1958–1969.

Summary

Two hundred and twenty-six patients with acute arterial injuries were treated from 1942 through 1969. Penetrating arterial injuries occurred in 90.2 per cent, and blunt trauma caused injury in 9.8 per cent of patients. Attention to the frequency of vascular trauma and the increasing use of arteriography have resulted in improvement in the recognition of these injuries.

Prompt restoration of arterial flow is possible in most patients with acute arterial injuries, and repair of concomitant major venous injuries by direct suture whenever feasible is recommended. Patients with arterial injuries associated with blunt trauma and those with other associated major injuries represent the most difficult problems in management.

Among the 226 patients there were 24 deaths (10.6%). For the 181 patients with injuries to arteries of the limbs the case fatality rate was 5.5 per cent and the ampu-

tation rate was 7.1 per cent. During the period included in this study the occurrence of chronic arteriovenous fistulas and false aneurysms has declined notably. Improvement in results depends largely upon reduction in the delay between injury and restoration of arterial flow.

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