The Surgical Treatment of Arterial Injuries in the Civilian Population

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During an 8-year period, 191 consecutive patients were treated for arterial injuries. Blunt trauma occurred in 46 patients (24%), low velocity gunshot wounds in 82 patients (43%), shotgun wounds in 22 patients (12%), stab wounds in 20 patients (10%), iatrogenic injury in nine patients (5%), high velocity gunshot wounds in two patients (1%) and other penetrating wounds in ten patients (5%). Preoperative arteriography was performed in 48 patients (25%) who were hemodynamically stable with injuries to major vessels in the thorax, base of neck or extremities and in whom the exact location or extent of injury was unknown. Surgical repair was performed in 184 of 191 patients (96%); seven patients expired intraoperatively before reconstruction could take place. Repair was accomplished in the 184 patients by end-to-end primary anastomosis in 80 patients (44%), lateral sutures in 21 patients (11%), SVG in 71 patients (85%) and Dacron® prosthesis in 13 patients (15%). One hundred seventy patients survived (89%) and 21 patients died (11%), seven of the 21 deaths were intraoperative and ten others were due to the effects of trauma to the aorta or its branches.

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THE REVIEW OF WORLD WAR II vascular injuries by DeBakey and Simeone,[11] the later experience of the Korean War[15,33] and the recent excellent review by Rich and Spencer[27] of reports of vascular trauma compiled in the Vietnam vascular registry at Walter Reed General Hospital provides a complete analysis of these injuries sustained in the military. During the past 20 years, arterial injuries in the civilian population have been recognized as complex surgical emergencies requiring prompt treatment with a well-planned patient management program. Analysis of vascular trauma in the civilian patient has been reported by different centers[6,9,12,14,20,22,28] emphasizing various methods of operative exposure, technique and clinical results.

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With improved methods of transportation and resuscitation, patients who would have died 10 years ago due to injuries of the cardiovascular system can now be treated with a reasonable expectation of survival; this improvement in survivals further emphasizes the importance of early recognition and treatment of vascular trauma. This review of 191 patients with arterial injuries extends over an eight year period at the University Hospital of the University of Alabama in Birmingham.

Clinical Material

From January 1, 1970 through December 31, 1977, there were 191 consecutive patients treated for arterial injuries by the Trauma Service at the University Hospital. The ages ranged from ten to 72 years. Forty-six (24%) patients were 20 years old or less, 59 patients (31%) were 21–30 years, 55 patients (29%) were 31–50 years and 30 patients (16%) were over 50 years of age. The age of one patient was not known. One hundred four patients (54%) were black and 87 (46%) were white. The type of injury (Table 1) was blunt trauma in 46 (24%) patients, low velocity gunshot wounds in 81 patients (43%), shotgun wounds in 22 patients (12%), stab wounds in 20 patients (10%), iatrogenic injury in nine patients (5%), other penetrating wounds in 11 patients (5%) and high velocity gunshot wound in two patients (1%). The location of the arterial injury occurred in the neck in eight patients (4%), the chest in 36 patients (19%), the upper extremity in 54 patients (29%), the abdomen in 20 patients (10%) and the lower extremity in 73 patients (39%). Associated injuries occurred in 116 patients (61%), some of whom had more than one arterial injury. There were 68 (36%) associated venous injuries. Although venous injury occurred in association with aortic, iliac, femoral and popliteal arterial injuries, arteriovenous fistula was present in only five

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TABLE 1. *Type of Vascular Injury*

Artery	No. Patients	Blunt	Gun-shot	Shot-gun	Stab	Other Pene-trating
Subclavian	15	3	6		6	
Carotid	8		5	2	1	
Innominate	2		2			
Thoracic aorta	19	14	4		1	
Abdominal aorta	8		5	2	1	
Renal	1	1				
Axillary	14	3	8	2		1
Brachial	40	6	8	4	5	17
Iliac	11		8	1	2	
Common femoral	5		3		1	1
Superficial femoral	32	6	19	5	1	1
Popliteal	36	13	15	6	2	
Total	191	46	83	22	20	20

patients. Two of these had injury to the popliteal artery, one to the superficial femoral artery, one to the brachial artery and one to the thoracic aorta.

Forty-eight patients (25%) had associated nerve injury. With the exception of five wounds to the base of the neck, these occurred in association with extremity trauma. Of these, 29 had partial or complete nerve disruption, and 19 had nerve dysfunction clinically but based on operative findings were determined to have an intact nerve. Forty-nine patients (26%) had associated fractures.

On admission, the physical findings were as shown in Table 2. In general, central vessel injuries (aorta and its primary branches) were manifested by symptoms of significant blood loss, with 37 of 56 (66%) patients presenting in hemodynamic shock (systolic blood pressure less than 100 mmHg); this contrasts with 46 of 135 (34%) patients with peripheral injuries admitted in shock. Of the 127 patients with extremity injury, 108 (85%) presented with absence of distal pulse. Massive hematoma, arterial bleeding and a bruit also were frequently noted. Three of the eight patients with carotid artery injury presented with neurologic deficits. Hemothorax was commonly present in the patients with injury to thoracic or base of neck vessels. Nine of 19 patients with injury to the thoracic aorta had a widened mediastinal shadow on chest x-ray. Patients with injuries to the abdominal aorta presented in shock with peritoneal irritation and abdominal distension.

Preoperative arteriography was performed in 48 (25%) patients (Table 3) who were hemodynamically stable with suspected injury to major vessels in the thorax, base of neck or extremities and in whom there was some uncertainty about the exact location or extent of injury.

The time interval between trauma and the vascular repair varied widely and is documented in Table 4. One hundred thirteen patients (59%) underwent vascular reconstruction within 8 hours and 62 patients (32%) were delayed more than 8 hours.

Surgical repair was accomplished in 184 of 191 patients (96%). In the remaining seven patients (4%), all of whom had aortic injuries, death occurred intraoperatively before reconstruction could be attempted (Table 5). The methods of repair in the 184 patients included end-to-end primary anastomosis in 76 patients (41%) and lateral suture repair in 25 patients (13%). Seventy-four patients (40%) required a vascular graft; of these, 61 (82%) had reconstruction utilizing the saphenous vein interposition graft (SVG) and 13 (17%) a prosthetic graft material (Dacron). Among 68 patients associated venous injuries were repaired in 27 patients (40%), ligated in 38 patients (56%) and occluded by clamp alone in three patients (4%) who expired intraoperatively (Table 6).

Forty-nine patients with associated fractures were

TABLE 2. *Physical Findings on Admission*

Artery	Absent Pulse	Hematoma	Arterial Bleeding	Bruit	Major Neur. Def.	Hemothorax	Shock
Subclavian	6/15	4/15	1/15	6/15	2/15	2/15	7/15
Carotid	1/8	2/8		1/8	3/8	2/8	
Innominate						2/2	2/2
Thoracic aorta				1/19		8/19	12/19
Abdominal aorta							8/8
Axillary	14/14	2/14	1/14	1/14	6/14	1/14	1/14
Brachial	35/40	5/40	2/40	2/40	5/40		14/40
Iliac	1/11	2/11		2/11			8/11
Femoral							
Common	4/5	2/5	1/5	1/5	1/5		4/5
Superficial	21/32	10/32	4/32	6/32	6/32		13/32
Popliteal	34/36	6/36	2/36	2/36	10/36		14/36
Renal							

TABLE 3. *Preoperative Arteriography*

Artery	No. Patients	Arteriography	Per Cent
Subclavian	15	6	40
Carotid	8	0	0
Innominate	2	1	50
Thoracic aorta	19	16	84
Abdominal aorta	8	0	0
Axillary	14	0	0
Brachial	40	8	20
Iliac	11	0	0
Common femoral	5	0	0
Popliteal	36	12	33
Renal	1	1	100
Superficial femoral	32	4	12.5
Total	191	48	25

treated by either internal and/or external methods of skeletal stabilization.

Fasciotomy at the time of operation was done in 5% of patients with brachial artery injuries, 45% with interruption of the superficial femoral artery, and in 61% of the patients with popliteal artery injury.

Blood transfusion requirements were reviewed as an index of severity of injury. Eighty-nine per cent of aortic injuries required replacement of more than 5 units of blood, and most required more than 10 units. Overall, injuries to the central arteries required more than 5 units of blood 74% of the time, whereas extremity arterial injuries did so only 25% of the time.

Results

One hundred seventy of the 191 patients (89%) survived, and 21 patients (11%) died. The results are summarized in Table 7. Seven of the 21 patients who died had aortic injuries and died before revascularization could be completed. Treatment in these cases consisted of surgical exploration and clamping of the aorta (thoracic aorta in two, abdominal aorta in five). Ten patients died postoperatively secondary to the effects of the vascular trauma involving the aorta or its branches. Three patients with extremity arterial injury died, two of whom expired from concomitant brain injury, and one who died in the hospital postoperatively secondary to pre-existing ischemic heart disease.

All eight patients with carotid artery disruption sustained penetrating knife or bullet wounds. In two instances there was an associated internal jugular vein injury, and in three patients a major neurologic deficit was present preoperatively. Both patients with internal jugular vein laceration were treated by ligation. The carotid artery injury was repaired by lateral sutures in three patients, end-to-end anastomosis in four and by a vein graft in one instance. Six of the eight patients survived, one of whom had hemiparesis before surgery. One of the two deaths occurred on the seventh postoperative day, the patient having remained in a comatose condition since prior to operation.

Injury to the thoracic aorta occurred in 19 patients four of whom died. Fourteen of the 19 sustained blunt trauma with associated injuries to bone, brain, lung, heart, liver, kidney and spleen. Four patients had gunshot wounds, and there was one stab wound. Preoperative arteriography was done in 16 patients who were hemodynamically stable. The injured aorta was repaired by lateral sutures in six patients and prosthetic replacement in ten patients. Aortic clamping alone was performed in three patients who expired intraoperatively before reconstruction could be undertaken. Eight patients sustained penetrating injuries to the abdominal aorta with simultaneous associated injuries of the lung, gastrointestinal tract, pancreas, spleen, inferior vena cava and hepatic veins. There were five gunshot wounds, two shotgun injuries and one knife wound. Repair of the aorta was accomplished by lateral sutures in two patients and end-to-end anastomosis in one.

TABLE 4. *Ischemic Interval from Injury to Vascular Reconstruction*

Artery	No. Patients	<4 Hrs	4–6	6–8	8–10	>10	Unknown
Subclavian	15	1	2	4	2	4	2
Carotid	8	1	1	5		1	
Thoracic aorta	19		3	5		7	4
Abdominal aorta	8	7		1			
Axillary	14	1	5	3	2	1	2
Brachial	40	1	8	8	6	14	3
Iliac	11		6	3		1	1
Common femoral	5		3			1	1
Superficial femoral	32	2	15	6	2	6	1
Innominate	2	1					1
Renal	1				1		
Popliteal	36		6	15	5	9	1
Total	191	14	49	50	18	44	16

TABLE 5. *Method of Arterial Repair*

Artery	No. Patients	End–End	Lateral Suture	SVG*	Dacron	Ligation
Subclavian	15	4	3	6	1	1
Carotid	8	4	3	1		
Thoracic aorta†	19		7		10	
Abdominal aorta‡	8	1	2			
Iliac	11	9	1	1		
Common femoral	5	3		1	1	
Superficial femoral	32	13	4	3	1	11
Popliteal	36	16		23		
Brachial	40	21	2	17		
Axillary	14	4	1	9		
Innominate	2		2			
Renal	1	1				
Total	191	76	25	61	13	12

* SVG = saphenous vein graft.
† No repair—two patients.
‡ No repair—five patients.

TABLE 6. *Method of Venous Repair*

Artery	No. Patients	End–End	Lateral Suture	SVG*	Ligation	Clamp
Subclavian	5		2		3	
Carotid	2				2	
Abdominal aorta	4				1	3
Innominate	1		1			
Iliac	5		3		2	
Common femoral	2		2			
Superficial femoral	21	3	4	3	11	
Popliteal	16	2	2	4	8	
Axillary	3				3	
Brachial	9	1			8	
Total	68	6	14	7	38	3

* SVG = saphenous vein graft.

Six of the eight patients died. One of the two survivors required reoperation with aortic ligation and an axillofemoral graft.

Two patients had gunshot wounds to the innominate artery and vein. Both were repaired with lateral sutures with good result. Fifteen patients had subclavian artery injury, five of whom had simultaneous subclavian vein laceration. Complete and partial nerve disruption occurred in two of the 15 patients. Arteriography was performed in six patients. Repair was accomplished in six patients by a saphenous vein graft, in four by end-to-end anastomosis, in three with lateral sutures, in one by arterial ligation and in one by a prosthetic graft. Three of the 15 patients died, and 12 survived with palpable distal pulses. Fasciotomy was not performed, even though seven of the injuries were repaired after more than 8 hours of ischemia.

Fourteen patients had axillary artery injury, 11 of which were penetrating and three of which were from blunt trauma. Three patients had associated axillary vein injury, and ten of the 14 had partial or complete brachial plexus injury. Four patients had associated fractures. The arterial repair was accomplished by lateral sutures in one instance, end-to-end repair in four

TABLE 7. *Results*

Artery	No. Patients	Good	Amputation	Death	Reoperation
Subclavian	15	12 (80%)		3 (20%), 1 sec. to mult. trauma	
Carotid	8	6 (75%)		2 (25%), 1 at PO 7	
Innominate	2	2 (100%)			
Thoracic aorta	19	14*(74%)		5 (26%)	
Abdominal aorta	8	2 (25%)		6 (75%)	1 convert to axillofemoral graft
Iliac					
Common	4	2 (50%)		2 (50%)	
External	7	7 (100%)			
Femoral					
Common	5	5 (100%)			
Superficial	32	26 (81%)	6 (19%)		
Popliteal	36	31 (86%)	5 (14%)	2 (5%), sec. to head inj.	3
Axillary	14	11 (79%)	2 (14%), shotgun wound	1 (7%), sec. to cardiac, PO 2	
Brachial	40	39 (98%)	1 (2%)		
Renal	1	1 (100%)			
Total	191	158 (83%)	14 (7%)	21 (11%)	4 (2%)

* One patient with paraplegia.

patients and a saphenous vein graft in nine patients. A fasciotomy was performed once. Good results were achieved in 11 patients, one patient died, and in two patients substaining shotgun wounds, subsequent amputation was necessary.

Brachial artery injury occurred in 40 patients: in eight from gunshot wounds, in six due to blunt trauma, in five from stab wounds and in four from shotgun blasts. Ten injuries were related to a variety of causes and seven were of iatrogenic origin. There were nine patients with associated brachial vein injury and one with an A-V fistula. Associated bone and nerve trauma with maximal degree of soft tissue loss was common. The arterial injury was repaired by end-to-end anastomosis in 21 patients, saphenous vein graft in 17 patients and by lateral suture repair twice. Thirty-six patients maintained a good result with palpable distal pulses; three patients had a good result, but no distal pulse was palpable; and one patient required amputation because of gangrene. A fasciotomy was performed in two instances.

Common iliac artery injury secondary to gunshot wounds occurred in four patients, three of whom had iliac vein or vena cava injury. The artery was repaired by end-to-end anastomosis in all four instances. The iliac vein injuries were treated by ligation. Two patients survived with good distal pulses, and two died.

Disruption of the external iliac artery by penetrating injuries occurred in seven patients. Repair of the artery was by lateral suture in one instance, end-to-end anastomosis in five patients and saphenous vein graft in one. All seven patients had good results, one of whom required a fasciotomy.

Five patients had penetrating injuries to the common femoral artery, two of whom had a common femoral vein injury. The artery was repaired by end-to-end anastomosis in three patients, by a saphenous vein graft in one and by a prosthetic graft in one. Good results occurred with palpable distal pulses in all five patients. A fasciotomy was performed once.

The superficial femoral artery was injured in 32 patients. Six injuries resulted from blunt trauma, one from a stab wound, five were secondary to shotgun wounds, 19 were from gunshot wounds, and one was due to a miscellaneous injury. Fractures and nerve disruption were common findings. Arterial repair was accomplished by lateral sutures in four patients, end-to-end anastomosis in 13 and SVG in three. Arterial ligation was performed in 11 patients. A fasciotomy was performed in 14 instances. Twenty-six patients had good results with palpable distal pulses, and six patients required subsequent amputation. Three of the six patients requiring amputation sustained blunt trauma, open fractures or popliteal artery injury. Two patients with shotgun wounds and limb ischemia for more than 15 hours required amputation, and one patient with a combined gunshot wound and open fracture required amputation.

Thirty-six patients sustaining blunt and penetrating injury to the popliteal artery underwent vascular reconstruction, with an average ischemic interval of 8½ hours (range 4–14 hours). There were 16 associated venous injuries, 15 nerve injuries and 21 fractures and/or knee dislocations. Arterial repair was by SVG in 23 and by end-to-end anastomosis in 16 patients. Three patients had more than one operation. In eight of 16 venous injuries reconstruction was done, and the remaining veins were ligated. Fasciotomy was performed in 22 patients. Skeletal stabilization was achieved by external support in 12 patients and by internal fixation in the remaining nine patients. Five patients (14%) required amputation after vascular reconstruction failed. A prolonged ischemic interval of greater than ten hours, with fractures and/or knee dislocation, carried a particularly serious prognosis. In 23 of the 31 patients available for follow-up, there was no vascular impairment, but six had chronic disability secondary to the associated orthopedic injury.

Discussion

A complete discussion of all types of arterial injuries encountered by civilian patients is beyond the scope of this paper, and the extensive review by Rich and Spencer[27] is recommended as a definite analysis of the subject. However, certain types of vascular trauma are particularly complex regarding diagnosis, operative approach and treatment. Therefore, we plan to analyze in some detail several kinds of vascular injuries encountered in this study, with recommendations for management.

The general principles pertinent to the repair of vascular trauma are applicable with modification in the presence of skeletal fractures, large soft tissue defects and in some instances in carotid artery disruption. Satisfactory exposure of the injured vessel with prompt proximal and distal control has long been recognized as essential in the treatment of vascular injuries. Repair can be achieved in select situations by lateral sutures, provided there is no compromise to the vessel lumen. More often the vessel requires excision of the traumatized segment and end-to-end anastomosis without suture line tension. If end-to-end anastomosis is impossible, then an interposition graft is indicated using an autogenous vein, if at all possible, in an effort to avoid subsequent infection of a prosthesis.

Base of Neck and Mediastinum

Penetrating injuries to the base of the neck and mediastinum present a particularly challenging prob-

lem in that they often have little or no external signs of injury other than the skin laceration, yet they may be associated with significant subcutaneous, thoracic or mediastinal hemorrhage. If the wound is explored locally, the bleeding may be found to be massive and proximal and distal control may be difficult or impossible.[16,31] Rich and Spencer[27] reviewed the civilian and military experience involving patients with these injuries, emphasizing that the low incidence suggests few patients survive long enough to receive medical attention.

A variety of surgical incisions have been advocated for penetrating injuries of the base of the neck in an effort to obtain adequate exposure.[2,7,8,13,17,25,30,34] Because of the urgency to control bleeding in lacerations of the cervicomediastinal vessels, we favor median sternotomy as the initial incision with appropriate extension into the neck for further control. This incision is particularly suited for injuries to the innominate artery and vein, including the right subclavian and common carotid artery. Proximal control of the left subclavian artery at its origin can be achieved by this approach, but injuries to this vessel distal to the thyrocervical artery will require a cervical incision and excision of the middle third of the clavicle.

Under some circumstances, an internal shunt may be used for a carotid or innominate artery injury in order to avoid a prolonged ischemic interval and will require temporary heparinization. In certain instances, particularly blunt trauma, the use of preoperative arteriography may be of special value in confirming the diagnosis of injuries to the cervicomediastinal area, enabling one to obtain a precise anatomical location of the injury. The management of injuries to the innominate, proximal left common carotid and subclavian arteries close to their origin of the aortic arch is especially difficult because of massive hemorrhage, as emphasized by Bricker and associates.[8]

Carotid artery. Injuries to the carotid artery are usually penetrating in origin, although rarely blunt trauma will precipitate arterial occlusion.[37] Carotid artery trauma between the suprasternal notch and the cricoid cartilage is classified as an injury to the base of the neck and mediastinum and treated as outlined above. Injury to the carotid artery between the cricoid cartilage and the angle of the mandible, without evidence of mediastinal involvement, can be approached directly through the neck. Those patients with carotid artery trauma between the angle of the mandible and the mastoid bone are best managed first by preoperative arteriography to determine whether or not the lesion can be approached with a cervical incision.[16]

Although most carotid injuries are not associated with neurologic deficits,[10] Rubio et al.[29] reported that 25 of 72 patients with carotid injuries were admitted with neurologic deficits. Thal and associates[36] suggested that patients with a mild neurologic deficit may undergo reconstruction with a low risk, but those individuals with major preoperative neurologic deficits are poor risks for carotid revascularization, similar to the patient with an acute stroke. Thal et al., prefer ligation of the carotid artery if there is complete occlusion with a frank neurologic deficit rather than restoration of blood flow and conversion of an ischemic infarct to a hemorrhagic infarct with further neurologic deterioration. This dilemma is even more complex when the patient with a carotid artery injury is comatose from intracranial trauma and an accurate neurologic assessment is impossible.

Arteriography and CAT scan may be useful diagnostic procedures to evaluate both the extracranial and intracranial circulation prior to carotid artery revascularization. Rubio and colleagues,[29] contrary to the proposal of Thal et al.,[36] concluded that primary revascularization was the best approach to the injury, indicating there was little evidence that a stroke was created or worsened by this method of treatment. The use of internal or external shunts in these patients remains unsettled but in some instances may offer protection in avoiding prolonged periods of cerebral ischemia.

Left subclavian artery. Injuries to the left subclavian artery occur more commonly than to the innominate artery[7,8,16,22,27] and may be particularly difficult to manage if the lesion is in the proximal one-third of the vessel close to its origin at the aortic arch. Proximal control by either a median sternotomy or left anterior thoracotomy via the third intercostal space should be performed first, with a secondary supraclavicular incision, including resection of the middle third of the clavicle.

Aorta. Aortic injuries have the highest mortality of all vascular trauma, and only 14–18% of such patients reach the hospital alive.[18,19,35] Of those individuals who do obtain medical care, 30–70% ultimately die as a result of the injury, usually from hemorrhage.[1,4,5,23] In our experience and that of others,[27] patients with thoracic aortic injuries who reach the hospital alive have a more favorable prognosis than do those with injuries to the abdominal aorta. Eleven of the 27 patients with aortic injuries in this series died. Nineteen of the 27 had thoracic aortic injuries, five of whom died (26%); whereas six of eight patients with abdominal aortic injuries died (75%), all of massive hemorrhage. Major venous injury (inferior vena cava in three, hepatic vein in one) accompanied the abdominal aortic injury in four of the eight patients, three of whom died. All abdominal aortic injuries had associated involvement with multiple other organ systems. Paraplegia occurred postoperatively in one patient after thoracic aorta occlusion for 45 minutes, and this

incidence is similar to that reported earlier from this institution with closed thoracic aorta injuries.[3]

Extremities

Popliteal artery. The most serious and complicated extremity injury involves the popliteal artery, with a risk of amputation ranging from 15–70%. Factors influencing the outcome include the nature of the wounding agent, ischemic interval, patient variables (age and degree of atherosclerosis), location of the wound and associated soft tissue, osseous, nerve and venous injuries. Civilian popliteal artery injuries differ from war wounds in that many are of blunt origin, whereas military injuries are largely of the penetrating type.

The precise anatomic location of the injury may be especially important, since arterial division near or within the popliteal trifurcation has a less favorable prognosis than more proximal lesions. In addition, vascular disruption from massive injury interfering with the collateral blood supply of the knee will result in total ischemia to the leg, whereas patency of the geniculate arteries may continue to provide some blood to the leg. It has been emphasized that primary repair of venous injuries may be important in preventing extremity edema;[27] however, in our experience eight of 16 patients were treated with venous ligation with no increase in the incidence of amputation.

Skeletal fracture and/or knee dislocation have been recognized as serious associated conditions in the presence of popliteal artery injury.[32] The Vietnam experience favored external immobilization because of the high incidence of infection.[26] In our experience, skeletal stabilization was achieved by internal fixation in eight patients and external fixation in 12, with no apparent advantage to either method. Four of 21 patients with combined arterial and skeletal injuries in this series required amputation.

We favor immediate operative exploration of blunt and penetrating injuries of popliteal vessels, thereby minimizing the ischemic interval, and recommend arteriography only when it is required for planning the operative approach. The traumatized vessel should be debrided, Fogarty catheters passed proximally and distally and heparin saline instilled. Arterial reconstruction is best accomplished by either end-to-end anastomosis or by SVG from the opposite leg. If the nerve is divided, the ends are identified and nerve repair is postponed to a later time. Early fasciotomy as described by Patman and Thompson[21] is performed almost routinely if the ischemic interval is more than 3–4 hours.

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Discussion

Dr. Louis G. Britt (Memphis, Tennessee): There's very little that one can add to this rather complex series of injuries. When we looked at the entire manuscript, we found that the numbers in Alabama were almost precisely the same as those in Memphis, and it was difficult to find areas of great difference or controversy.

We did notice that in 24% of the patients in Alabama that blunt trauma was the cause of injury, whereas, our incidence has only been 5%, probably indicative of the economic disadvantage of the State of Tennessee, as compared to Alabama.

Secondly, we had an 18% incidence of abdominal aortic injury, as compared to only 4% for Dr. Diethelm. One of his final comments concerned operative angiography, and we agree with that middle-of-the-road approach. However, we have embraced, at least in the extremity, intraoperative angiography as a critical part of evaluation, not only of the repair, but the status of the distal circulation, thrombus formation, etc.; and I wonder if he could comment on that.

The other area of great interest is the distal extremity in which a compound injury including bone, muscle, skin, nerve, artery and vein occurs. How do you decide whether or not you revascularize these patients? The decision to attempt to restore a limb may cost someone his life.

Dr. George Johnson, Jr. (Chapel Hill, North Carolina): It was a disappointment to learn that Birmingham has a knife and gun club like Philadelphia, Baltimore, Houston, New Orleans, Richmond, Dallas, and the rest of us.

We have heard so many great things about open heart and transplantation operations in that city that I had naively assumed that it did not have the Saturday night meetings of this club.

Our experience in North Carolina is unlike Dr. Diethelm's in quantity, but similar in quality. Being a more peaceful site than Alabama, we have seen only 76 vascular injuries, compared to his 191. We have not included our brachial artery injuries that occurred from cardiac catheterization in this number.

Seventy-five per cent were similar to his 66% involving the extremities, although most of ours were found in the upper extremity. Like that just reported, most were due to gunshot wounds. We used an end-to-end anastomosis in 66%, compared to his 44%, and we used a graft in only 22%.

Although we had a 9% amputation rate, similar to his, there was another 11% who actually had a useless extremity because of nerve damage. This has been discussed in a publication by Peacock and Proctor, of our institution. Perhaps he would comment on how he manages a patient with extensive nerve damage.

Dr. Diethelm's manuscript is a very complete report of a large experience with these injuries. He addresses the many questions all of us have, such as: When do you repair the carotid artery injury? When are the associated injuries such that an amputation is the most humane treatment? When is a preoperative angiogram indicated? Is external or internal fixation the best for associated skeletal injuries? Should a median sternotomy be used for injuries to the base of the neck rather than a thoracotomy? For most of these questions, he has more experience than I.

Forty of his patients had brachial artery injuries. We agree with him that they should be repaired. He used the saphenous vein to repair almost half of these. We have had excellent results with brachial artery injuries with resection and end-to-end anastomosis, using interrupted sutures. A saphenous vein graft is used infrequently and only if the tension is too great.

I suspect the high incidence of gunshot wounds in his series accounts for the difference. Most of the brachial artery injuries that we encountered were due to stab wounds. He uses fasciotomy of the lower extremity if the ischemic interval is more than three to four hours. I would agree with this; but since all arterial injuries to the lower extremity do not produce ischemia, fasciotomy is not routinely used at our institution. Judgment and the measurement of compartment pressure have been our criteria for fasciotomy. I will admit that this is not always with complete accuracy.

This and other recent reports on the management of vascular trauma demonstrate that excellent results are being obtained with early and appropriate management. It is difficult to fully delineate the reasons for the improved results. Pre- and intraoperative angiography, the Fogarty catheter, use of end-to-end anastomoses rather than lateral repair, and attempts at venous repair may have contributed.

One question: Has he had any experience with the use of expanded polytetrafluorethylene, or Gortex, in any of these wounds, rather than the saphenous vein? Mattox, at Houston, has suggested this, and perhaps Dr. Diethelm, with his extensive experience, has had an opportunity to appraise it.

Dr. Larry H. Hollier (New Orleans, Louisiana): (slide) Coming from New Orleans, we see an occasional gunshot and stab wound at Charity Hospital; but I would like to direct my comments to the problem of proximity injuries, and would like Dr. Diethelm's comments about this.

(slide) Several years ago, we looked over the previous experience at Charity Hospital, and noticed that with the policy in force at the time, over the past several years, there was a mandatory exploration for all proximity injuries. We found that, as a result of this, there was a 54% negative exploration rate and an extremely high