MANAGEMENT OF BLUNT VASCULAR TRAUMA TO THE EXTREMITIES

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During a seven and one-half year period from 1984 to 1991, 106 patients admitted to a Level I trauma center had blunt vascular injury to the extremities. This subset of patients was analyzed with respect to mechanism of injury, associated injuries, method of repair, morbidity and mortality.

Twenty patients sustained vascular injuries of the upper limb. Eighty percent of the patients (16 patients) underwent primary vascular repairs, 15 percent had primary amputations and 5 percent (one patient) were observed. Eighty-eight percent (14 of 16 repairs) of the vascular repairs demonstrated excellent neurologic function postoperatively.

Eighty-six patients had arterial injuries of the lower extremity. Forty-eight percent (41 patients) of the injured legs were amputated, 41 percent (35 patients) underwent vascular repairs, 6 percent (five patients) underwent ligation of the primary vessel with no amputation and 24 percent (21 patients) underwent no surgical procedure. Sixty-two percent of the 37 patients (23 patients) with popliteal injuries required amputation and 57 percent (21 patients) underwent vascular repair. The overall mortality rate was 11 percent—zero percent for injuries to the upper limb and 14 percent for injuries to the lower limb. *Surg. Gynecol. Obstet.*, 1993, 177: 41-48.

BLUNT INJURIES of the vasculature of the extremity are associated with higher morbidity and mortality rates than penetrating wounds to the limb (1–4). Studies of impact biomechanics readily provide an explanation. In a frontal crash at 30 miles per hour, an unrestrained occupant experiences a deceleration of 15 g. Much of the force is absorbed initially by the feet and legs and then by the knees, which undergo a velocity change of 34 feet per second when they contact the instrument panel (5). Multiple bilateral fractures and dislocations result. Motorcyclists can sustain crush injuries when the lower extremities contact the bumpers or sides of vehicles, as well as fractured and dislocated upper extremities when projected from their cycles or dragged along the ground. In the most common pedestrian accident, the lower extremities are struck by the front bumper of a car (5), resulting in crush injury and knee dislocation, frequently involving the popliteal artery. Even after successful vascular repair, patients may lose limbs as a result of muscle ischemia and soft tissue necrosis as well as systemic compromise (6).

The assessment and management of blunt injuries of the extremity vasculature at a Level I trauma center were reviewed. The findings of that study constitute the current report.

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MATERIALS AND METHODS

From 1984 to 1991, 17,275 patients were admitted to the trauma center of the Maryland Institute for Emergency Medical Service Systems; 15,146 (88 percent) sustained blunt trauma. A subset of 475 patients had vascular injuries, 106 (22 percent) involving the extremities. Data were obtained from the trauma registry of the institution (prospectively collected) (7) and from chart review.

All patients with extremity injuries were examined by trauma surgeons and orthopedic surgeons in the admitting area. If an injured extremity was deemed potentially viable, the patient was taken to the operating room for exploration and management of bony injuries. If there was any question of compromised circulation based on the initial assessment—diminished or absent pulses, pallor, coolness, delayed capillary refill, motor or sensory loss, active bleeding, hematomas, bruits, bony injuries (fractures or dislocations), or wound proximity—one-shot angiography was performed in the admitting area through an 18-gauge angiocath placed percutaneously, using 50 to 100 milliliters of full-strength Renografin® (diatrizoate sodium and diatrizoate meglumine). Eighty-three percent of the patients (64 of 77) with blunt vascular trauma to the extremities who did not

Reprint from SURGERY, *Gynecology & Obstetrics,* July, 1993, Vol. 177, 41-48

TABLE I.—MECHANISMS OF INJURY FOR PATIENTS WITH BLUNT TRAUMA OF THE EXTREMITY VASCULATURE

	Upper extremity		*Lower extremity*	
	No.	*Percent*	*No.*	*Percent*
Motor vehicle crash	8	40	26	30
Motorcycle crash	4	20	25	29
Industrial accident	3	15	—	—
Crush	2	10	—	—
Fall	1	5	1	1
Pedestrian struck	—	—	31	36
Football injury	1	5	—	—
Fight	1	5	—	—
Train	—	—	2	2
Work	—	—	1	1
Total	20*	—	86†	—

*Fifteen men and five women.
†Seventy-three men and 13 women.

undergo early amputation had angiography. An angiogram was considered positive if it showed an intraluminal irregularity indicating laceration, intimal flap or pseudoaneurysm. Angiography required 30 to 45 minutes to perform and usually was done in the admitting area within four hours after arrival.

Fasciotomy was performed liberally for any clinical signs or symptoms of compartment syndrome. In equivocal situations, compartment pressures were measured by the saline solution injection method of Whitesides. Pressures greater than 30 millimeters of mercury prompted immediate four-compartment fasciotomy of the lower part of the leg (8).

Open fractures were graded according to the modified Gustilo and Chapman classification (8)—Type I, open fracture with a clean wound less than 1 centimeter; Type II, laceration larger than 1 centimeter without extensive soft tissue damage, and Type III, high-energy segmental fractures with severe loss of soft tissue. Fractures were treated by external stabilization rather than internal fixation.

If the trauma surgeon and orthopedist concluded early that the limb was not salvageable, based on assessment of vascular, soft tissue, neurologic and bony compartments, guillotine amputation was performed at the appropriate level. These were classified as early amputations. Amputations done after attempted limb salvage procedures were classified as late.

When bony and vascular injuries occurred together, the usual policy was to place external fixation devices before revascularization. Standard vascular exposure and repair followed. Local heparinization was used after the passage of No. 3 Fogarty embolectomy catheters before clamping vessels. A saphenous vein from the contralateral extremity was the graft material of choice. Polytetrafluoroethylene (PTFE) grafts were used if extreme speed was required or if varicosities precluded the use of saphenous veins. Anastomoses were performed with running No. 6-0 or No. 7-0 polypropylene sutures. Completion angiography was obtained if there was a question about repair success.

RESULTS

Upper extremity. Twenty-two injuries to the axillary, brachial, radial and ulnar arteries were treated in 20 patients (Table I). Fifteen percent (three of 20 patients) underwent early amputation. Eighty percent (16 of 20 patients) had vascular repair and 5 percent (one of 20 patients) were observed (Table II). The two patients with two upper extremity arterial injuries had one observed and one operated upon. Fifteen of the 17 patients who did not undergo early amputation were assessed with angiography; the other two injuries were diagnosed in the operating room. Indications for angiography included diminished or absent pulses (12 patients), pale extremity with poor capillary refill (one patient) and motor or sensory deficit (two patients). No extensive venous injuries were sustained. All but three of the injuries were near a fracture or dislocation (Table III).

Axillary artery. Three injuries to the axillary artery were seen. One artery was transected and repaired within five hours of injury with an interposition PTFE graft. Two instances of thrombosis of the axillary artery (one from a shoulder dislocation and one incurred in a fight with no other documented orthopedic injury) were repaired (one reverse saphenous vein [RSV] and

TABLE II.—MANAGEMENT AND OUTCOME OF ARTERIAL INJURIES OF THE UPPER EXTREMITY (N=22) INJURIES IN 20 PATIENTS

			Amputations			
Vessel	*No. of injuries*	*OR*	*Early*	*Late*	*Obs.*	*Deaths*
Axillary	3	3 (100)	0	0	—	0 (0)
Brachial	8	6 (75)	2 (25)	—	—	0 (0)
Radial/ulnar	11	7 (64)	1 (9)	—	3 (27)*	3 (27)

*Two of these also had either an axillary or brachial artery injury.
Numbers in parentheses are percentages.
OR, operating room (vascular repair), and Obs., observed.

one PTFE graft). Both patients with PTFE grafts had poor recoveries secondary to brachial plexus injuries.

Brachial artery. Eight brachial artery injuries were identified. Two patients with severe nerve and soft tissue damage underwent early amputation. The other six patients were revascularized—five with RSV grafts and one with PTFE. All patients had excellent neurologic function postoperatively.

Radial or ulnar arteries. Eleven patients sustained injuries to the radial or ulnar vessels (five ulnar arteries and six radial arteries [two patients had injuries involving these vessels plus another upper extremity vessel]). One amputation was required for a nearly amputated limb; seven revascularizing procedures were done (repairs or RSV grafts). All patients had good neurologic recovery.

Of the 16 patients with injuries of the upper limb requiring restoration of vascular flow, five had fasciotomies based on clinical examination or compartmental pressures. In 14 of the procedures, orthopedic manipulation came after the vascular work. The time from injury to operation varied but was never more than five hours.

Complications included thrombosis of the repair (one patient) and pseudoaneurysm (one patient). There were no infections in this small group of patients and the mortality rate was zero.

Lower extremity. Eighty-six patients (Table I) had blunt vascular trauma to the lower extremity. Associated injuries are listed in Table IV. Twenty-six early amputations were performed—five at the scene to allow extrication and 21 in the admitting area or operating room after evaluation revealed a nonsalvageable extremity. Sixty patients underwent further evaluation (Table V).

Diagnosis was based on angiography in 82 percent of patients (49 of 60). Injuries were diagnosed in the operating room in nine of the remaining patients—two of the popliteal, three of the peroneal, three of the posterior tibial and one of the anterior tibial artery. One injury to the popliteal artery was diagnosed by Doppler (necessitated by a dye allergy) and ligated. In one patient, a popliteal injury was missed initially.

TABLE III.—UPPER EXTREMITY VASCULAR TRAUMA, ASSOCIATED INJURIES

	Patients	
	No.	*Percent*
Injury		
Extremity fracture/dislocation	16	80
Closed head injury	5	25
Pelvic fracture	4	20
Chest	2	10
Facial fractures	1	5
Spinal cord/vertebral column	1	5
Leg fracture	1	5
Extremity severe soft tissue injury	1	5

Forty-one percent of the patients (35 of 86) had vascular procedures—23 RSV grafts, nine primary repairs, one PTFE graft and two miscellaneous (Table V). Forty-three percent of these procedures (15 of 35 patients) resulted in late amputations. The overall mortality rate was 14 percent (12 of 86 patients).

Femoral artery. Seven patients had blunt trauma to the femoral vessels. Three ampuations were performed (one early and two late) as well as five operative repairs and one vessel ligation. Two patients died.

Mechanisms of injury included four motor vehicle crashes, one motorcycle crash, one crush and one pedestrian hit. All four patients in vehicular crashes sustained thrombosis of the femoral artery. Bony injuries to the lower extremity were seen in four patients (one knee arthrotomy, two combined femur and tibia fractures and one massive pelvic and lower extremity crush). Angiography was performed in all patients for pulseless, cool extremities.

Of the five operative procedures, three were revascularizations with saphenous vein interposition grafts (one resulted in an amputation above

TABLE IV.—VESSEL INJURY VERSUS ORTHOPEDIC INJURY

		Knee dislocation		*Closed tib/fib fracture*		*Open tib/fib fracture*		*Tibial plateau fracture*		*Femur fracture*	
Vessel	*No. of pts.*	*No.*	*Percent*	*No.*	*Percent*	*No.*	*Percent*	*No.*	*Percent*	*No.*	*Percent*
Femoral artery*	3	—	—	1	33	1	33	—	—	2	67
Popliteal artery	37	12	32	2	5	25	68	7	19	6	16
Anterior tibial artery	12	1	8	3	25	8	67	2	17	1	8
Posterior tibial artery†	14	—	—	3	21	9	64	1	7	—	—
Peroneal artery	4	—	—	—	—	3	75	—	—	1	25
Combined distal vessel injury‡	13	2	17	—	—	13	100	—	—	3	23

*One traumatic arthrotomy as well.
†Two open ankle dislocations.
‡One open foot fracture.
Tib, Tibial, and fib, fibial.

TABLE V.—MANAGEMENT AND OUTCOME OF ARTERIAL INJURIES OF THE LEG

		OR					Amputations			
Vessel	*No. of pts.*	*Repair*	*RSV*	*PTFE*	*Misc.*	*Ligated*	*Early*	*Late*	*Obs.*	*Deaths*
Femoral	7	—	3	—	2*	1	1	2	—	2
Percent		71				14	43		0	29
Popliteal	37	4	16	1	—	—	15	8	1	8
Percent		57				0	62		3	22
Anterior tibial	12	—	—	—	—	1	1	1	10	1
Percent		0				8	17		83	8
Posterior tibial	14	4	1	—	—	2	—	1	7	—
Percent		36				14	7		50	0
Peroneal	4	—	1	—	—	1	1	1	1	—
Percent		25				25	50		25	0
Combined distal	13	1	2	—	—	—	8	2	2	1
Percent		23				0	77		15	8
Total	86†	9	23	1	2	5	26	15	21	12
Percent		41				7	48		28	14

*Thrombectomy and axillobifemoral bypass procedure.
†87 injuries.
RSV, Reverse saphenous vein; PTFE, polytetrafluoroethylene; Obs, observed, and OR, operating room.

the knee; one axillobifemoral bypass was done, but the patient died (old aortic thrombosis with new femoral artery thrombosis); and one thrombectomy was successful.

A transfer patient with a massive open crush injury to the pelvic area and lower extremity required hemipelvectomy for progressive muscle ischemia and necrosis. This patient died within two days of admission.

Popliteal artery. Thirty-seven patients sustained 40 injuries of the popliteal artery. Twenty-six patients were direct admissions from the accident scene, and 11 were transfers. The mortality rate was 22 percent (eight of 37 patients)—all deaths were caused by injuries unrelated to the popliteal disruptions. The amputation rate was 62 percent (23 of 37 patients) (Table VI). Fifty-seven percent of the patients were revascularized and one patient with a severe head injury was observed.

Of the 11 patients who were transferred, ten (91 percent) required amputation. Two patients had attempted vascular repairs at the sending hospital and were sent to our center 48 hours after injury. Both patients required amputation because of extensive muscle and soft tissue necrosis. Three additional patients underwent amputation at admission because the neurovascular and soft tissue injuries were deemed irreparable.

Of the remaining six patients who were transferred, three arrived within six hours and the other three more than six hours after injury. Angiography was performed in all six patients (diminished or absent pulses [five patients] and sensory deficit [one patient]). All patients underwent attempted revascularization, only one successfully. This patient (who had sustained only a closed knee dislocation, had intact sensory and motor function and was never hypotensive) was operated upon within six hours of injury. In the five unsuccessful revascularizations, four legs were amputated for progressive muscle necrosis and one after thrombosis of the RSV graft.

One-half of the 26 patients admitted directly from the scene ultimately required amputation (ten early and three late). Bony injuries included five knee dislocations, ten Grade III tibia or fibula fractures, two tibial plateau fractures, one closed comminuted tibia or fibula fracture and three Grade III femur fractures. Of the ten patients undergoing early amputations for nonsalvageable limbs, three had bilateral procedures. Twelve of the 16 patients who did not require early amputation underwent one-shot angiography in the admitting area. One patient who had dye allergy was diagnosed with Doppler studies. The other three injuries were diagnosed in the operating room.

The 15 revascularizations involved 11 RSV bypass grafts, three primary excision or repairs and one PTFE graft (secondary to severe varicosities). The latter patient died shortly after surgical treatment as a result of intracranial hemorrhage. An additional patient with popliteal thrombosis did not undergo repair because of severe head injury. He died several hours after admission.

Three late amputations were required—one after an attempted RSV graft in a vasculopathic man who had a previous femoral and popliteal procedure on the same side, one at day 23 after an excision and repair in a patient with a Grade IIIC tibia and fibula fracture and a tibial plateau fracture and another after a RSV graft in a late

TABLE VI.—TREATMENT AND OUTCOME OF POPLITEAL ARTERY INJURIES

	Amputation								
	Early		Late*						
No. of pts.	*No.*	*Percent*	*No.*	*Percent*	*RSV repair*	*PTFE repair*	*Primary repair*	*Obs.*	*Death*
37	15	41	8	22	16	1	4	1	8
Total, percent			62			57		3	22
Transfers, 11	5	45	5	45	5	—	1	—	6
Direct admissions, 26	10	38	3	12	11	1	3	1	2

*Amputation after revascularization (eight RSV repairs resulted in delayed amputation).
RSV, Reverse saphenous vein; PTFE, polytetrafluoroethylene, and Obs, observed.

diagnosed popliteal injury. One saphenous vein graft had to be redone 13 days postoperatively because of thrombosis after cessation of heparin therapy and one required thrombectomy at day one.

Of the 15 patients who had revascularization, nine had orthopedic procedures (external fixator or relocation) done first and six had the vascular repair first. Of the three late amputations, two had orthopedic procedures done first. Despite severe orthopedic injuries, all patients with successful repairs were discharged home or to rehabilitation centers with functional limbs.

Anterior tibial artery. Twelve isolated anterior tibial artery injuries occurred. Two amputations were required (one early and one late), no reparative procedures were done and one patient died (Table V).

Associated orthopedic injuries are listed in Table IV. One early amputation above the knee was performed upon a patient who was transferred who arrived with a necrotic leg. Eleven of the 12 patients underwent angiography for diminished or absent pedal pulses (eight patients) or for motor or sensory deficit (three patients). None of the injuries was repaired.

Ten patients with an uneventful hospital course after orthopedic procedures walked without difficulty, with full range of motion. However, one patient with severe multisystem trauma had necrotizing soft tissue infections and eventual multiple organ failure. A knee disarticulation was performed three weeks after admission and the patient was discharged to rehabilitation in good condition.

Posterior tibial artery. Fourteen patients had isolated, unilateral posterior tibial artery injuries. One late amputation was required, five operative repairs were done and no deaths occurred.

Associated bony injuries are listed in Table IV. Angiography was performed upon ten patients because of decreased or absent pulses (seven patients), pallor and poor capillary refill (two patients) and motor or sensory deficit (one patient).

Seven patients were observed and all did well without vascular repair. The posterior tibial artery was ligated in two patients as a result of hemorrhage at the fracture site; both had a good outcome. The remaining five patients underwent attempted revascularization by primary repair (four patients) and RSV (one patient). One repair was eventually ligated after multiple failed attempts. One patient with a severe degloving injury contaminated by paint and chrome had a satisfactory vascular repair but required amputation two weeks after admission as a result of extensive and progressive muscle necrosis.

Peroneal artery. Four patients had isolated peroneal artery injuries. All incurred Grade III fractures of the tibia or fibula with significant soft tissue loss. One early amputation for a severe crush injury was done; one RSV graft was attempted, which ultimately resulted in an amputation below the knee; the artery was ligated in one patient because of bleeding, and the fourth injury was observed. The patients who did not have an amputation had excellent recovery of function in the affected extremity. No preoperative angiography was done because the previously described indications were absent.

Combined injuries. Thirteen patients had various combinations of anterior tibial, posterior tibial and peroneal injuries. Seven underwent angiography for diminished or absent pulses. All had Grade III tibia or fibula fractures.

Ten amputations resulted (eight early and two late). Three vascular repairs were attempted (two RSV and one primary repair); one RSV graft was successful, but the other two repairs resulted in amputations. Two patients were observed (one died from a head injury and the other did well).

DISCUSSION

Blunt injuries to the vessels of the upper extremity are less common than penetrating injuries. However, they are more likely to be overlooked because active bleeding may not be obvious and the "proximity of injury" guideline may not

be easily applied. Early diagnosis and treatment remain critical to optimal outcome. When suspicion is high, angiography should be done.

Few series have been devoted to blunt vascular trauma of the upper extremity (9–12). Most articles describe blunt and penetrating vascular injuries and do not separate the blunt instances (13–15). About 2 to 16 percent of upper extremity vascular injuries result from blunt trauma (16, 17).

Treatment of vascular injuries is not always straightforward. Other injuries may delay diagnosis and management. Priority decisions are based on the perceived threat of the injury to survival or function, or both. Management of blunt venous injury is controversial (15, 16).

Trauma involving the lower extremity vasculature has always been surgically challenging. Ligation of the popliteal artery, commonly practiced during World War II, resulted in an amputation rate of 72.5 percent (18). Arterial repair during the Korean conflict decreased this rate to 32.4 percent (19). The war in Vietnam highlighted the importance of quick, definitive treatment of penetrating and blunt lower extremity vascular trauma (20). Studies since then have defined "quick" as six hours from time of injury, during which flow should be re-established to an ischemic extremity (1, 21). Obviously, expeditious diagnosis is the main factor in repair. Adherence to the policy of performing angiography upon finding diminished or absent pulses, a pale extremity with impaired capillary refill or a motor or sensory deficit resulted in only one injury being overlooked.

Other factors that correlate with extremity salvage are early liberal use of fasciotomy, re-establishment of flow before orthopedic stabilization, use of a temporary shunt while preparing the anastomotic sites or stabilizing fractures, systemic heparinization, repair of venous injuries, primary repair and use of completion angiography (22–29). When orthopedic stabilization was required, it usually preceded vascular repair, especially in the leg. In the current patient population, bony stabilization frequently must be performed initially because of instability or foreshortening of the extremity. However, because this procedure clearly adds to ischemia time, limb salvage might have been improved by using a temporary shunt. We have used shunts if time since injury approached five to six hours or if the limb appeared ischemic.

Systemic heparinization has been advocated as contributing to limb salvage (28). Many patients with trauma have head trauma, fractures of the pelvis and retroperitoneal hematomas, which make systemic heparinization risky. Therefore, we prefer local vessel heparinization; however, even local instillation may produce systemic effects.

Repair of concomitant venous injuries has been stressed by others (22, 24, 25), but the current small series does not allow comment on this subject. Eight popliteal vein injuries (not reported herein) were documented. Two of three repairs were successful; the third culminated in an amputation above the knee despite a patent arterial bypass graft. All five patients who had no venous repair underwent amputation after initial operative assessment revealed a nonsalvageable extremity.

Unlike penetrating trauma, blunt trauma rarely involves clean severance (the usual presentation is an edematous, contused artery with several centimeters of intimal disruption). Bypass or resection of the injured segment is the only way to provide a tension-free anastomosis.

Completion angiography allows documentation of technical success (23) but has not been used routinely at this institution, partly because many patients have multisystem injuries that require additional surgical treatment. If a palpable pulse was obtained distal to the anastomosis and the extremity appeared pink and well perfused, an additional study was often foregone. However, completion angiography should be performed when there is a question of graft patency and should be done routinely if the condition of the patient permits.

Popliteal artery injuries deserve special mention. Sixty-two percent of the patients (22 of 37) in the current series required amputation (Table VI). Forty-one percent of these were performed immediately when examination of the extremity revealed severe destruction of the nerve or substantial loss of bone and tissue. Of limbs deemed potentially salvageable and then revascularized, 38 percent eventually were amputated because of progressive ischemia and necrosis of the muscle. All the popliteal injuries were associated with severe extremity trauma (Table IV). The mortality rate was 22 percent. The poorer outcome in patients with popliteal artery injuries who were transferred, as opposed to those who arrived directly from the scene, supports the concept that time is important in limb salvage.

Although from this review we are unable to make any conclusion regarding early versus late

repairs as affects outcome, it is our opinion that early repair is still preferable and perhaps does lead to better outcome. Certainly in patients with popliteal artery injuries, time may have had a role.

The results of a previous study from this center found that blunt trauma of the lower extremity vasculature resulted in an amputation rate of 31 percent, with 50 percent occurring after failed revascularization (22). The overall lower limb amputation rate in this series (48 percent) was somewhat higher, but the success rate for arterial repair improved—57 percent (20 of 35 patients) of lower extremity vascular repairs had a good outcome (Table V).

Each patient with a badly injured extremity deserves individualized analysis, taking into consideration the overall clinical status and premorbid medical history, as well as the condition of the extremity. The contraindications to salvage attempts used at our institution are massive crush injury to the leg or thigh, or both; severe degloving injury to the plantar surface of the foot or completely crushed foot; anesthetic extremity secondary to crushed or multiply injured nerves; patients with premorbid, advanced peripheral vascular disease, and patients with multiple other injuries in whom lengthy revascularization procedures would pose a threat to life (8). Spending long hours revascularizing a nonviable extremity only adds to the morbidity of an already seriously ill patient. Amputation should not be considered a failure in management of these severely injured patients, but rather a contribution to survival.

SUMMARY

The higher morbidity and mortality rates associated with blunt vascular injuries of the extremity, compared with penetrating trauma, make them a matter of clinical import. Among 15,146 patients with blunt trauma admitted to a Level I facility during a seven and one-half year period, 106 had vascular injuries of the extremities (20 upper and 86 lower). Angiography had a central role in the assessment of those patients without obvious indications for amputation (83 percent of this group had angiograms). Blunt vascular injuries of the extremities are always challenging. The clinical scenario is compounded by special needs of patients with blunt vascular trauma—heparinization, early bony stabilization, multiple other injuries, and urgency of vascular repair.

REFERENCES

1. Downs, A. R., and MacDonald, P. Popliteal artery injuries: Civilian experience with 63 patients during a 24-hour period (1960-1984). J. Vasc. Surg., 1986, 4: 55-62.
2. Fabian, T. C., Turkelson, M. L., Connelly, T. L., and Stone, H. H. Injury to the popliteal artery. Am. J. Surg., 1982, 143: 225-228.
3. Feliciano, D. V., Herskowitz, K., O'Gorman, R. B., and others. Management of vascular injuries of the lower extremities. J. Trauma, 1988, 28: 319-328.
4. Krige, J. E. J., and Spence, R. A. J. Popliteal artery trauma: A high risk injury. Br. J. Surg., 1987, 74: 91-94.
5. Mackay, M. Kinematics of vehicle crashes. In: Advances in Trauma. Edited by K. Maull. Pp. 28-29. Chicago: Mosby-Year Book Medical Publishers Inc., 1987.
6. Burgess, A. R., and Mandelbaum, B. R. Acute orthopedic injury. In: Trauma: Emergency Surgery and Critical Care. Edited by J. H. Siegel. Pp. 1055-1056. New York: Churchill Livingstone Inc., 1987.
7. Dunham, C. M., Cowley, R A., Gens, D. R., and others. Methodologic approach for a large functional trauma registry. Md. Med. J., 1989, 38: 227-233.
8. Yaremchuk, M. J., Burgess, A. R., and Brumback, R. J. Lower Extremity Salvage and Reconstruction: Orthopedic and Plastic Surgical Management. Pp. 33-70. New York: Elsevier, 1989.
9. Cleveland, J. C., Ellis, J., and Dague, J. Complete disruption of axillary artery caused by severe atherosclerosis and trivial nonpenetrating trauma. J. Trauma, 1979, 19: 635-636.
10. Cofer, J. B., and Burns, R. P. Blunt vascular trauma of the upper extremity. J. Tenn. Med. Assoc., 1988, 81: 307-309.
11. Faris, I., Jury, P., and Malycha, P. Blunt injury to the subclavian artery. Aust. N. Z. J. Surg., 1984, 54: 249-251.
12. Golueke, P., Sclafani, S., Phillips, T., and others. Vertebral artery injury—diagnosis and management. J. Trauma, 1987, 27: 856-865.
13. Graham, J., Mattox, K. L., Feliciano, D. V., and DeBakey, M. E. Vascular injuries of the axilla. Ann. Surg., 1982, 195: 232-238.
14. McCready, R. A., Procter, C. D., and Hyde, G. L. Subclavian-axillary vascular trauma. J. Vasc. Surg., 1986, 3: 24-31.
15. Orcutt, M. B., Levine, B. A., Gaskill, H. V., and Sirinek, K. R. Civilian vascular trauma of the upper extremity. J. Trauma, 1986, 26: 63-67.
16. Hardin, W. D., O'Connell, R. C., Adinolfi, M. F., and others. Traumatic arterial injuries of the upper extremity. Am. J. Surg., 1985, 150: 266-270.
17. Reynolds, R. R., McDowell, H. A., and Diethelm, A. G. The surgical treatment of arterial injuries in the civilian population. Ann. Surg., 1979, 189: 700-708.
18. DeBakey, M. E., and Simeone, J. A. Battle injuries of the arteries in World War II: An analysis of 2,471 cases. Ann. Surg., 1946, 123: 534.
19. Hughes, C. W. Arterial repair during the Korean War. Ann. Surg., 1958, 147: 555-561.
20. Chandler, J. G., and Knapp, K. W. Early definitive treatment of vascular injuries in the Vietnam conflict. J. A. M. A., 1967, 202: 136-142.
21. Miller, N. H., and Welch, C. S. Quantitative studies on the time factor in arterial injuries. Ann. Surg., 1949, 130: 428-438.
22. Hardin, W. D., Adinolfi, M. F., O'Connell, R. C., and Kerstein, M. D. Management of traumatic peripheral vein injuries. Am. J. Surg., 1982, 144: 235-238.
23. Orcutt, M. B. The continuing challenge of popliteal vascular injuries. Am. J. Surg., 1983, 146: 759.
24. Rich, N. M. Principles and indications for primary venous repair. Surgery, 1982, 91: 492-496.

25. Rich, N. M., Collins, G. J., Jr., Andersen, C. A., and McDonald, P. T. Autogenous venous interposition grafts in repair of major venous injuries. J. Trauma, 1977, 17: 512-520.
26. Shah, D. M., Naraynsingh, V., Leather, R. P., and others. Advances in the management of acute popliteal vascular blunt injuries. J. Trauma, 1985, 25: 793-797.
27. Snyder, III, W. H. Vascular injuries near the knee: An updated series and overview of the problem. Surgery, 1982, 91: 502-506.
28. Wagner, W. H. Blunt popliteal artery trauma. J. Vasc. Surg., 1988, 7: 736-743.
29. Ransom, K. J., Shatney, C. H., Soderstrom, C. A., and Cowley, R A. Management of arterial injuries in blunt trauma of the extremity. Surg. Gynecol. Obstet., 1981, 153: 241-246.