

Combat Wounds of the Popliteal Artery

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THE CURRENT treatment of arterial trauma has evolved from wartime experiences, the most notable being the Korean conflict where direct arterial surgery was first applied on a large scale with a resultant increase in survival of limbs.^{6, 7, 13} Subsequent contributions of military and civilian surgeons alike have been responsible for the high percentage of survival of limbs now expected following reconstruction of major arteries.^{10, 11}

Despite advances in vascular surgical technic, trauma to the popliteal artery continues to be associated with a high rate of amputation in some instances exceeding rates reported at the inception of restorative surgery 15 years ago^{2, 4, 5, 8, 12} (Table 1). This study constitutes a review of acute combat injured popliteal arteries observed during a one year period in the Republic of South Vietnam, with attention to factors which adversely influence survival of limbs.

Clinical Material

Reconstructive operations were performed on 91 acute limb-threatening arterial injuries in the Naval Hospital, USS *Repose* (AH-16) from January 7, 1967 to January 1, 1968. Of these, 18 involving popliteal arteries, provide the basis for this study. Excluded were injuries to tibial vessels unless both were involved or were associated with a more proximal wound. All patients, save one, were military personnel of an average age of 23 years. In

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each instance the etiologic agent was a fragmenting missile wound, ten of which were classified as high velocity. The types of injuries were as follows: lacerations—four; transections—nine; contusions and thromboses of intact vessels—five. All patients were evacuated to the *Repose* via helicopter with a mean "time lag" from injury to operating suite of 5.5 hours. The facilities aboard the hospital ship permitted a postoperative period of observation in excess of 10 days in all but one patient, the average being 2 weeks, a period deemed sufficient to warrant short-term analysis of results. Associated injuries to distant organ systems and adjacent structures were common (Table 2). With few exceptions arterial wounds were given equal priority with abdominal and thoracic injuries utilizing a second operative team when necessary.

Figure 1 illustrates the frequency and site of injuries. For purposes of review the artery was arbitrarily divided into proximal and distal segments, the mid-point being the opposing articular surfaces of the femur and tibia, anatomically corresponding to the inferior geniculate vessels.

Management

Diagnosis. Recognition of arterial injury was readily apparent clinically in the majority of patients. In comparison to more proximal vessel injuries, wounds of the popliteal artery were invariably associated with absent distal pulses, earlier skin discoloration and varying degrees of muscle contracture (Fig. 2). Tests employing capillary or venous filling were unreliable in assessing arterial integrity, whereas digital motor deficits and "boot-like" anes-

TABLE 1. Comparative Results Following Repair of Popliteal Artery Injuries

Author	No. of Cases	Functional Limb (%)
Hughes ⁵	37	72
Spencer ¹²	24	63
Hoover ⁴	12	8
Miller ⁹	6	33
Fisher ²	16	62

TABLE 2. Associated Injuries with 18 Cases of Popliteal Artery Trauma

<i>Remote</i>		
Head and Neck		2
Thoracic		2
Abdominal		3
Extremity		4
<i>Regional</i>		
Major Fracture		11
Popliteal Vein		9
Nerve		3

thesia in the absence of nerve injury were characteristic.

An incorrect diagnosis of arteriospasm was initially entertained in three patients all of whom were found to have intimal laceration and thrombosis. The use of sympathetic blockade or intra-arterial vasodilating agents to differentiate vasospasm was not utilized and a policy of proving patency of the vessels in such cases was adopted. Although this involved two negative arterial exploratory operations, procrastination with conservative measures was not considered justified.

Preoperative arteriography as a means of detecting arterial injury was rarely used and was reserved for patients in whom pseudoaneurysm or arteriovenous fistula was suspected (Fig. 3). This technic was also of value in the immediate postoperative period in determining the patency of a repaired vessel, especially when operation was under consideration.

Operative Treatment. Wide exposure of the popliteal artery was necessary in most instances because of the magnitude

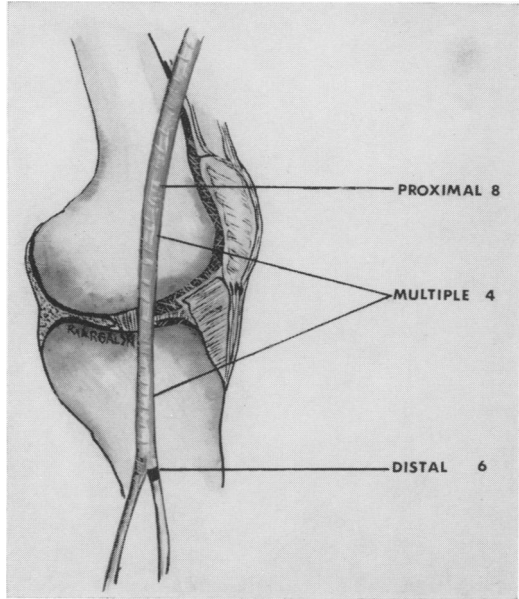


FIG. 1. Site and frequency of popliteal artery wound.

of the trauma (Fig. 4). This was best achieved via a medial incision providing simultaneous access to both proximal and distal arterial segments. Emergency operation for uncontrollable blood loss prior to resuscitation was obviated by short term application of the pneumatic tourniquet

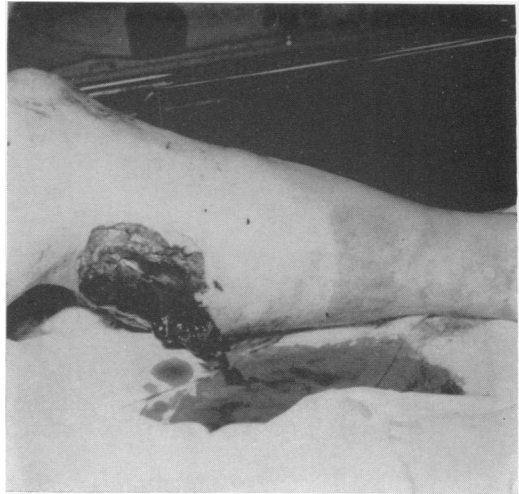


FIG. 2. Exit of high velocity missile wound with transection of distal popliteal artery.

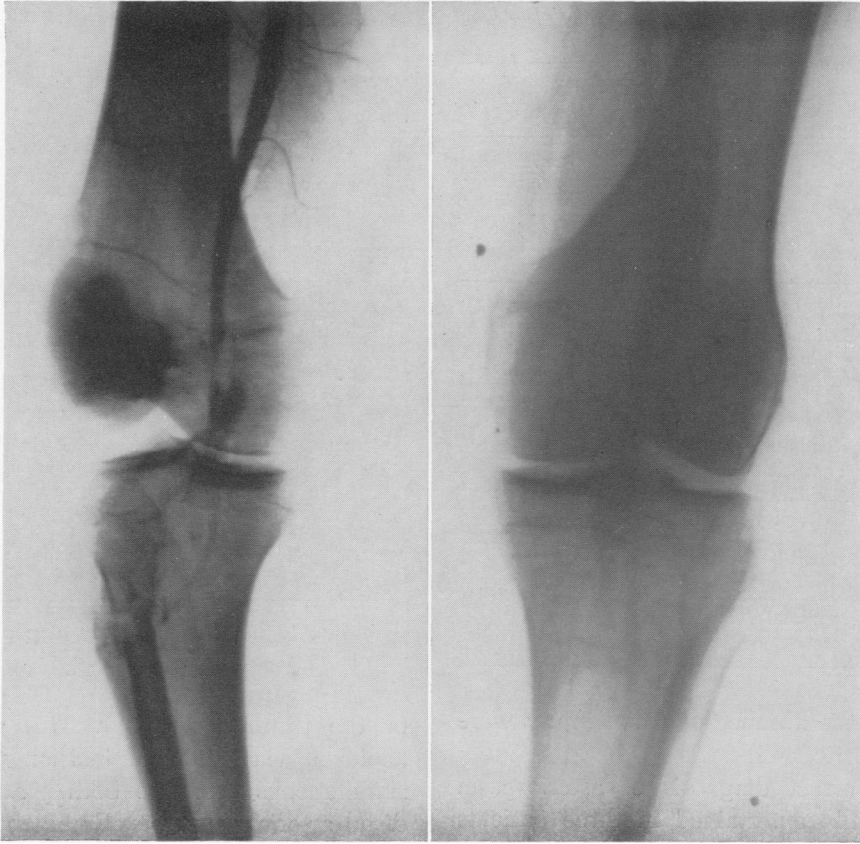


FIG. 3. Acute false aneurysm (A, left) and arterio-venous fistula (B, right) of popliteal artery.

which provided time to complete preoperative evaluation and therapy.

Adjacent fractures of the distal femur or proximal tibia occurred in 11 of 18 patients (Fig. 5). Every attempt was made



FIG. 4. Multiple fragmentation wounds with injury to proximal and distal popliteal artery.

to insure stability of the co-existing fracture and this was satisfactorily accomplished in most instances by skeletal traction. Internal fixation was avoided in contaminated wounds and was necessary only in widely displaced fractures in close proximity to arterial repairs. Concomitant injury to popliteal veins was not common and reconstruction was undertaken whenever possible, as ligations resulted in disabling edema and in two instances was considered contributory to amputations.

The types of repairs are listed in Table 3. Although primary anastomosis was attempted whenever feasible, vein grafts were required in the majority of patients. The extent of trauma following high velocity missile wounds frequently required excisions of 3 to 5 cm. of vessels precluding

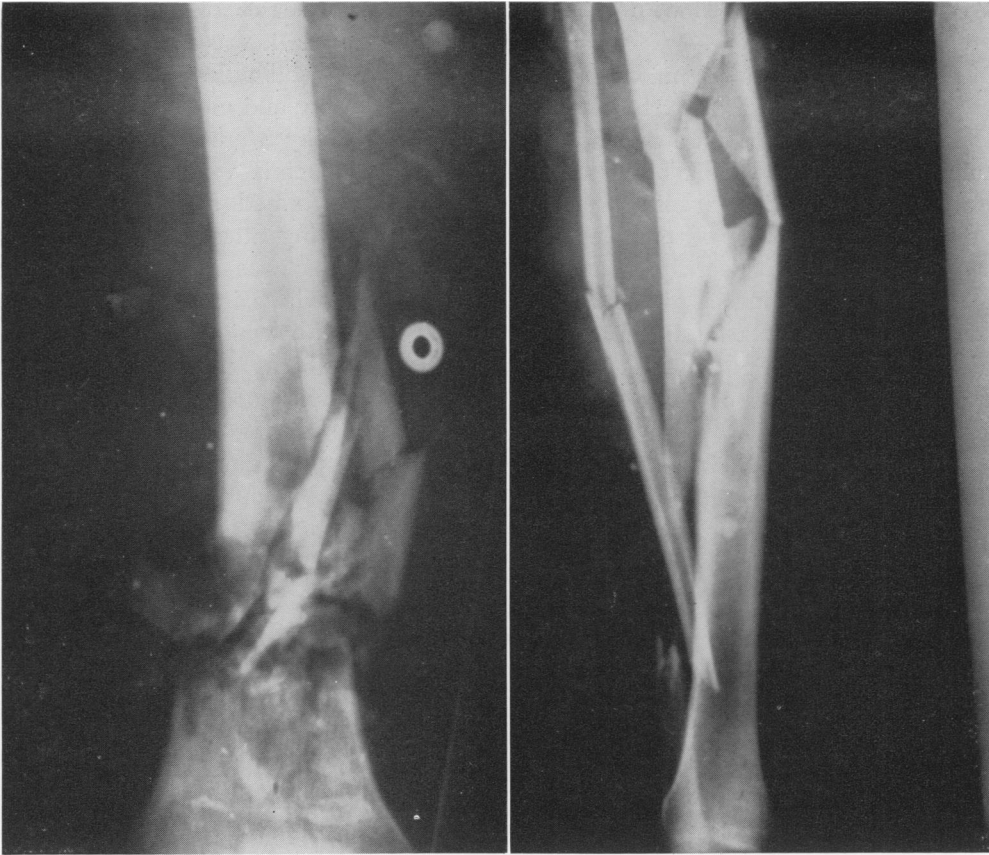


FIG. 5. (A, left) Supra-condylar fracture with injury to proximal popliteal artery. (B, right) High velocity wound of calf with fracture of tibia and transection of popliteal artery bifurcation.

tension-free anastomoses particularly with injuries to the mid and distal popliteal arteries. Patch grafts were used whenever thrombectomy was the primary procedure permitting excision of damaged intima at the same time avoiding luminal constriction. Reoperation was necessary in all instances when lateral repair without patch graft was the original procedure. In retrospect reoperation could have been avoided had simple suture of the arterial wound not been done at the expense of adequate debridement.

All patients required fasciotomies as cessation of blood flow through the popliteal artery was quickly followed by edema of the calf. This was accomplished by incising all fascial compartments of the calf

via multiple small skin incisions. In ten instances fasciotomies were performed under local anesthesia during resuscitation. Evacuation of compartmental hematomas was also facilitated by this maneuver with improvement of distal arterial perfusion in many instances. Although reconstruction of vessels were performed in all borderline cases, the finding of cool immobile muscle, hardened by ischemia at the time of fasci-

TABLE 3. *Method of Vessel Repair*

Lateral Vessel Repair	3*
Primary Anastomosis	5
Venous Patch Graft	2
Autogenous Vein Graft	8

* Later replaced by vein graft.

otomy was usually followed with eventual amputation.

Of lesser prognostic significance was the quality of retrograde arterial flow which was dependent upon location of trauma. A diminished backflow was the rule with distal injuries in spite of retrograde flushing and use of embolectomy catheters. Even though decreased backflow was an ominous finding, it was not considered an absolute contraindication to arterial repair in young individuals who had no established collateral network about the knee, and several limbs were salvaged with this apparent runoff deficit.

The massively contaminated wound complicated by ischemia required wide debridement of all devitalized tissue both adjacent and distal to the arterial injury. Despite prompt restoration of blood flow inadequate debridement was complicated by rapidly advancing cellulitis and patchy necrosis the predominant causative organism being *Pseudomonas aeruginosa*. Once established, this process was difficult to control in spite of repeated debridement and intensive local wound care. In two patients the complication was of sufficient magnitude to require amputation in the presence of functioning arterial repairs. *Clostridial myositis* was encountered in one patient postoperatively who responded to amputation supplemented by administration of high pressure oxygen.

All soft tissue wounds were treated by delayed primary closure the arterial repair being covered with surrounding muscle or fascia. Prophylactic antibiotic drugs, usually penicillin and streptomycin, were used in each case for 5 to 7 days. Long term therapy particularly with broad spectrum agents was avoided as this commonly resulted in overgrowth of coliform organisms.

Results

The viability and functional status of all extremities were determined at time of

discharge. In cases of extensive musculoskeletal trauma it was occasionally difficult to palpate distal pulses, hence determination of sensory and motor functions as well as angiography were important. Amputations for ischemia were required in eight patients performed at an average of 60 hours following attempts at vessel reconstruction. This was in contrast to arterial wounds elsewhere in the upper and lower extremity with which immediate survival of the limb was not always dependent upon continuity of the vessels.³ Amputations were supracondylar, three initial below-knee procedures eventually required above-knee revisions. In the remaining ten patients restorative operations were successful for a short-term limb salvage rate of 55%. Reappearance of ischemia immediately following repair necessitated a second operative procedure in four patients. Operation in each instance revealed errors in technic the most common being thrombosis at the site of repair on the basis of inadequate arterial debridement. There were no deaths during the brief follow-up period.

Comment

Survival of an extremity following major arterial injury is related to the ability of alternate channels to maintain distal perfusion until continuity of the injured vessel can be re-established. In young patients popliteal arteries are in every sense "end arteries" with under-developed collateral vessels also frequently interrupted by trauma.

An analysis of the patients requiring amputation is summarized in Table 4. There was no correlation between the time interval preceding repair and survival of the limb, the average time for failures being slightly less than that of the entire series. Re-establishment of blood flow was successful in two patients with time lags of 10.5 and 11 hours but in no case did the limb survive when the time exceeded 12

hours. Time lag was more important, however, when the wound involved the distal popliteal segment in proximity to the bifurcation. Reconstruction in such instances was successful only when performed within 3 hours of injury.

Survival of the limb was also dependent upon the location of the arterial wound. Extensive trauma involving one or more tibial vessels in the mid-calf in conjunction with a proximal popliteal wound was associated with poor results; only one of four limbs survived. Reconstruction of solitary injuries of the proximal popliteal segment was successful in six of eight patients and in retrospect two failures could have been avoided had not lateral repair been employed as the initial procedure. By comparison, single wounds of the infragenual segment including the bifurcation, resulted in a 50% rate of amputation.

Major fractures co-existing with arterial injury unfavorably influenced survival of the limb. Severely displaced and comminuted fractures were frequently associated with damage to the poorly protected collateral vessels shortening the period of ischemia during which blood flow could be restored. In contrast to civilian injuries,^{1, 8} all fractures were open and did not necessarily produce arterial injury but reflected the magnitude of the missile wound. Five of eleven patients with osseous injury were discharged with viable limbs, all of whom had distal fractures of the femur and injuries to the popliteal arteries adjacent to the adductor hiatus. Prognostically the most lethal fracture was of the proximal tibia with distal arterial and soft tissue injury to the calf, as early amputation was necessary in every instance. Lacking guides to predict survival attempts were made to restore arterial continuity in several such cases in which on review amputation was initially indicated.

Methods of arterial reconstruction were also related to survival of extremities.

TABLE 4. *Factors Influencing Limb Survival in Eight Patients Requiring Amputation*

Patient	Time Interval Preceding Repair (Hrs)	Site of Injury	Fracture	Type of Repair
1	4	Proximal	Femur	Lateral Repair
2	12	Distal	Tibia	Lateral Repair
3	1.5	Multiple	None	Vein Graft
4	3	Distal	None	Vein Graft
5	14	Proximal	Femur & Tibia	Lateral Repair
6	2	Distal	Tibia	Vein Graft
7	2.5	Multiple	Tibia	Vein Graft
8	2	Multiple	Femur & Tibia	Vein Graft

There were no amputations in cases in which primary anastomoses or patch grafts were utilized. Although segmental vein graft replacement was unsuccessful in the majority of instances, the technic was employed only for severe injuries and to bridge long defects involving the mid and distal popliteal artery. Lateral suture of an arterial wound was inadequate and resulted in early thrombosis which seemingly contraindicates its use in missile injuries.

At the time of amputation all repairs were inspected and distal arteries were dissected to determine factors responsible for failure. Excluding two cases in which amputations were necessary for uncontrolled sepsis, arterial thrombosis of the distal arterial complex was seen in all limbs. Unrecognized injury to the tibial vessels in the lower calf with subsequent runoff obstruction was encountered in three limbs. Although surface wounds had been debrided, in no case were the tibial vessels exposed at the time of initial operation. Operative arteriography also failed to demonstrate distal lesions as attention was primarily directed to the site of repair. One limb retained distal thrombus which was not completely evacuated at the time of operation. In the remaining two cases the reason for failure was not apparent although massive venous thrombosis following popliteal vein ligation suggested a causal relationship.

Summary

Eighteen cases of acute combat incurred popliteal arterial injuries have been reviewed.

All wounds were the result of fragmenting missiles which frequently produced extensive damage to adjacent structures including the poorly protected collateral network about the knee. In such cases early fasciotomy was important in prolonging the critical period of ischemia during which repair could be successfully undertaken.

Co-existing fractures *per se* did not materially effect survival of limbs and were managed by external immobilization. Every attempt was made to repair venous injuries as ligations of veins contributed to morbidity.

Restorative procedures were successful in most wounds involving the proximal popliteal artery segment. By contrast multiple injuries or infragenuous trauma were associated with a high rate of amputation.

Potentially amenable lesions of distal arteries were found in one half of the failures at the time of amputation, emphasizing the importance of thorough exploration.

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