ACUTE VASCULAR INJURIES IN THE KOREAN WAR:

AN ANALYSIS OF 77 CONSECUTIVE CASES*

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THE SUDDEN DISRUPTION of major arterial continuity, so frequently seen in battle casualties, confronts the military surgeon with a serious and discouraging problem. If death from massive hemorrhage does not occur, a high percentage of these patients rapidly pursue the inevitable course of ischemia and gangrene, necessitating early amputation of the whole or part of an extremity. In the interval between every war, outstanding discoveries have been made in most fields of medical research. The encouraging results of these have been the ultimate reduction in mortality of the wounded, reaching a forward medical installation to less than 2 per cent. During the past ten years, many experimental and clinical contributions have been made in the realm of cardiovascular surgery which have provided satisfactory solutions to problems previously unsolved and opened unlimited horizons for further research. Despite these advances, there has been no significant decline in the number of limbs lost following major vascular injury in battle casualties. This, undoubtedly, can be attributed to the fact that the recommended treatment in the majority of cases, namely, immediate ligation of the bleeding artery, has remained unchanged since World War I or even earlier.

Prior to the numerous surveys made during World War II, there were no really accurate statistics regarding the incidence of gangrene and subsequent amputation following ligation of a damaged artery. Makins'[14] monumental work on vascular injuries in World War I showed an over-all amputation rate of 18.1 per cent and in popliteal injuries, an amputation rate of only 43 per cent. Others have reported up to 70 per cent gangrene following early ligation of major vessels and up to 100 per cent in ligation of the popliteal artery.[1, 4, 16, 17, 24, 25] DeBakey and Simeone[4] have partially explained this inconsistency in figures by showing that previously reported series contained many cases of false aneurysms and ever simple vein ligations. Neither of these lesions was in any way comparable to acute arterial injury and ligation. In addition, some vascular lesions were not basically counted as such because of associated infection and/or massive trauma.

It was not long after the onset of World War II that it became clear that the sequellae of early arterial ligation were more serious than had been reported. The statistics of DeBakey and Simeone,[4] Rose, Hess, and Welch,[17] and others[1, 16, 24, 25] showed an incidence of gangrene varying from 45 to 55 per cent when a major artery was initially ligated. It was realized that some method of approach other than ligation would have to be utilized if more limbs were to be saved. In selected cases, those with small wounds or small areas of arterial damage, repairs were attempted. The methods used were, for the most part, the direct suture repair,

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the nonsuture vein graft, and the nonsuture tube anastomosis. The over-all results were disappointing in that the incidence of gangrene, even in these selected cases, varied between 36 and 50 per cent. This was questionable improvement over the results of immediate ligation, especially since the reparative treatment was time-consuming and required a great deal of specialized technical skill. DeBakey and Simeone[4] found that the incidence of gangrene following the nonsuture tube anastomosis was 50 per cent and following the nonsuture vein graft was 57 per cent, even higher than the 49 per cent incidence after ligation. There was only slight improvement following suture repairs, with an amputation rate of 35.8 per cent. The adjunctive use of sympathetic block and fasciotomy was of questionable value.

In view of the statistical evidence accurately recorded from World War II, the policy at the beginning of the Korean conflict was to ligate all vascular injuries unless they were of such size that transverse suture repair or simple end-to-end anastomosis was possible. The destructive force of the modern military weapons made the number of lesions suitable for repair quite small. Reports from the Far East[13, 23, 26] have indicated that the incidence of success, even in these cases, was quite low. Some series have been reported in which over 70 per cent of the repairs failed.

It has been observed that in some instances vessels have been repaired only to develop a thrombosis later. Some of these patients have required amputation of the involved extremity at a higher level than would have been anticipated initially. This, it was believed, was due to propagation of the thrombus up and down the vessel with occlusion of important collateral channels. However, this was only an impression based on personal communications with numerous surgeons in forward areas and was not confirmed by statistical proof.

Scattered reports on several small series of cases in which grafts were inserted in arterial defects are also available from the Korean conflict.[13, 26] The circumstances concerning their use in regard to the extent of the injury, the time-lag from wounding to repair, associated fractures, and other factors (to be discussed later), which may be of greater or lesser importance in the ultimate outcome, are not available. The results, though, have been most discouraging. The incidence of failure in one series of six cases was 100 per cent.[13]

In contrast to the universally poor results obtained in repair of early vascular lesions were the results reported from this hospital in the repair of late vascular lesions.[19-21] The series consisted of 150 arteriovenous fistulas and false aneurysms in Korean war wounded. Ligation and excision was performed in the first 26 cases involving major arteries. The results were similar to those of Elkin[6, 7] and others.[22] There were no cases of gangrene requiring amputation. It is significant, however, that 30 per cent of the patients presented definite symptoms of arterial insufficiency, even with the adjunctive use of sympathectomy. Reparative surgery in 67 cases of major arterial lesions by other methods such as the end-to-end suture anastomosis, the homologous artery graft, and the autogenous vein graft gave much better functional results. Thrombosis occurred in only two patients. The overall results were so satisfying that it was established that all major arterial lesions would be repaired by anastomosis or graft.

It is not meant to imply that one can in any way compare the results of repair of acute arterial injuries with repair of arteriovenous fistulas and false aneurysms. In the former group, many factors enter which are never encountered in the latter group. Collateral circulation has had a chance to develop in the chronic lesions so that even ligation is followed by an extremely small incidence of gangrene. Russell[18] has shown

that the collateral circulation can develop sufficiently in a few weeks, and in many cases within a few days, to significantly lower the incidence of gangrene following arterial ligation. The important point to be emphasized, however, is that it was believed that certain technics perfected during the study and treatment of the fistulas and aneurysms could be applied to the acute vascular injuries and significantly reduce the incidence of gangrene.

This manuscript reports the initial results and follow-up obtained in a series of 77 consecutive vascular injuries treated by one of us (E. J. J.), a member of the Surgical Research Unit from the Army Medical Service Graduate School.

MATERIAL

All patients in this series were treated during a four-month period in Korea at the Mobile Army Surgical Hospital, 8055 Army Unit. Approximately 75 per cent were members of the Eighth United States Army. The remaining 25 per cent was divided among soldiers of the British, Canadian and Republic of Korea Armies, and Chinese prisoners of war.

The vascular injuries were divided into two main groups: those with injuries to

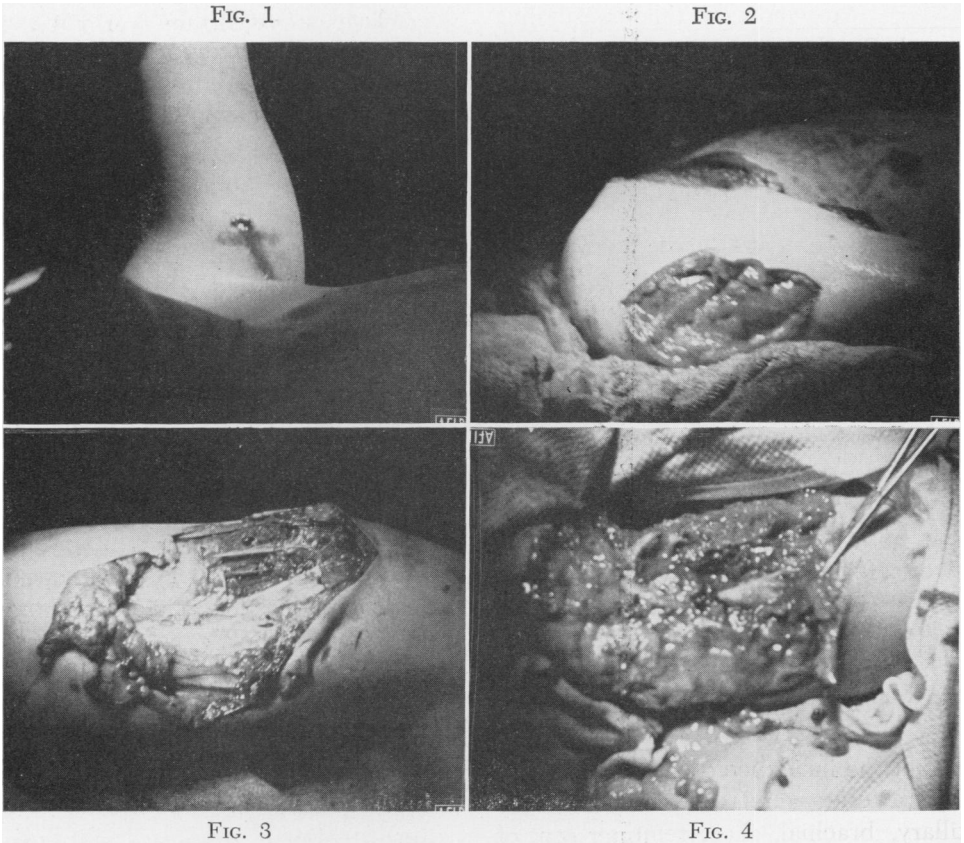


FIG. 1 FIG. 2

FIG. 3 FIG. 4

FIG. 1. A bullet wound of the arm which lacerated the brachial artery. There was marked swelling in the tissue from the large hematoma which was formed.

FIG. 2. An extensive wound of the right shoulder that severed the axillary artery.

FIG. 3. A massive artillery shell fragment wound of the left thigh. The femoral artery was severed. There was minimal hemorrhage in the area.

FIG. 4. An extensive mortar fragment wound of the arm. The brachial artery was severed. In one area a spicule of bone impaled the artery.

minor arteries and those with injuries to major arteries. There were 43 patients, or 55.8 per cent in the former group, and 34 patients, or 44.2 per cent, in the latter group. Arteries classified as minor were the brachial profunda, radial, ulnar, femoral profunda, anterior tibial, posterior tibial, peroneal, or any combination of these vessels. Major arteries were considered the carotid, axillary, brachial, iliac, femoral and popliteal (Table I).

TABLE I. *Distribution of 77 Consecutive Vascular Injuries Treated and Incidence of Gangrene.*

Vessel	Total Number	% Total	Loss of Limb No. Cases	%
Common Carotid	1	1.3	-	—
External Carotid	1	1.3	-	—
Axillary	5	6.6	-	—
Brachial	12	15.7	-	—
Above Profunda	4	5.2	-	—
Below Profunda	7	9.0	-	—
Profunda	1	1.3	-	—
Radial	6	7.9	-	—
Ulnar	5	6.6	-	—
Radial and Ulnar	2	2.6	-	—
External Iliac	1	1.3	-	—
Femoral	14	18.5	2	14.2
Above Profunda	1	1.3	-	—
Below Profunda	8	10.6	1	12.5
Profunda	5	6.6	1	20
Popliteal	7	9.0	2	28.5
Anterior Tibial	6	7.9	1	16.6
Posterior Tibial	9	11.4	3	33.3
Both Tibials	2	2.6	-	—
Peroneal	3	4.0	-	—
Anterior Tibial & Peroneal	1	1.3	-	—
Posterior Tibial & Peroneal	1	1.3	-	—
Both Tibials & Peroneal	1	1.3	-	—
TOTAL	77	100	8	10.6

FACTORS AFFECTING TREATMENT

In all types of surgery the ultimate results are dependent upon, or are at least partially influenced by, many factors. The interplay of these factors is often clear-cut and well understood. Vast amounts of well-documented evidence have firmly established the criteria as to operability and probable outcome. Such is not the case with the acute vascular injuries. These lesions, though quite uncommon in general civilian practice, constitute approximately 1 per cent or more of all battle casualties. Therefore, data of statistical significance can best be obtained during periods of armed conflict. The exigencies of the military medical service, from a tactical standpoint, often preclude the compiling of complete and accurate medical records. Despite this unavoidable handicap, surveys from World War II have enumerated and explained many factors common to vascular injuries which are instrumental in determining the final results of treatment. This series was studied on the basis of these findings. Several other observations were made which were felt to be significant in the handling of the acute arterial interruption.

1. *Type and Size of Wound.* The day of the sword, spear and cannon ball as major instruments of warfare has long passed. Modern military weapons, with their high muzzle velocity and their tremendous propensity to fragmentation, aimed at inflicting mass casualties, present an almost incalculable destructive force. Rarely is the military surgeon fortunate enough to see a clean-cut knife wound or a small round bullet wound associated with a vascular injury which is usually a simple transection of the vessel or a small laceration in its wall (Fig. 1). Such a lesion can often be adequately and successfully repaired by direct suture anastomosis or transverse suture of the laceration. Even if the repair fails, the collateral circulation is undisturbed and will usually preserve the viability of the limb. In most cases, however, the military surgeon is confronted with a large, jagged and gaping wound. This may be single, but in a high percentage of cases it will be multiple. The damaged artery will be destroyed for large segments and a simple repair will be impossible (Fig. 2, 3 and 4). In addition, it has been previously shown that the larger the wound, the greater the chance that the vital collateral circulation will be destroyed. It may also be implied that the effectiveness of the collaterals will

FIG. 5

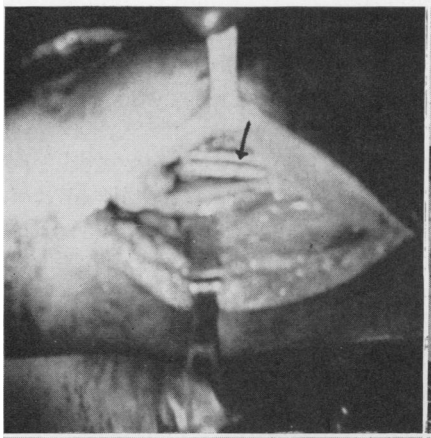
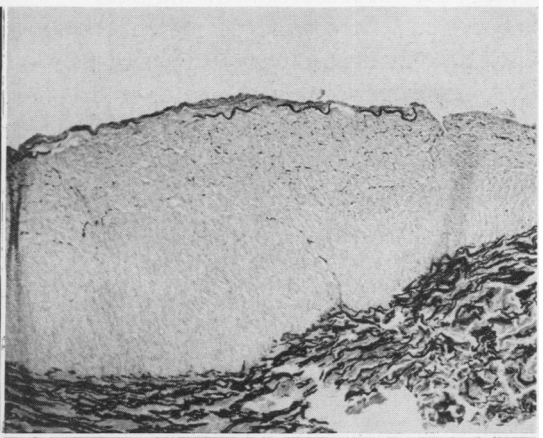


FIG. 6



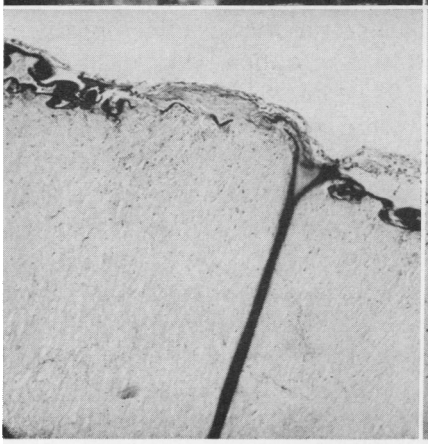


FIG. 7

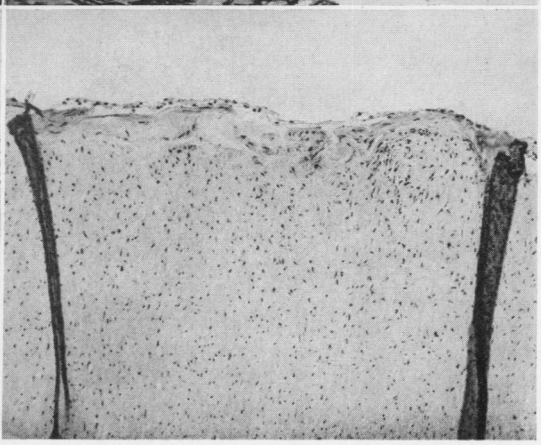


FIG. 8

FIG. 5. The approach used for a femoral artery lesion. An anastomosis was performed. Note the initial wound in the lower right hand corner. This wound was at the upper end of the popliteal fossa.

FIG. 6. Segment of brachial artery removed 3½ hours after injury. Note the extensive areas of internal elastic membrane fragmentation. There is also an intimal tear. Elastic tissue stain.

FIG. 7. Segment of popliteal artery removed 9 hours after injury. The internal elastic membrane is thickened and fragmented. There is also intimal disruption and thrombus formation. Elastic tissue stain.

FIG. 8. Segment of iliac artery removed 10½ hours after injury. In the middle of the section there is an area of media herniated through a small defect in the internal elastic membrane. H. & E. stain.

be proportionately decreased with the multiplicity of wounds in the extremity. Further accessory channels may be damaged with the performance of a complete and adequate débridement. On this basis, it would seem almost mandatory that some type of reparative surgery be instituted to re-establish the major channel, especially in such vital areas as the axillary, iliac, common femoral and popliteal.

Studies on wound ballistics have shown that the damage inflicted by modern military weapons is not confined to the actual path of the missile. At the time of wounding, a large temporary cavity, many times the size of the actual injury, is formed in the tissues. This is not confined by the fascial planes. In this manner, arterial wall damage may occur far beyond that observed by the naked eye. This damage may not be suffi-

cient to cause thrombosis in the areas where injury has resulted from cavitation. It is not inconceivable, however, that thrombosis may occur in arterial injuries associated with multiple wounds of the extremity, where numerous destructive cavities may be formed. In some areas, these cavities may overlap and the cumulative damage on the arterial wall may be sufficient to serve as a nidus for thrombus formation. In this type, failure of a vascular repair is not due to technical factors, but is based on a condition far beyond the control of the surgeon.

Of the 34 major vascular injuries in this series, it was found that only four, or 11.9 per cent, were caused by small arms fire. Artillery, mortar, mine and hand grenade fragments accounted for the remaining 30, or 88.1 per cent. As would be expected from this, over 60 per cent of the patients had more than one wound. The amount of gross soft tissue loss in the wounds associated with the major vascular lesions was compared. Small wounds were found in six, or 17.7 per cent of the cases. Medium-sized wounds were observed in 17, or 50 per cent, and massive wounds in 11, or 32.3 per cent. The condition of the artery observed at operation closely paralleled the magnitude of the wound and will be discussed later.

2. *Location of the Wound.* Results of detailed statistics from World War II have shown that great prognostic value could be placed upon the location of an acute vascular injury. DeBakey and Simeone[4] reported the incidence in the lower extremity to be almost twice that of the upper extremity, with 1561 cases in the former and 892 cases in the latter. Of these cases, 774 (49.6 per cent) in the lower extremity resulted in amputation, while only 214 (24 per cent) in the upper extremity went on to amputation. It was also observed that in the brachial and femoral artery, considerably different results were obtained, depending on whether the lesion was above or below the profunda branch. The incidence of amputation following brachial artery injury below the profunda was 25.8 per cent. This rose to 55.7 per cent when the lesion was above the profunda. Almost as dramatic results were noted in the femoral artery with an amputation incidence of 54.8 per cent in lesions below the profunda and 81.1 per cent in lesions above this branch. When it is considered that the majority of all these vascular lesions were ligated, it is obvious that the collateral circulation must be quite inadequate in areas with the greatest percentage of amputation. Here again one must consider vascular repair, especially in the critical areas, as essential for limb preservation.

It was found that of the 77 vascular injuries reported, 32 (41.5 per cent) occurred in the upper extremity, and 45 (58.5 per cent) occurred in the lower extremity (Chart I). Amputation, following any of the upper extremity lesions, was not necessary, but was performed in eight (17.7 per cent) of the patients with lesions located in the lower extremity. When tabulating the lesions of the major vessels of the lower extremity, three cases (17.6 per cent) came to amputation as compared with 62.1 per cent reported by DeBakey and Simeone.[4] Again in our series there were no amputations following lesions either above or below the brachial profunda artery. In the femoral area, the only amputation performed followed a lesion below the profunda. This represents an incidence of amputation of 12.5 per cent.

It is also of interest that lesions involving so-called minor vessels resulted in amputation in five cases (11.6 per cent) of the 43 cases in that group. The highest percentage followed lesions of the posterior tibial artery, there being three, or 33.3 per cent.

These figures seem to indicate that with the routine utilization of vascular repair in all major arterial injuries, the incidence of amputation can be significantly reduced. In this series, that incidence is even less than

in the minor vessels which were ligated. This is especially significant when it is realized that the entire group of cases were uncontrolled and unselected.

TABLE II. *Type Repair in 35 Vascular Injuries.*

Repair	No. Cases	Per cent
Transverse Suture	3	8.6
Anastomosis	28	80
Vein Graft	4	11.4

3. *Associated Injuries.* It has been mentioned previously that over 60 per cent of this series had other wounds in addition to the vascular disruption. In the majority of cases, however, these associated wounds were noncritical (not acutely life-endangering) and their débridement was delayed until the vascular repair was completed. In a few cases where associated abdominal or chest wounds were present, the vascular repair was still given preference. The average time necessary for repair varied from 15 to 45 minutes, depending upon whether an anastomosis or a graft was necessary. No case was observed in which it was felt that the order of preference adversely affected the ultimate recovery of the patient. The only patients who required immediate surgery, without the benefit of adequate preoperative resuscitation, were those few with uncontrollable hemorrhage and persistent shock, despite massive whole blood replacement by the intra-arterial route. Even in these, the indication for immediate surgery was vascular damage. Certainly all patients in whom treatment could be delayed for resuscitation from one to three hours or more could well afford an additional delay of 30 minutes to permit a vascular repair, and thus perhaps save a limb. More and more, the opinion has been expressed that all surgery should be delayed until adequate resuscitation has been performed and the patient's apprehension concerning his wound and impending surgery allayed. This would give additional support to the premise that vascular repair should be given early priority.

Of the major vascular injuries seen, shock was present to a greater or lesser degree in 52 per cent. Of this group, 16 per cent were in profound vascular collapse and were treated by intra-arterial transfusion. Much credit must be given in this regard to the Battalion Surgeon for his initial resuscitation, many times with whole blood or dextran. Several of the patients with major vascular injury were entirely resuscitated with dextran. In these cases, the erythrocyte count a week after surgery was still less than two million cells per cu. mm. and the hematocrit was in the range of 15 to 20 per cent. In no case did this prevent successful vascular repair or result in loss of a limb, despite the obviously prolonged period of decreased oxygen-carrying power of the circulating blood.

TABLE III. *Comparison Incidence Gangrene in Major and Minor Vascular Injuries.*

Vessels	Total Cases	% Total	Gangrene No. Cases	Gangrene Per cent
Major	34	44.2	3	8.8
Minor	43	55.8	5	11.6

The incidence of fractures and nerve injuries associated with the vascular lesions was also studied. Often a patient arrived at the Mobile Army Surgical Hospital suffering from exposure and profound shock. Both legs and arms were cold and pulseless. It was almost impossible to determine accurately whether a vascular injury was present or whether the condition of the extremity represented a combination of exposure, shock, and/or vascular spasm. In many of these cases, the decision to explore the limb for a vascular injury was at least partially based on the presence or absence of associated fractures and nerve damage.

It was found that in patients with axillary artery injury, associated fractures were present in only 20 per cent as compared with 80

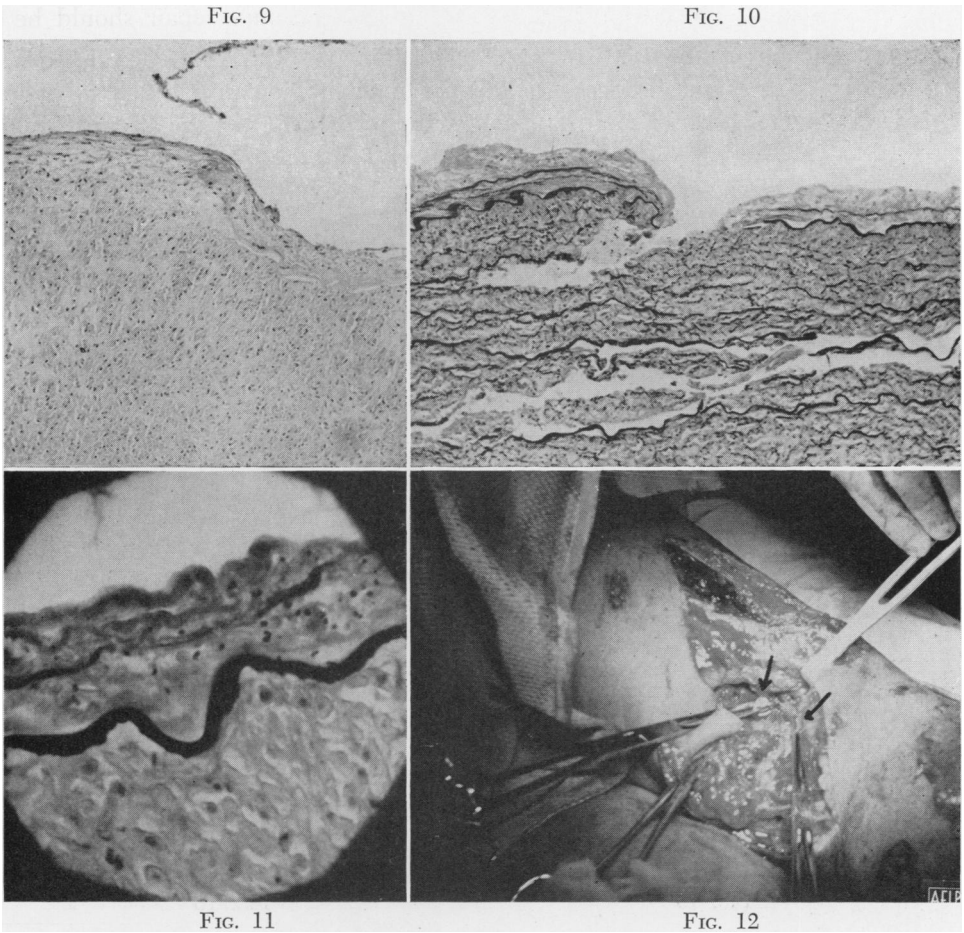


FIG. 9. Segment of common femoral artery removed 8 hours after injury. There is a large defect in the internal elastic membrane with a wart-like protrusion of the media. H. & E. stain.

FIG. 10. Segment of axillary artery removed 5½ hours after injury. Note the tear through the intima and media with the beginning thrombus within the wall of the vessel. Elastic tissue stain.

FIG. 11. Segment of femoral artery removed 9 hours after injury. Observe the numerous blebs along the external surface of the internal elastic membrane. This is indicative of minute injury. Elastic tissue stain.

FIG. 12. A severed popliteal artery. Potts coarctation clamps are seen on the ends of the artery prior to anastomosis.

per cent with nerve damage. In 20 per cent there were combined fractures and nerve injury. This might well be expected when it is recalled that the axillary artery is surrounded by the cords of the *brachial plexus*. Bone and nerve damage, in association with brachial artery injuries, were quite common. The percentage was 63.6 and 81.8 respectively. Combined damage was found in 54.5 per cent. This also might be anticipated, since the artery is not only accompanied by the median and ulnar nerves, but lies in close proximity to the humerus. Of the patients with femoral artery lesions, 44.4 per cent had fractures in the involved limb, while only 11.1 per cent had neuropathy, since the vessel lies close to the femur but quite a distance from the sciatic nerve. Associated fractures were very common in patients with popliteal artery injuries. They

constituted 95.7 per cent of the cases as against only 42.8 per cent with associated nerve damage. Combined lesions of the bone and nerve were found in 28.5 per cent (Chart II).

trast to the results reported by DeBakey and Simeone,[4] no difference was found in the incidence of amputation following arterial repair whether the artery was initially severed, lacerated, or had undergone throm-

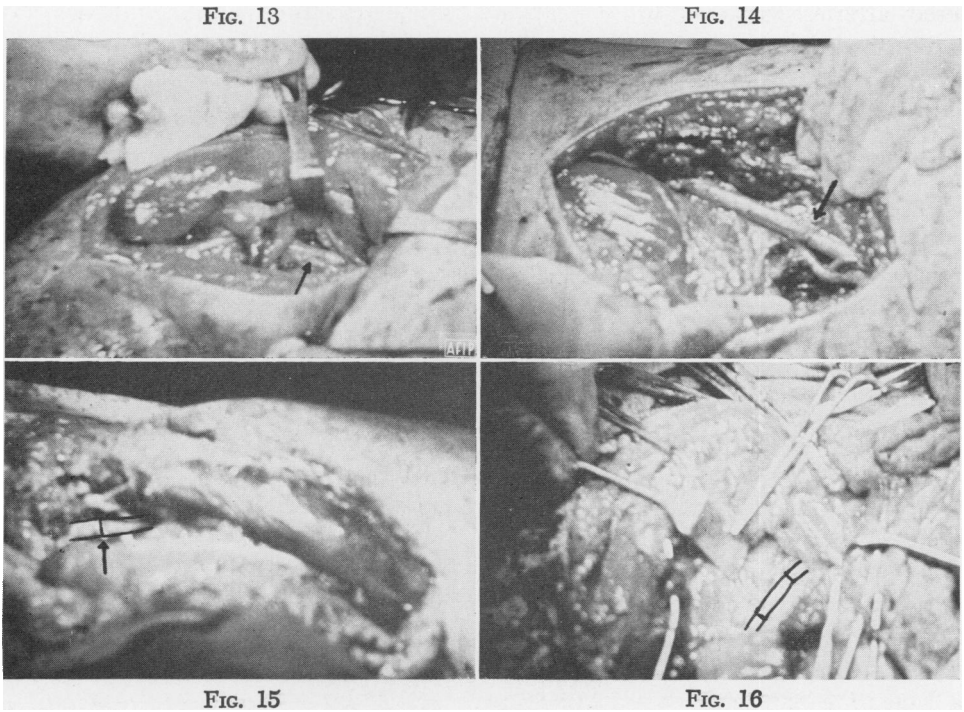


FIG. 13 FIG. 14

FIG. 15 FIG. 16

FIG. 13. The pectoralis major muscle has been divided and retracted. The anastomosis of the axillary artery is seen at the tip of the right angle retractor.

FIG. 14. An anastomosis of the femoral artery just proximal to the adductor canal. The adductor tendon was divided for exposure.

FIG. 15. There is an extensive wound of the popliteal fossa and calf. An anastomosis was performed on the popliteal artery.

FIG. 16. A cephalic vein graft has been inserted in a defect in the axillary artery. The deltoid and pectoralis major muscles are retracted.

It cannot be inferred from these figures that any definite percentage of patients with fractures and nerve damage may have arterial injuries. On the other hand, the presence of bone or nerve injury in certain areas implies a sufficiently high percentage of vascular injury to justify giving surgery a priority, which would lessen the incidence of amputation.

4. *Condition of the Artery.* Care was taken in all cases of major vascular damage to record the condition of the artery observed at the time of the operation. In contbosis. It did make a difference in the type of repair utilized, but not in the final results. The lacerated vessels varied from those with small tears in otherwise intact walls, to those with segmental defects of two inches held together by only strands of adventitia. Whenever any tissue of the arterial wall connected the ends of the vessel, it was considered a laceration. Cleanly severed arteries were noted in only two cases. All others had jagged defects varying from one to five inches in length. Thrombosis of an intact major artery was found at the time of

the operation in only one case. This was a patient with a large popliteal wound.

A study was also made of the condition of the artery at the time of operation as compared with the amount of hemorrhage in the surrounding tissue. As expected, the severed arteries retracted in to the surrounding muscle, then contracted and underwent thrombosis. The lacerated arteries could not retract into the tissue and the formation of large hematomas resulted. Lacerated arteries were found in 12 cases (34.3 per cent). In one case (2.9 per cent) the vessel was intact but thrombosed. Of the patients with lacerated vessels, 83.3 per cent had moderate to severe hemorrhage in the extremity. In 16.7 per cent the hemorrhage was mild. In patients with severed vessels where retraction was possible, 86.3 per cent showed minimal hemorrhage in the extremity, and only 13.7 per cent had moderate to severe hemorrhage (Chart 3).

The degree of hemorrhage in the extremity was also of value in helping to determine which patients had vascular injuries. A large tense hematoma in the limb almost always indicated a vascular injury, usually of a lacerating nature. Figure 1 shows an extremity with a lacerating wound of the brachial artery, with the swelling in the upper arm quite obvious. Arteries which were severed or thrombosed could not be diagnosed by the extent of hemorrhage in the surrounding tissue.

5. *Time-Lag.* Probably one of the important, if not the most important, factors which predetermines the final outcome of vascular injuries is that described as time-lag. This term refers to the time elapsing between the moment of injury and the initiation of surgical treatment. The upper limit which had been used previously was arbitrarily set at six to eight hours. It was felt that treatment of arterial lesions beyond that time would rarely be successful. Thrombosis which probably have occurred in the distal arteries, and changes in the tissue, as a result of the diminished oxygen and nutrition supply, would have been irreversible. This thesis was well borne out in the reports of DeBakey and Simeone[4] and others.[1, 17] The incidence of amputation following arteriol wounds treated within 10 hours was 36.7 per cent. In those treated from within 10 to 20 hours, it was 48.8 per cent. After 20 hours, the incidence of amputation almost doubled, reaching 63 per cent.

Previous reports[4] have indicated that in World War II the time-lag averaged over 12 hours. Half of that was the time consumed between wounding and initial tagging. This portion of time was usually influenced by the tactical situation and was thus beyond the control of the Medical Department. In an attempt to decrease the time-lag, surgical care was brought as close to the front lines as possible. In the Korean conflict, improvement has been made by the use of helicopter evacuation. Even this is limited, since the helicopter can operate only during daylight hours and under favorable weather conditions.

During the period covered by this report, a record was kept of the time-lag in 33 repaired major vascular injuries. A comparison was also made of the time-lag in relation to the incidence of amputation. The time from injury to operation averaged 9.8 hours, a little more than two hours less than the average in World War II. This varied greatly with the tactical situation, the terrain, and the type of fighting.

Table IV shows that the majority of patients were treated between 3 and 12 hours, with the largest single group being treated in from 6 to 9 hours. None of the patients treated within 9 hours required amputation. In the 9 to 12 hour group, 28.5 per cent required amputation, and in the group treated in from 12 to 15 hours, the incidence was 25 per cent. Thus it might be concluded that the best results will be obtained in those patients treated within 9 hours. However, even in the group treated within 9 to

15 hours, at least 75 per cent could be successfully repaired. Two patients operated upon after 15 hours had severed arteries; one received treatment 18 hours after injury, and the other 48 hours after injury. Without doubt these two patients had sufficient collateral circulation to maintain the viability of the limb. By repairing the artery, however, the patients had excellent functional as well as viable limbs.

TABLE IV. *Results in 33 Major Arteries Repaired.*

Vessel	Total Cases	% Total	Treatment			Loss of Limb	
			Anast.	Vein Graft	Transverse Repair	No. Cases	%
Carotid	1	3	1	–	–	–	–
Axillary	5	15.2	4	1	–	–	–
Brachial	10	30.4	9	1	–	–	–
Above Profunda	4	12.2	4	–	–	–	–
Below Profunda	6	18.2	5	1	–	–	–
External Iliac	1	3	1	–	–	–	–
Femoral	9	27.2	6	2	1	1	11.1
Above Profunda	1	3	1	–	–	–	–
Below Profunda	8	24.2	5	2	1	1	12.5
Popliteal	7	21.2	6	–	1	2	28.5
Total	33	100	27	4	2	3	9.1

The inference to be gained from these figures is that time-lag alone is not the basis for the success or failure of vascular repair. Many of the previously mentioned factors must also be considered in the end result.

6. *Use of the Tourniquet.* The tourniquet is probably one of the most valuable life-saving implements available to the soldier, immediately following an injury of a vascular nature. It has been improvised from everything from a shoestring to a strip of the soldier's jacket or pants. In many cases, though poorly applied by inept persons, it has stemmed the flow of blood until more adequate first aid could be given by a trained medical corpsman. Despite its value, however, the use of the tourniquet is fraught with many hidden dangers. There are no statistics available to indicate the influence of the tourniquet on the incidence of amputation following a vascular wound, especially if it is left in place for long periods of time.

Many reports on the use of the tourniquet emphasize its hazards. The syndrome of profound shock following its release is well known, thus it should never be released unless adequate whole blood is available to combat vascular collapse. Intermittent release is also dangerous in that even the small amounts of blood lost at such times are not well tolerated by an already depleted vascular tree. Certainly all would agree that the thesis of "better to lose a limb than a life" is basically sound. Experimental work has shown that a tourniquet can be applied to a limb for as long as eight hours without its resulting in permanent damage.[2, 15] Its value in traumatic amputation is well recognized. However, observations made during the treatment of this series of cases seem to indicate that the use of the tourniquet has some bearing on the results obtained. It could be replaced in the majority of cases by traction to the extremity and the application of a pressure dressing. This was possible even when the blood volume had been restored and the severed ends of the vessel were still open.

Of those patients with major vascular injuries, only eight, or 23.5 per cent, had tourniquets in place at the time of arrival at the

Mobile Army Surgical Hospital. Bleeding was adequately controlled in the manner mentioned above after removal of the tourniquet. It was believed significant that all patients who later required amputation gave histories of prolonged application of the tourniquet.

There is a tendency toward the development of thrombosis in a wounded extremity. Despite the destruction of the major vascular channel, many small collaterals still function. To place a tourniquet on an extremity under these conditions not only occludes the main artery, but also occludes all collateral vessels enroute to the distal limb. These collaterals, it is true, may not be sufficient to nourish the limb, but they at least keep some blood flowing through the vessels and may impede the tendency toward thrombosis. On this basis, the application of a pressure dressing or, when possible, the actual clamping of the involved vessel is recommended as soon as the patient is seen by the first medical officer. This will usually be at the Battalion Aid Station.

METHODS OF TREATMENT

A standard method was used in the treatment of all vascular injuries. Lesions of minor arteries were ligated unless it was obvious that this procedure would result in arterial insufficiency and gangrene. There were 43 cases with minor vessel injury of which 41 were ligated. Repairs were performed on the two posterior tibial artery lesions, one by transverse suture and the other by direct end-to-end suture anastomosis. In both of these cases it was believed that ligation would have been followed by amputation.

All major vascular injuries were repaired without regard to the size of the defect, the length of time between wounding and operation, or to any other factor which could adversely affect the result. Three types of repair were utilized. Transverse suture anastomosis was carried out in three cases, or 8.6 per cent. This was employed only if the defect in the vessel wall was quite small, involving less than 10 per cent of its circumference. The majority of cases, 28 (80 per cent), were repaired by the direct end-to-end suture anastomosis. In the remaining four cases (11.4 per cent), arterial continuity was re-established by autogenous vein grafts (Table II). Arterial homografts were not used, since previous personal experience had indicated that vein grafts were more satisfactory.[5] In addition, no case was seen in which adequate sized veins were not readily available for use.

TECHNIC OF REPAIR

As early as 1907 many of the basic principals of successful vascular repair were thoroughly described by Alexic Carrel.[3] He emphasized the importance of not having any foreign material within the lumen of the vessel at the site of anastomosis, especially strands of adventitia which are most likely to produce thrombosis. He also advised against the use of smooth crushing clamps on the arterial wall because of their tendency to cause intimal damage and again predispose to thrombosis. These facts, recognized many years ago, were firmly adhered to in all the vascular repairs performed.

We wish to emphasize the approach used in the vascular injuries. In all cases the location of the soft tissue wound of the extremity was ignored. Accurate appraisal was made as to the probable location of the vascular injury. The classical approaches described by Henry[12] and by Elkin[8-11] were employed to expose the involved segment of artery. The initial wound was extended if it lay in this course. If not, a separate incision was used for the vascular repair (Fig. 5). This served a threefold purpose. First, it enabled rapid exposure and accurate dissection of the involved artery on both sides of the damaged segment. When such lesions were approached through the initial wound.

FIG. 17

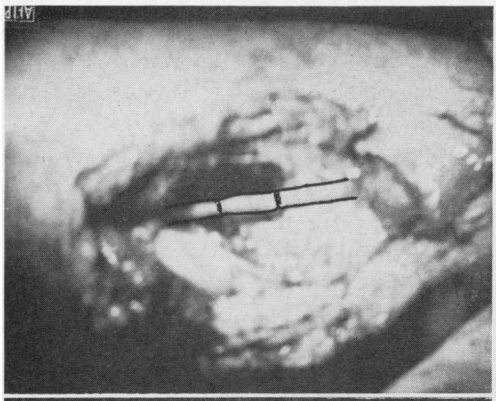
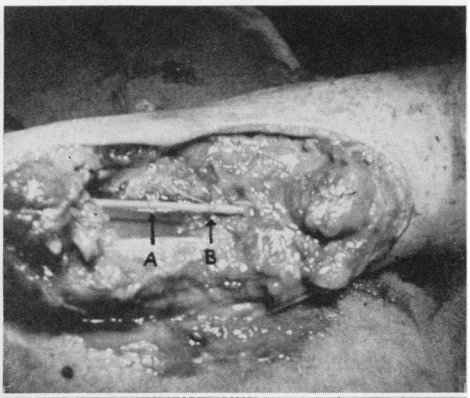


FIG. 18



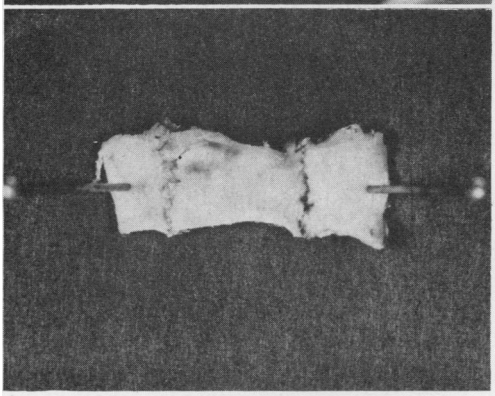


FIG. 19

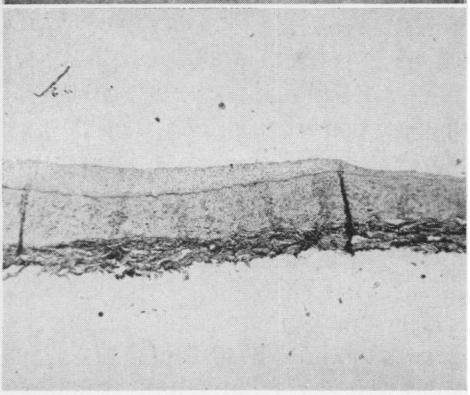


FIG. 20

FIG. 17. A saphenous vein graft has been inserted in a defect in the femoral artery. Remnants of the sartorius muscle are visible at the right.

FIG. 18. A massive wound of the upper extremity. A five inch defect in the brachial artery was repaired with a three inch cephalic vein graft. The upper end of the graft has been tunneled through the remnants of the biceps muscle. The lower suture line is behind the flexor muscle group. A and B are ties on branches on the graft.

FIG. 19. A saphenous vein graft in the femoral artery. Amputation was performed on the eighth postoperative day. The graft was functioning. There were no thromboses at either suture line. See text.

FIG. 20. A photomicrograph of the vein graft in the femoral artery after removal. Note the thickened intima and the intact internal elastic membrane. There was active fibroblastic proliferation. See text.

the extensive damage, loss of normal relationships, extravasation into the tissues, and retraction of the ends of the artery made the operation difficult and time-consuming. Secondly, it permitted initial control of the damaged vessel and prevented extensive hemorrhage during the remainder of the operation. In lesions approached without this preliminary vascular control, hemorrhage was always excessive, impending shock was a continuous threat, and lower nephron nephrosis was a dangerous possibility. Finally, the classical approach to the involved artery gave better exposure and made the suture repair technically easier and more rapid.

One facet of the problem of vascular repair caused much concern. As previously mentioned, the cavitational effect of the initial injury was known to cause damage far beyond the actual tract of the wounding missile. The question arose as to just how extensive this damage was in the involved artery. Certainly it could be assumed to

have extended further than those areas grossly visible. To have repaired a major artery after removing only the grossly damaged segment would have been courting disaster. This may, in part, account for the very poor results of vascular repair reported from World War II as well as from the early days of the Korean conflict. To study this problem, at least one centimeter of apparently normal vessel was excised from each end in addition to removing all grossly injured areas. This technic converted small defects into large ones and made large defects of more frightening size.

Histologic sections were made of the apparently normal vessel removed. These were stained by hematoxylin and eosin and by elastic tissue technics. We were surprised to find that in all specimens, microscopic evidence of damage of various types was found even in the most proximal areas of apparently normal artery. Almost every case showed irregular thickening and fragmentation of the internal elastic membrane with areas of intimal loss and incipient thrombus formation (Fig. 6 and 7). Some areas showed actual herniation of the media through the fragmented areas (Fig. 8 and 9). Occasionally there were complete tears into the media with thrombosis in the wall of the vessel (Fig. 10). Closer examination often revealed bleb formations on the external surface of the internal elastic membrane, an even more minute indication of injury (Fig. 11). Though microscopic in nature, this was indisputable evidence of damage far beyond the actual site of injury.

Just how much of this damage could have resulted in thrombosis is difficult to estimate. It can be assumed that damage was present in the vessel at the site of repair and probably for an unknown distance proximally and distally. From the results obtained, this apparently did not cause thrombosis. Many of the areas examined under the microscope showed definite evidence of incipient thrombosis which probably would have caused the vascular repair to fail had they not been excised. This was obviously an important part of the technic of surgery, namely, the excision of a segment of apparently normal vessel from each end of the injured artery. We had arbitrarily set this at one centimeter. Future work may require revision of this figure. It is, of necessity, a phase of the over-all problem which deserves much basic study.

After débridement of the artery had been performed, it was apparent that simple anastomosis *per se* was impossible. Yet anastomosis was preferred over the vein graft, since it was felt that there was less chance of thrombosis if only one suture line was present. Therefore, the decision was made to sacrifice obvious important collateral branches and to strip the artery of adventitia for long distances, both proximally and distally, if this would permit end-to-end apposition. Some vessels were stripped for distances up to ten inches. Care was taken to ligate all branches flush with the main channel to avoid possible thrombosis in those areas. Partial flexion of the extremity was also utilized for relaxation of the vessel. Elbow joints were flexed to a 90 degree angle and knee joints to a 135 degree angle. In this manner, only four cases were encountered where the final defect had to be bridged by a vein graft.

Potts coarctation clamps were placed on the cut ends of the artery to control the blood flow. The interdigitating-toothed blades of the clamps caused no intimal damage, and thus the possibility of later thrombosis was decreased. The clamps also allowed moderate traction to be exerted on the vessel which permitted easier apposition (Fig. 12).

The anastomosis was performed by first bisecting the vessel with two interrupted everting mattress sutures. An intima to intima repair was then completed, using a continuous everting mattress suture of 00000 arterial silk. Leaks at the suture line were

controlled by gauze pressure for several minutes or by a simple through and through suture.

Care was always taken to completely cover the line of anastomosis with muscle or fascia. This covering tissue was never tightly closed. In most areas, the natural elasticity of the tissue and the pressure of the sterile dressing were sufficient to attain satisfactory coverage. Figures 13, 14 and 15 show some of the anastomoses performed in extensive lesions.

The technic employed when inserting a vein graft was essentially the same except that two suture lines were necessary. In addition, the direction of the graft was reversed so that any valves present would not interfere with the arterial blood flow. All grafts were taken from the cephalic or saphenous veins, since the walls of these vessels were much thicker than those of the concomitant veins. Of necessity, lesions requiring grafts were more extensive than those in which anastomoses were done. In spite of this, it was always possible to completely cover the graft with viable muscle tissue (Figs. 16 and 17).

The greatest problem arose in the instance of a five-inch defect in a brachial artery (Fig. 18). A three-inch graft from the cephalic vein of the same arm was inserted. Because of extensive tissue destruction, the entire graft was exposed. Coverage and support were obtained by tunneling the upper part of the graft through the remnants of the biceps muscle. The flexor group of muscles of the forearm were then freed and rotated to cover the lower part of the graft, with the elbow flexed to approximately 90 degrees.

Not a single case was seen in which it was felt impractical or impossible to carry out vascular repair or to cover that repair when completed.

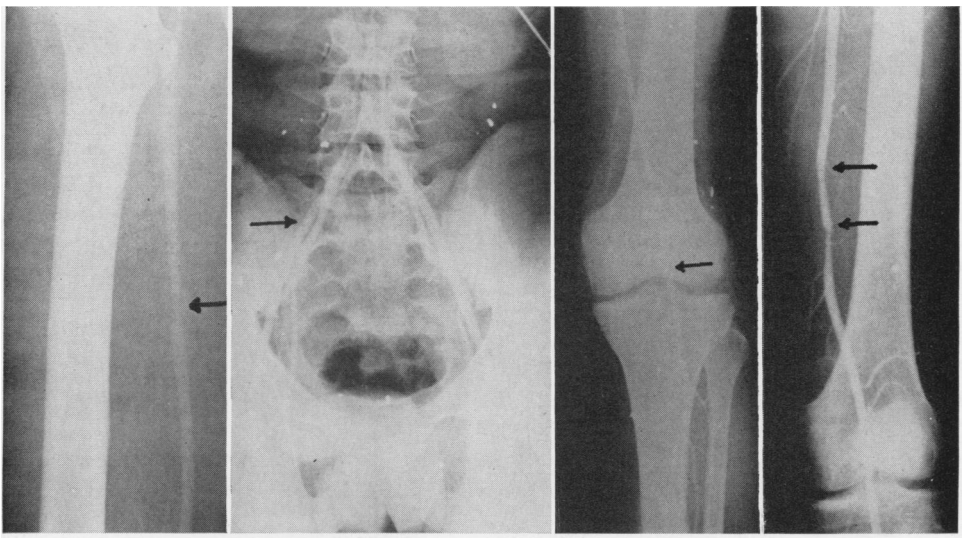


FIG. 21 FIG. 22 FIG. 23 FIG. 24

FIG. 21. Arteriogram of an anastomosis of the femoral artery. Note the slight constriction at the suture line.

FIG. 22. An aortogram of an anastomosis of the external iliac artery about two centimeters below the internal iliac branch. No constriction was seen at the suture line.

FIG. 23. An arteriogram of a popliteal anastomosis. There was no constriction at the suture line.

FIG. 24. An arteriogram of a vein graft in the femoral artery. Note the conical area of constriction in the artery distal to the lower suture line. See text.

RESULTS OF TREATMENT

Of the 43 minor vascular injuries treated, gangrene, requiring amputation, occurred in five patients, or 11.6 per cent. At the time of amputation there was evidence of thrombosis in the remaining vessels of the limbs. This was particularly interesting in a patient in whom the *profunda femoral* artery was ligated. The main femoral channel was observed at the time of débridement and was found to be grossly normal. Within 24 hours it was obvious that the limb would not survive. At the time of amputation, the femoral artery was found to be thrombosed. This was not an unusual situation. A report from the 406 Medical General Laboratory showed that in 30 per cent of a group of limbs amputated following vascular insufficiency, thrombosis of the apparently uninjured vessel was found. These cases might have represented microscopic injury as previously indicated. Gangrene might also have been the result of persistent vascular spasm or a combination of spasm and microscopic arterial injury. No investigations have been carried out to evaluate sympathectomy or anticoagulant therapy in such cases. It would be most difficult to decide which cases would be candidates for this type of therapy until thrombosis actually occurred. However, one might expect a higher incidence of thrombosis in patients with multiple wounds of the extremity.

The two cases in which the posterior tibial artery was repaired resulted in amputation. In both, the anastomoses were functioning when the limbs were removed. In one case the absorption of toxic products from the limb was the basis of amputation. In the other patient, the limb was viable, but the extensive bone, nerve and soft tissue loss made it useless and a midcalf amputation was done approximately three weeks after the initial injury.

Reports from World War II, and the results of this series, would seem to indicate that little improvement can be expected in the treatment of minor vascular injuries. Ligation continues to remain the treatment of choice. In very selected cases, repair of the posterior tibial artery may be indicated, since the anterior tibial and the peroneal arteries are relatively small and much may depend upon continuity of the posterior tibial.

The results obtained in the 34 major vascular injuries treated were far more encouraging, with an amputation rate of but 8.8 per cent (three cases, Table III). Thirty-three arteries were repaired by the methods previously described. One brachial artery, severed just above the elbow, was ligated. The retrograde flow was equal to that of the proximal segment and there was no advantage in repair.

We were impressed that of the 77 cases treated, the incidence of amputation was actually higher in those cases in which minor vessels were ligated than in those where major vessels were repaired. We have no definite explanation for this most unusual result. Possibly, if the basis of amputation in the minor vascular lesions was thrombosis, this factor may have been of less significance in the major vascular lesions. It has been shown experimentally that thrombosis is more prone to occur in injury to the smaller arteries. This factor, together with the unusually high incidence of successful repairs, may in part account for this reversal of the expected ratio.

Two of seven patients with popliteal artery repairs, or 28.5 per cent, later required amputation of the involved limb. One patient with a vein graft in the femoral artery, among a total of nine patients repaired in this location, required amputation. This was an incidence of 11.1 per cent. In the remaining 30 patients with major vascular repairs, no limbs were lost (Table IV).

There was only one known thrombosis at the suture line. This occurred in a patient who had both the femoral and popliteal ar-

teries severed in the same limb. On admission, he was in profound shock and had had a tourniquet on the involved limb for over six hours. Only the femoral artery injury was recognized initially. At the time of operation, which was 10 hours after injury, an end-to-end anastomosis was performed in the femoral area. A total of two inches of femoral artery was excised. During débridement of the other wounds of the leg, the severed popliteal artery was recognized. Because of the large segment of artery excised in the femoral area, only grossly damaged vessel was removed in the popliteal area so that an anastomosis could be performed. Postoperatively, the patient had a good posterior tibial pulse at the ankle on the involved side. He developed a lower nephron syndrome which was successfully treated by two "runs" on the artificial kidney. On the fourth postoperative day, however, it was obvious that the limb was necrotic. At the time of amputation, the popliteal anastomosis was occluded. The femoral anastomosis was found to be patent.

FIG. 25

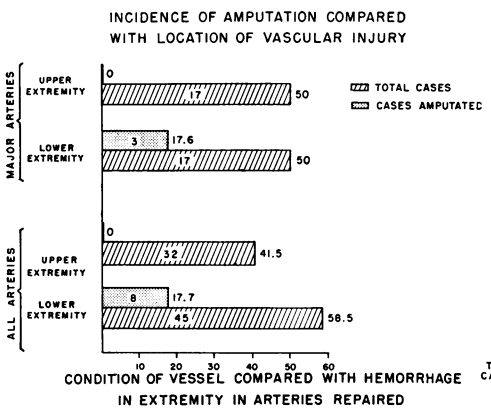
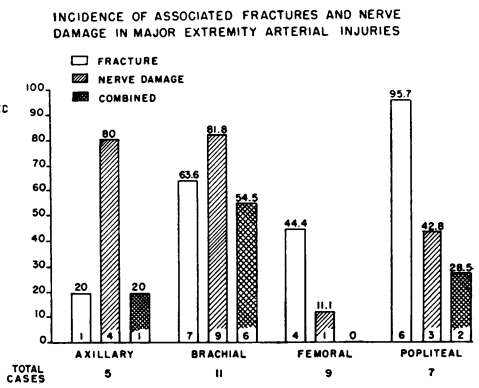


FIG. 27

FIG. 26



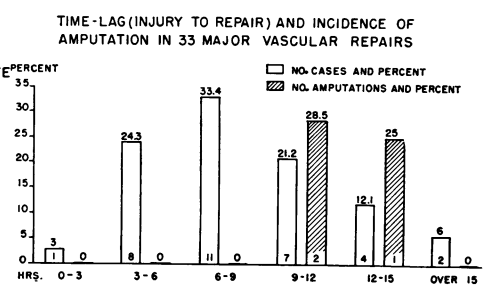


FIG. 28

Many factors were present which could have accounted for this thrombosis. The fact that there were two lesions in the same limb, of which only one failed, permitted us to use the successful femoral repair as a control. On this basis, the one outstanding difference in treatment was the lack of excision of a cuff of relatively normal artery in the popliteal region. In retrospect, we would have excised a cuff and inserted a vein graft. This case helped to confirm our impression that a generous segment of vessel must be removed prior to repair. The profound shock, the time-lag of 10 hours, and the lower nephron syndrome were also

complicating factors which could have resulted in failure. We felt they could be discounted, since they had no apparent effect on the femoral repair.

A most unusual situation was encountered in the two remaining cases of a vein graft of the femoral artery and a popliteal anastomosis which terminated in amputation. Both had had tourniquets applied to the limb for long periods of time. Both had some degree of vascular collapse which was rapidly overcome with whole blood transfusions. The time-lag in the former was 10 hours, and in the latter, 14 hours. Following operation, the limbs which had been cold, firm and pulseless, became warm, and good arterial pulsations were felt at the ankle. It was expected at the time that both limbs would survive.

The patient with the popliteal anastomosis developed dry gangrene of the tips of the second, third and fourth toes. This did not progress. On the fourteenth postoperative day, because of some beginning signs of toxicity, it was decided that an exploration of the wound be made and the toes amputated. At that time the patient still had excellent arterial pulsations at the ankle. On exploration, it was obvious that the muscles of the leg were nonviable. However, on cutting across the calf muscles, normally pulsating arterial blood flowed from all the major arteries and the large arterioles. The anastomosis was still functioning and was, therefore, left in the limb. Amputation was performed below the knee.

The patient with the vein graft in the femoral artery showed an almost identical picture. He was re-explored on the eighth postoperative day for early signs of toxicity. Dry gangrene was observed on the tips of the great and second toes. Again good arterial pulsations were present at the ankle, and during operation arterial blood pulsated from all the major arteries of the leg and from the large arterioles. A supracondylar amputation was performed and the vein graft was removed for examination. There was no evidence of thrombosis at the suture lines (Fig. 19). Microscopic sections of the graft revealed the usual extensive intimal proliferation and active fibroblastic growth. There was also active connective tissue growth in the media, and the internal elastic membrane was intact (Fig. 20).

We believe these two failures were due to probable thrombosis of the small arterioles and capillaries in the muscle which prevented the oxygenated blood from reaching the tissue cells where it was needed. Possibly the long period of initial anoxemia and ischemia, before the blood flow was restored, caused the irreversible changes in the tissues and smaller vessels of the limb.

We feel it is important to emphasize that in both cases the vascular repairs were successful and functioning. Probably these patients, had they been treated earlier, would have maintained a viable limb. These cases are also important in that they demonstrate the interplay of the many factors referred to above, which help determine the ultimate results of treatment.

It was obvious that some of the major vascular lesions which were repaired could have been ligated without fear of subsequent gangrene and amputation. Based on past reports, we felt that utilization of reparative surgery in all major vascular lesions would not only decrease the incidence of amputation, but, of more importance, would result in a high degree of functional, as well as viable, extremities.

LATE FOLLOW-UP

It has been possible to obtain late follow-up studies on 18 of the 33 major vascular injuries repaired. Patients who had no associated bone or nerve damage were returned to military duty, having never left the Theater of Operation. This in itself was evidence of the excellent functional results obtained by arterial repair. Fourteen of 42.4

per cent of the patients with major vascular repairs were returned to the Zone of the Interior and Walter Reed Army Medical Center because of associated injuries. Complete vascular surveys were made on this group.

Excellent peripheral arterial pulsations were present in all but two patients. Both of these had brachial artery anastomoses. Even in these patients the pulses were present, but weak. One was explored because of median nerve damage and the anastomosis was seen and known to be functioning though moderately constricted. The other patient was being treated for hepatitis, thus delaying further study.

Skin temperature studies and oscillometric studies have been done and have consistently shown readings on the repaired limb equal to those on the normal side. The only exceptions were in the cases of the two brachial repairs. Here the readings were depressed. Functionally, there has been no evidence of arterial insufficiency.

Probably the most important and convincing evidence of patency of the repair is an arteriogram. Whenever possible, this procedure has been done. Three patients, on whom neurolyses were performed and the anastomoses were found to be functioning, were not subjected to the further discomfort of an arteriogram. In all patients in whom this procedure was carried out, the repairs were observed to be patent. Slight constriction was noted at the suture line in some cases (Fig. 21). This has been observed in all our experience with arterial repairs. In other cases it was impossible to see the actual suture (Fig. 22 and 23). A conical type of constriction was noted in a femoral artery just distal to a vein graft, but this apparently did not interfere with its function (Fig. 24). It may have resulted from scar tissue formation, but it is more likely due to tension or constriction at the distal suture line, a technical fault which could have been avoided.

Of the group of foreign patients with major vascular repairs, which constituted only a small percentage of the entire group, follow-up has been by correspondence. There have been no losses of limbs or complaints of symptoms which could be considered due to arterial insufficiency. Excellent palpable distal pulses have been described in all limbs.

It is possible that these vascular repairs may become occluded at some later date. Based on previous extensive experience with anastomoses and grafts, we do not feel that this will occur. But should it happen, the patient will certainly not lose a limb. The follow-up in this series has been only four to seven months. We firmly believe that the repair of the acute vascular injury is of unquestionable value and should be carried out in all cases of major arterial damage.

SUMMARY

This is a report on the treatment and results obtained in 77 consecutive acute vascular lesions occurring in war wounds in Korea. Many of the factors influencing the results obtained are discussed in relation to this group of cases. Forty-three minor vascular injuries were treated by simple ligation of the artery. Amputation of the involved limb was later necessary in five patients, or 11.6 per cent. Thirty-four major vascular lesions were repaired by direct end-to-end suture anastomosis or autogenous vein graft. Amputation was later necessary in only three (8.8 per cent) of the patients in this group. Repair is recommended in all cases of acute major arterial injury if the incidence of amputation is to be decreased, and if a functional as well as viable limb is to be obtained.

ACKNOWLEDGMENT

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phase of vascular research. Appreciation is also extended to Major General William E. Shambora, U.S.A. M.C., Surgeon, Far East Command; Brigadier General James P. Cooney, U.S.A., M.C., Surgeon, Japan Logistical Command; Brigadier General L. Holmes Ginn, Jr., U.S.A., M.C., Surgeon, Eighth United States Army in Korea; Colonel Richard P. Mason, U.S.A., M.C., Commanding Officer, 406 General Medical Laboratory, and Captain John M. Howard, A.U.S., M.C., heading the Surgical Research Unit in Korea, for their great interest and invaluable assistance, without which the work covered by this report could not have been done. Finally, acknowledgment is made of the Commanding Officer and the Staff of the Mobile Army Surgical Hospital, 8055 Army Unit in Korea, who assisted in all of the vascular repairs.

BIBLIOGRAPHY

[1] Bradford, B., Jr.: Vascular Injuries in War. Surg., Gynec. & Obst., **83**: 667, 1946.

[2] Campbell, D.: Walter Reed Army Medical Center, Washington 12, D. C. Unpublished Data.

[3] Carrel, A.: The Surgery of Blood Vessels. Johns Hopkins Hosp. Bul., **18**: 18, 1907.

[4] DeBakey, M. E., and F. A. Simeone: Battle Injuries of the Arteries in World War II. Ann. Surg., **123**: 534, 1946.

[5] Cooke, F. N., C. W. Hughes, E. J. Jahnke, Jr., and S. F. Seeley: Homologous Arterial Grafts and Autogenous Vein Grafts Used to Bridge Large Arterial Defects in Man. Presented at the Society for Vascular Surgery, Chicago, June 8, 1952.

[6] Elkin, D. C.: Vascular Injuries of Warfare. Ann. Surg., **120**: 284, 1944.

[7] ———: The Treatment of Aneurysms and Arteriovenous Fistulas. Bull. New York Acad. Med., **22**: 81, 1946.

[8] ———: Arteriovenous Aneurysms. J. A. M. A., **129**: 26, 1945.

[9] Elkin, D. C., and F. W. Cooper, Jr.: Resection of the Clavicle in Vascular Surgery. J. Bone & Joint Surg., **28**: 117, 1946.

[10] Elkin, D. C., and M. H. Harris: Arteriovenous Aneurysm of the Vertebral Vessels. Ann. Surg., **124**: 934, 1946.

[11] Elkin, D. C., and R. P. Kelly: Arteriovenous Aneurysm. Ann. Surg., **122**: 529, 1945.

[12] Henry, A. K.: Extensile Exposure Applied to Limb Surgery. Baltimore, 1945, Williams and Wilkins Co.

[13] Howell, W. H.: Mobile Army Surgical Hospital, 8055 Army Unit. Personal Communication.

[14] Makins, G. W.: Gunshot Injuries to the Blood Vessels. Bristol, 1919, John Wright and Sons, Ltd.

[15] Miller, H. H., and C. S. Welch: Quantitative Studies of the Time Factor in Arterial Injuries. Ann. Surg., **130**: 428, 1949.

[16] Odom, C. B.: Causes of Amputation in Battle Casualties With Emphasis on Vascular Injuries. Surgery, **12**: 488, 1942.

[17] Rose, C. A., O. W. Hess and C. S. Welch: Injuries of the Extremities in Battle Casualties. Ann. Surg., **123**: 161, 1946.

[18] Russell, J. P.: Secondary Hemorrhage in War Wounds. Symposium on Military Medicine in the Far East Command. September, 1951.

[19] Seeley, S. F., C. W. Hughes and E. J. Jahnke, Jr.: Direct Anastomosis Versus Ligation in Traumatic Arteriovenous Fistulas and Aneurysms. Surgical Forum, American College of Surgeans, New York City, September 23, 1952.

[20] Seeley, S. F., C. W. Hughes, F. N. Cooke and D. C. Elkin: Traumatic Arteriovenous Fistulas and Aneurysms in War Wounded. Am. J. Surg., **83**: 471, 1952.

[21] Seeley, S. F., C. W. Hughes and E. J. Jahnke, Jr.: Unpublished Data.

[22] Shumacher, H. B., Jr., and K. L. Carter: Arteriovenous Fistulas and Arterial Aneurysms in Military Personnel. Surgery, **20**: 9, 1946.

[23] Simeone, F. A.: Notes on Treatment of Wounds of the Arteries. Symposium on Military Medicine in the Far East Command. September, 1951.

[24] Smith, M. K.: Arterial Injuries. Ann. Surg., **126**: 866, 1947.

[25] Steward, C. F.: War Experiences with the Nonsuture Technic of Anastomosis in Primary Arterial Injuries. Ann. Surg., **125**: 157, 1947.

[26] Warren, R.: Report to the Surgeon General, Department of the Army. Washington 25, D. C., April, 1952.