Arterial Repair During the Korean War *

CARL W. HUGHES, LT. COLONEL, MC, U. S. A.**

From the Division of Surgery, Walter Reed Army Institute of Research, Walter Reed Army Medical Center, Washington 12, D. C.

PROBABLY the most important advances made in surgery as a result of the Korean War were those made in the repair of acute arterial injuries. Because of the dramatic results achieved in this field, some investigators have published their results independently and also combined with others, so that there has been duplication of reporting of the same cases in the literature. This paper represents an attempt to eliminate the duplication and to compile an accurate statistical study of all major vascular injuries reported in the literature from the Korean War. This study has been undertaken with the cooperation of the individual investigators with whom the author has communicated in order to tabulate accurately these important data.

Few data are available on the results of vascular injuries before April 1952. Prior to this date, ligation of major arteries following injury was generally practiced. While no data have been compiled by the author on the rate of amputation from ligations early in the war, it is expected that the amputation rate must have been similar to that reported by DeBakey and Simeone [2] from World War II.

One of the earliest groups of cases in which repairs were attempted in Korea consisted of 18 cases of traumatic transections of low femoral and popliteal arteries.[12] Of these 18 cases, the authors reported only four with satisfactory results. At the time of evacuation, three had palpable pulses at the ankle and the fourth had a warm, viable foot without a pulse. Two of the group were evacuated during offensive actions; therefore, their outcome was unknown. These patients were operated upon under adverse circumstances and without the benefit of proper vascular instruments which were later employed in the theatre. Two of the 12 known failures in this group were repaired with the use of vein grafts.

Dr. Richard Warren,[13] visiting the theatre as a consultant to the Surgeon General early in 1952, talked with a number of surgeons who reported the approximate numbers of vascular repairs attempted. At one hospital approximately 40 vascular repairs were said to have been attempted of which 11 were considered as successful. Considerable use had been made of lumbar sympathetic blocks and, occasionally, of sympathectomy. Other instances of attempted repairs were reported, but none of these have been published.

Since April 1952, when the repair of acute vascular injuries became an active study of the members of the Surgical Research Team,[1] five major reports of blood vessel repairs have been published.[3, 5, 8, 9, 11] Some of these, authored and co-authored by the same individuals, have resulted in duplication of reporting.[5, 6, 7, 8, 9] These reports, which represent work of individual investigators between the period of April 1952 to the end of the war in 1953, also contain data on injuries of minor arteries, and major veins. In analyzing these reports,

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** Now at Tripler U. S. Army Hospital APO 438, San Francisco, California.

it is found that 304 major vessel injuries were actually treated. Of the total number of arteries treated, 269 were repaired and 35 were ligated. Major arteries are here defined as the carotid, subclavian, axillary, brachial, iliac, femoral, and popliteal.

In addition to the five preliminary reports listed [3, 5, 8, 9, 11] two other major reports have been published as follow up studies.[4, 14] These should not be confused with the initial reports when totaling the number of vascular injuries repaired. In the first of these follow up studies, Ziperman [14] reported 169 major vascular injuries treated in Korea during the first nine months of 1952, of which 127 arteries were repaired and 42 ligated. The second follow up study was published by the author,[4] who reported 211 major vascular cases treated in Army hospitals the first six months of 1953. When all the cases reported as follow up studies by Ziperman and the author are combined, it may appear that considerable discrepancy exists between the total number of follow up cases and total cases reported as initial studies. No such discrepancy exists. The additional number reported in the follow up studies represents cases repaired by individuals at various hospitals which were included in the follow up studies, but which were never reported initially.

An analysis of the five initial reports [3, 5, 8, 9, 11] shows that the major vessel surgery was done under more or less comparable conditions. One variation was the nonavailability of the Potts-type vascular clamps to Spencer and Grewe [11] until later in their series. This probably accounts for their increased usage of vascular grafts and, in turn, a slightly higher limb mortality.

Amputation rates were reported from seven to 22 per cent following primary repair. The time lag from injury to surgery averaged about 9.2 hours. There was general agreement that while the results were generally better in vessels repaired within ten hours after injury, no specific time could be set beyond which an arterial repair should not be considered.

Preoperative Care

Patients with major blood vessel injuries received a priority for evacuation. Evacuation time of these patients to the hospital averaged four to six hours. An additional six hours was usually spent in preparing these patients for surgery. Resuscitation was often a problem since major blood vessel injury more often than not resulted in severe blood loss. The time lost during resuscitation sometimes militated against recovery of the limb. This is a reflection of the severity of the injury and shock in such patients. The need for adequate amounts of blood and complete resuscitation in such individuals is stressed. It is pointed out that rushing the improperly resuscitated patient to surgery in an attempt to save a limb may possibly result in loss of life.

Operative Care

General anesthesia was most often used, but spinal anesthesia and brachial plexus block anesthesia was used in some instances. With a tourniquet in place whenever possible, an anatomic incision was made over the damaged artery, the artery exposed, and controlled. Most repairs were done with 5–0 arterial silk using a continuous everting type suture. Lateral or transverse suture repairs were done when minimal debridement was required and when the vessel diameter was not narrowed to any degree. Extensively lacerated or severed vessels were debrided and, whenever possible, the ends approximated. Extensive mobilization of the vessel was practiced by one investigator [9] while others used grafts when a simple anastomosis was not possible.

After completion of the arterial repair, the soft tissue wound was thoroughly debrided and the repaired artery covered with

TABLE 1. *Methods of Treatment*

Artery	Obliterative	Reparative Surgery				Other		Total
	Ligation	Anastomosis	Vein Graft	Artery Graft	Transverse Suture	Conservative Care	Release Spasm	
Carotid	2	1	1	—	2	5	—	11
Subclavian	1	—	1	1	—	—	—	3
Axillary	5	9	3	2	1	—	—	20
Brachial	9	59	9	4	8	—	—	89
Iliac	—	4	1	1	1	—	—	7
Femoral	7	35	13	22	16	—	2	95
Popliteal	11	37	6	18	7	—	—	79
Total	35	145	34	48	35	5	2	304

muscle or adipose tissue. It was found that fascia was not adequate coverage for protection and nutrition of the vessel. After coverage of the repaired vessel, the remainder of the wound was left open for delayed closure in approximately four to six days. Fasciotomies were done in the arm and leg as indicated for swelling and the importance of these fasciotomies is stressed. Injured major nerves and tendons were debrided without repair.

Limbs with arterial injuries and associated fractures were found to have a poorer prognosis. Arterial injuries complicated by fractures, especially of the popliteal area, in the past have often been an indication for amputation. Such fractures are usually accompanied by severe soft tissue damage with widespread destruction of the collateral circulation which decreases the time interval in which a successful arterial repair can be accomplished. Other fractures have been reported to slip and compress or lacerate the repaired artery.

Postoperative Care

Following surgery, variable degrees of immobilization were utilized by some, while others encouraged limited active and passive motion. It is stated, however, that when arterial repair is done in the presence of a fracture and a cast is applied, the cast should be bi-valved to permit access to the bleeding point should hemorrhage occur. In some instances, bounding pulses appeared almost immediately following repair. In others, although adequate capillary flow was present, the return of pulses was sometimes delayed three to four hours, possibly because of spasm. In instances where adequate arterial flow was in doubt following satisfactory arterial repair, sympathetic blocks were practiced as indicated.

Results

An overall tabulation of the vessels treated is presented in Table 1. The percentage distribution of injuries is not unlike that reported by DeBakey and Simeone [2] from World War II. In order to analyze the results of treatment shown in Table 1, the vessels are grouped and discussed according to the method of treatment.

Treatment

Ligation. Most of the vessels treated by ligation were reported by Inui, Shannon and Howard.[5] These vessels were treated prior to beginning their study of reparative surgery. Although this group of ligated vessels is quite small by comparison, the overall amputation rate following ligation (Table 2) is almost identical to that reported by DeBakey and Simeone. The percentage

TABLE 2. *Incidence of Gangrene Following Ligation*

Artery	Ligated	Amputated	Per Cent
Carotid	2	—	
Subclavian	1	1	
Axillary	5	1	20.0
Brachial	9	3	33.3
Femoral	7	5	71.4
Popliteal	11	8	72.7
Total	35	18	51.4

TABLE 3. *Evaluation of Methods of Repair*

Method	Treated	Amputated	Per Cent
Anastomosis	145	13	9.0
Vein graft	34	4	11.8
Artery graft	48	16	33.3
Transverse suture	35	1	2.9
Conservative care	5	—	
Release spasm	2	1	50.0
Total	269	35	13.0

amputation rate of the individual vessels is also quite comparable to the group reported from World War II.

There are indications for ligation of major vessels in certain instances. When the condition of a patient will not tolerate the additional time required for reparative vascular surgery, ligation is indicated. In instances where the soft tissue loss is so great that coverage of the repaired artery or graft is not practical, ligation is also probably indicated.

Back bleeding from the end of a distal artery has not been found to be an infallible criteria as to whether or not an extremity will survive following ligation. Even though ligation of the damaged artery becomes indicated, ligation of the concomitant vein should not be practiced.

Anastomosis. Omitting from Table 1 the 35 cases treated by obliterative technic, there remain 269 cases treated by reparative surgery. Over half of these, 145, were treated by direct anastomosis. The percentages shown in Table 3 verify the statements that a direct anastomosis is the preferred type of repair of a severed blood vessel. It is obviously desirable to suture the patient's own vessel end to end rather than to insert a graft. However, if after adequate debridement of a severed vessel the ends cannot be brought together without undue tension, a graft should be inserted rather than sacrifice important branches and collaterals.

Vein Graft. In this series, 34 autogenous vein grafts were inserted with only four resulting in amputations, a percentage of 11.8 per cent (Table 3). This technic gave the second best results for repair of a severed vessel. The veins most often used for grafts were cephalic and saphenous. When vein grafts were used, they were turned end for end to prevent the valves from obstructing the blood flow. Some prefer the use of vein grafts because they are autogenous and always available to the patient; however, the position of the patient at times during surgery may make procurement of the vein difficult.

Artery Graft. The third method of repairing severed arteries was by the use of homologous artery grafts. Forty-eight such grafts were inserted into various vessels as shown in Table 1. Thirty-three per cent of these repairs resulted in amputation (Table 3). These artery grafts were secured on the battlefield, preserved in a nutrient solution, and kept in a blood bank refrigerator. Some preferred the use of artery grafts because of their availability and because they are easier to insert than vein grafts. The artery homograft, however, does not remain viable and furnishes only a collagenous framework, while the autogenous vein graft maintains a degree of cellular viability.

Transverse Repair. Table 3 shows 35 vessels treated by transverse repair with only one amputation. It would appear that

this is the ideal method for treating blood vessel injuries, but it must be remembered that many of the injuries repaired by this method were minimal lacerations requiring only one or two sutures. The soft tissue wound associated with a lacerated wound of the vessel, which can be repaired by a transverse suture, is usually not comparable to the soft tissue destruction asssociated with a completely severed vessel which must be repaired either by anastomosis or grafting. The results in the group of vessels repaired by transverse suture, therefore, cannot be compared with the results in those vessels repaired by anastomosis, vein graft or artery graft.

Conservative Care. Only five vessels are reported treated by this method (Table 1). This method of treatment was applied to carotid artery injuries when a pulsating hematoma or an arteriovenous fistula existed without continued hemorrhage or expansion of the hematoma. Such patients received minimal debridement and were observed carefully for hemorrhage, infection, or expansion of the hematoma which might cause respiratory difficulty. After development of a false aneurysm or arteriovenous fistula, definitive surgery was performed at a later date. This method of treating carotid artery injuries was utilized after complications resulted from attempting emergency surgery for these injuries. Inui, Shannon and Howard [5] reported two cases of ligation of the common artery (Table 2), although not showing in Table 2 as complications of ligation, both cases developed hemiparesis. It was also suggested that conservative care might be considered for injuries of the subclavian artery where an arteriovenous fistula is formed or a pulsating hematoma exists. The approach to this artery often involves entering the chest and rather complex surgery which may result in severe hemorrhage or additional infection.

Spasm. While only two cases were shown as operated upon for spasm, it was felt that these were important enough to list, since one resulted in amputation (Table 3). Marked generalized spasm of a vascular tree was not seen as often as might have been expected in Korea. When seen, it was usually treated by sympathetic blocks and in a few instances by sympathectomy. Segmental spasm, more commonly seen, was treated by various methods, but probably the most effective method was the utilization peri-arterially of two and one-half per cent papaverine.[10]

TABLE 4. *Incidence of Gangrene Following Repair*

Artery	Repaired	Amputated	Per Cent
Carotid	9		
Subclavian	2		
Axillary	15	1	6.7
Brachial	80		
Iliac	7	1	14.3
Femoral	88	11	12.5
Popliteal	68	22	32.4
Total	269	35	13.0

A study of the percentage of amputations in specific vessels following repairs, Table 4, is interesting, especially when compared to the amputation rate in those same vessels following ligation (Table 2). The amputation rate is greater in lower extremities both after ligation and repair (Table 2 and 4). The amputation rate of the popliteal artery, 32.4 per cent, is still quite high even following repair. This high amputation rate following repair probably results because the popliteal is a critical artery and, since it is small, is more difficult to repair. The common femoral artery is almost as critical, but is larger and more easily repaired.

Minor Arteries. In the five reports analyzed, 81 minor arteries are reported as treated. These consist primarily of the radial and ulnar, anterior and posterior tibial, the profunda brachii, and the profunda femoral. The majority of these were treated by ligation, but an occasional one was repaired. While it is generally conceded that

one can safely ligate one of the two principal arteries in the forearm or leg, it was suggested that in cases where both of the principal branches were severed, an attempt should be made to repair one of them. Rarely was this practical or successful. In most instances where the two principal branches in an arm or leg were injured, the soft tissue wound was so severe as to make the repair of the arteries impractical. Jahnke and Seeley [9] reported a higher incidence of amputation following treatment of their minor artery injuries than with their major artery injuries.

Vein Injuries. The author [3] noted 63 per cent major vein injuries accompanying major artery injuries. A number of other major vein injuries were treated in which there was no arterial involvement. Most of these vein injuries were treated by ligation, but in some, ligations resulted in various degrees of venostasis. On rare occasion, massive venostasis resulted in amputation of the extremity. To eliminate this complication, two investigators [3, 11] began the repair of major veins. They reported 20 major veins repaired, all by lateral suture except one which was repaired by direct anastomosis. Some of these are known to have thrombosed later without complications. No embolic complications resulted.

Conclusions

These studies demonstrate the practicability of the repair of acute arterial injuries. Stress is placed on the importance of resuscitation and evaluation of the patient for priority of care of all injuries and for the ability of the patient to withstand the additional operating time required for vascular surgery.

The results achieved by the repair of acute arterial injuries in Korea is extremely gratifying. The figure of 13 per cent amputation rate following the suture repair of major arteries in the Korean War speaks for itself when compared with the amputation rate of 36 per cent resulting from such repairs in World War II. The low amputation rate of 13 per cent becomes even more impressive when compared with the 51 per cent amputation rate which resulted from ligation of the major arteries in this series.

It was the general opinion of the investigators that the amputation rate following vascular repair could have been further reduced except for the irreversible ischemic changes which had already taken place as a result of the prolonged time interval between injury and arterial repair. This is probably true since the average time from injury to operation was 9.2 hours and it was noted that the results were generally better in those vessels repaired within ten hours after injury.

Summary

1. A review of the literature shows some duplication of reporting of blood vessel repairs from the Korean War.

2. An analysis of the literature reveals 304 major vessel injuries treated and recorded from April 1952, to the end of the Korean War.

3. Of the 304 major vessels treated, 269 were repaired and 35 ligated.

4. The amputation rate for vessels repaired by suture was 13 per cent as compared to 36 per cent for vessels repaired in this manner during World War II.

5. The overall amputation rate for vessels ligated in the Korean War was 51.4 per cent, quite comparable to the figure quoted from World War II.

6. An evaluation of methods of repair of severed vessels showed best results after anastomosis, next best by autogenous vein graft, and poorest by artery homograft.

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Book Review

REGULATION AND MODE OF ACTION OF THYROID HORMONES, Ciba Foundation Colloquia on Endocrinology, Volume X. Edited by G. E. W. Wolstenholme and Elaine C. P. Millar. Little Brown and Company, 1957, price $8.50, 311 pages.

The title of this colloquium accurately delineates the scope of the topic and discussions it contains. The format consists of article presentations regularly followed by specific discussions, with general discussions interspersed throughout the book. The most recent research and thoughts on the subject are presented by many of the outstanding workers in this field throughout the world. This gives the reader the unique opportunity of knowing the latest work being done, and also of recognizing the differences in perspectives and emphases between the various countries represented.

However, national boundaries have not deviated the presentations from an overwhelming preoccupation with the thyroid's relationship to the pituitary-hypothalamus axis. Some notable variations from this primary theme are exemplified by such studies as: Odette Thibault's article on the Chemical Transformations of Thyroid Hormones which make them peripherally active; J. Roche et al's work on tri-iodothyroacetic acid; and D. A. Long's demonstration of the role of the thyroid in immunity. Almost all the investigations reported are experiments on laboratory animals and are concerned with basic chemical and physiologic factors. Although practical applications are not within the scope of this volume, many fundamental problems such as the mode of action of various anti-thyroid agents or the mechanism by which thyroid substances affect edema, are not covered. Such diversity would have made this book more general and less intricate for the clinician, without diminishing its stimulating intensity for the investigator in this field.

CARL A. SMITH, M.D.