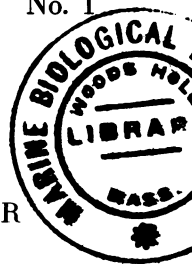


ANNALS OF SURGERY

Vol. 139

JANUARY, 1954

No. 1



ACUTE ARTERIAL INJURIES IN THE KOREAN WAR

A STATISTICAL STUDY*

LT. COL. H. HASKELL ZIPERMAN, M. C., U. S. A., F.A.C.S.

THE SURGERY OF acute arterial injuries has made tremendous advances since World War II. During the last war it was exceptional for an attempt at vascular repair to be made, as witness the fact that of 2,471 acute wounds of the arteries reported by DeBakey and Simeone,¹ only 135 were repaired. Of these, 40 were repaired by non-suture vein graft, 14 by tube anastomosis and 81 by suture repair. Since 1946 when this statistical survey of World War II arterial injuries was published, great strides have been made in the field of vascular surgery and the attention and interest of large numbers of surgeons has been focused upon it. As a result of these factors, plus the development of rapid casualty evacuation by helicopter to surgical hospitals close to the battle line, more acute arterial injuries have been repaired by suture in 9 months of the Korean War than in this World War II sample series.

This survey was conceived as a means of analyzing the results of arterial injuries now rather than waiting for a year or two after the war is over to collect and analyze all available statistics. This is an important consideration in a continuing war where analysis can result in immediate improvement in technics, skills, and other surgical factors as a means of saving life and limb. It is recognized that there are certain shortcomings in the field collection of data needed for such a survey but, within limitations to be mentioned, this has

proved to be a surprisingly accurate analysis of results.

Because of the rapid turn-over of medical personnel in this combat zone, the time limit for this study was set as January 1, 1952 to September 30, 1952, thereby having available for interview those doctors who in most instances had done the major portion of this arterial surgery. All cases were taken from operating room records and were then traced through the evacuation channels to their destination in Japan. It is realized that one shortcoming of this method is that an occasional patient might have developed further complications after leaving Japan for the Zone of the Interior.

It is further realized that the ultimate method for determining the success of arterial repair is by arteriography with radiopaque substances. Since all of these patients had already been evacuated from the combat zone at the time this study was undertaken (November, 1952), and since there is no practical need for such refined technics in a combat zone, this was not attempted. Such a survey has been conducted at Walter Reed Army Medical Center on a small number of these casualties, and is being reported separately by Major Edward J. Jahnke, Jr., USAF (MC).

As may be seen in Figure 1, the incidence of arterial wounds among American battle casualties of World War II was 0.96 per cent. The incidence of arterial injuries among wounded admitted to U. S. Army hospitals during the first nine months of

* Submitted for publication September, 1953.

1952 was 2.4 per cent. (This figure includes all U. N. wounded admitted to U. S. Army hospitals.) It is felt that the latter figure is a more accurate reflection of the actual incidence of arterial wounds among the wounded admitted to hospitals, because all medical officers in this theater are acutely conscious of vascular injuries and invariably record them in their operative notes, even though other notes may not be as complete. That the use of the armored vest

38 per cent to 43 per cent of all wounds studied, and of the lower extremities from 44 per cent to 53 per cent of all wounds studied. Obviously this is a proportional and not an absolute increase. Associated with this increase in extremity wounds, it is logical to assume an increase in vascular injuries of the extremities. No explanation can be offered for the exact correspondence of this figure of 2.4 per cent with that of the Russo-Japanese War.

INCIDENCE OF ARTERIAL WOUNDS AMONG BATTLE CASUALTIES

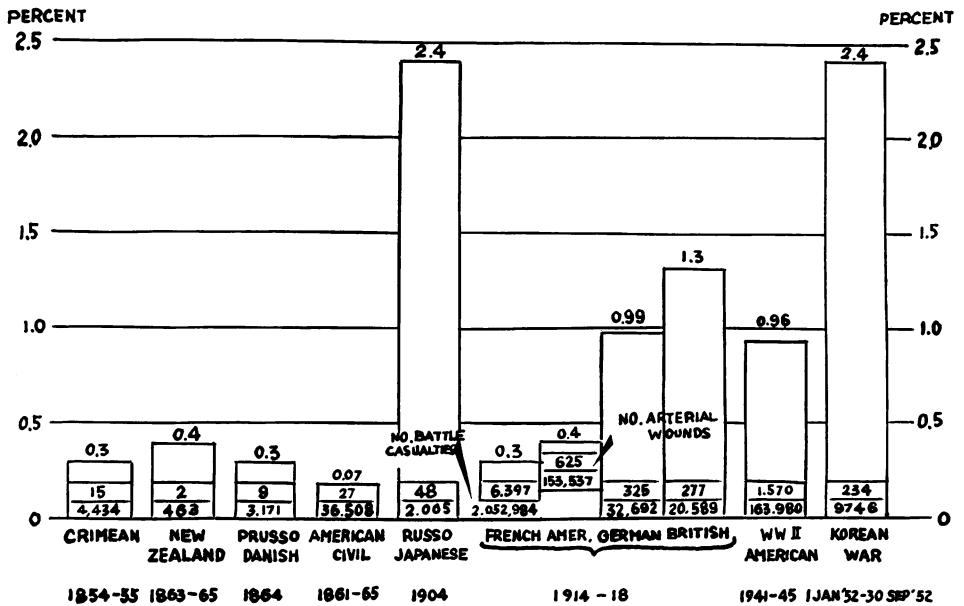


FIG. 1

has had some influence on this increased incidence is probably true, but the extent of that influence is problematical, since this armor was available in limited quantities, as a research project only, from February to July, 1952.

In August, 1952, these vests became available in large enough quantities so that most combat personnel in the line had them for use. According to the report of the team conducting the body armor research, the use of the armored vest was associated with an increase in the incidence of wounds of the upper extremities from

Since the most complete statistical report of the results of acute arterial injuries presented in the American literature was reported in 1946 by DeBakey and Simeone, a deliberate attempt has been made in this analysis to duplicate their method of reporting. This duplication will serve to give a fair and accurate comparison of the DeBakey and Simeone World War II sample study with Korean War results. In both surveys, only acute arterial trauma has been studied. There have been approximately 10 per cent as many arterial wounds in the nine month period of this war as is

results by method of treatment. The most outstanding feature to be noted is the total percent of extremities lost—17.9 per cent in this series and 40.3 per cent in the earlier one. It is recognized that this difference could easily have been caused by a high percentage of injury to noncritical arteries in the former, as compared with the latter. That this is not true and that the two series do compare may be noted by comparison of per cent involvement of arteries such as the axillary, brachial, popliteal and femoral. (A small difference in the method of reporting of two items in this table should be noted. In the World War II sample study, the figures after brachial and femoral represent the total experience with these vessels and include injuries both above and below the profunda. In the portion of the table devoted to the Korean War, the figures after brachial and femoral represent those wounds of these vessels in which the portion of the artery injured was not specified. The total experience with these vessels is the sum of the unspecified group and the group above and below the profunda. This was done in order to make the totals coincide with the itemized figures.) As may be seen, the axillary artery injuries represented 3.0 per cent of the World War II series, and 5.68 per cent of the Korean War series. The brachial injuries in the two wars are respectively 24.3 per cent and 28.39 per cent of the total series.

Wounds of the popliteal arteries are respectively 20.3 per cent and 12.66 per cent of each series. Femoral artery wounds represent 20.9 per cent and 22.27 per cent respectively of each series. It should be noted that the only significant difference in incidence in the two series is in wounds of the popliteal artery. In comparing the percentage of failures, note especially the differences listed for the critical arteries (axillary, brachial, femoral and popliteal). It may be noted that in each instance, a sig-

nificant improvement in result is shown in the Korean series as compared with the DeBakey and Simeone World War II series.

Of the total number of arterial wounds, 132 (56.4 per cent) were repaired (Table II). One hundred and two arteries were ligated. Of these 102 arteries, only 42 were critical vessels whose ligation might lead to either gangrene of an extremity or death. Because of the increased consciousness on the part of all Eighth Army Surgeons of the importance of attempting to repair all injuries of critical vessels, it may be stated unequivocally that failure to repair a critical vessel was usually due to associated injuries which would have led to death if the vessel, rather than the other injury, had been operated on. In other words, surgical judgment and the decision to save a life rather than a limb was involved. In an unknown number of cases, both the associated injury and the arterial repair were accomplished in the same patient.

Of the total of 132 arterial repairs, 26 (19.7 per cent) resulted in gangrene of the extremity with necessary amputation. Since we were interested in the total number of arteries which remain patent after repair, indicating complete success of the procedure, a search was made through all available reports for deaths, postoperative hemorrhage, and postoperative sympathetic blocks which occurred in these 132 casualties. Where death occurred and the extremity was viable and dissection showed no evidence of thrombosis at the repair site, the repair was counted as successful. It was felt that delayed postoperative hemorrhage indicated failure, since a procedure designed to repair the leak frequently led to thrombosis. Since in this Combat Zone, postoperative sympathetic block is not routine, but was reserved instead for extremities of questionable viability, it was felt that employment of this procedure indicated an admission on the part of the surgeon that some impairment of vascular

ACUTE ARTERIAL INJURIES IN THE KOREAN WAR

reported in the World War II sample study. (It must be remembered that whereas the 234 arterial wounds reported in the Korean series represents the total nine months experience with U. N. wounded admitted to U. S. Army hospitals, the DeBakey and Simeone series represents a sample study of 2,471 arterial wounds among 163,980 U. S. Army battle casualties of World War II. Since the total U. S. Army wounded for World War II is 598,528 [a tentative fig-

arterial wounds in combat casualties (Fig. 2) reveals that the brachial, tibial, femoral and popliteal arteries are involved more frequently than any others. These arteries were involved in 84.2 per cent of the extremity arterial wounds in the Korean War as compared with 86.5 per cent of the extremity arterial wounds in World War II. As may be noted, the incidence of involvement of each of the vessels is approximately the same as that for World War II,

LOCATION OF WAR WOUNDS OF ARTERIES

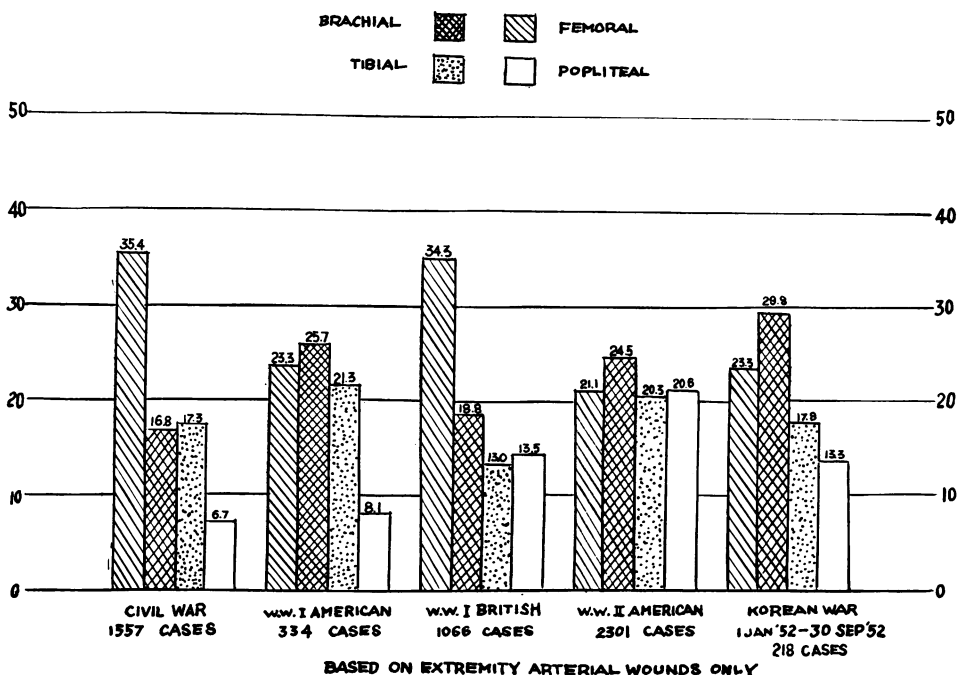


FIG. 2

ure], it may be seen that the DeBakey and Simeone series represents approximately 27 per cent of the total U. S. Army experience in World War II.)

A study of the incidence of these arterial injuries in the Korean War reveals that 218 of the 234 injuries, or 93.2 per cent, involved arteries of the extremities. Of these, 162 involved the "critical arteries" of the extremities (brachial, axillary, femoral, popliteal). This represents 69.2 per cent of the total arterial wounds in this series. An analysis of the relative frequency of

with the exception of popliteal arteries. Since this total experience with vascular injuries is only 10 per cent of that in this World War II sample study, it is entirely possible that a larger group would yield a wound distribution exactly like that of the last war.

In an attempt to compare more closely the outcome of arterial injuries in the two wars, the same breakdown of wounds and results as used by DeBakey and Simeone was done. Table I shows these side-by-side, with no attempt made to compare

TABLE I. *American World War II.*

	American World War II				Korean War 1 Jan-30 Sept '52			
	Total No.	% Total	No. Cases	Per Cent	Total No.	% Total	No. Cases	Loss of Limb Per Cent
Aorta.....	3	0.12	2	66.6	2	0.87	0	00.0
Innominate.....					1	0.44	0	00.0
Carotid.....	10	0.4	3	30.0				
External carotid.....	3	0.12	0	00.0	2	0.87	0	00.0
Internal carotid.....					2	0.87	1	50.0
Common carotid.....					4	1.75	1	25.0
Renal.....	2	0.10	2	100.0				
Vertebral.....								
Subclavian.....	21	0.85	6	28.6				
Axillary.....	74	3.00	32	43.2	13	5.68	1	7.7
Brachial.....	601	24.3	159	26.5	40	17.47	2	5.0
Above profunda.....	97	3.9	54	55.7	4	1.75	0	00.0
Below profunda.....	209	8.5	54	25.8	21	9.17	2	9.5
Radial.....	99	4.0	5	5.1	4	1.75	0	00.0
Ulnar.....	69	2.8	1	1.5	6	2.62	0	00.0
Radial and ulnar.....	28	1.1	11	39.3	2	0.87	0	00.0
Common iliac.....	13	0.5	7	53.8	3	1.31	0	00.0
External iliac.....	30	1.2	14	46.7				
Internal iliac.....	1	0.05	0	00.0	2	0.87	0	00.0
Femoral.....	517	20.9	275	53.2	20	8.73	7	35.0
Above profunda.....	106	4.3	86	81.1	7	3.06	3	42.9
Below profunda.....	177	7.2	97	54.8	24	10.48	6	25.0
Profunda.....	27	1.1	0	00.0	5	2.18	1	20.0
Popliteal.....	502	20.3	364	72.5	29	12.66	11	37.9
Anterior tibial.....	129	5.2	11	8.5	9	3.93	0	00.0
Posterior tibial.....	265	10.7	36	13.6	22	9.61	4	18.2
Ant. and Post. tibial.....	91	3.7	63	69.2	4*	1.75	2	50.0
Peroneal.....	7	0.28	1	14.3	1	0.44	0	00.0
Ant. tibial and peroneal.....					1*	0.44	0	00.0
Post. tibial and peroneal.....	5	0.20	2	40.0				
Both tibials and peroneal.....	1	0.05	1	100.0				
Volar arch.....					1	0.44	0	00.0
Total.....	2471		995	40.3	229*		41	17.9

*There were actually 234 separate arterial wounds but 5 cases had involvement either of both tibials or of the tibial and the peroneal and are simultaneously rather than separately recorded.

function was present. Five more were thus added to the group of amputations, making a total failure rate of 31, or 23.5 per cent. It must be assumed that other cases of vascular insufficiency may have been overlooked due to nonavailability of clinical records, and these can be finally determined only by performing arteriograms on the casualties in this series at some later date.

Of great interest is the method by which arterial repair was accomplished and the percent failure of each. Table III shows that 71, or 53.8 per cent, were repaired by end-to-end anastomosis, 43, or 32.6 per cent, by arteriorrhaphy of a laceration through

only part of the vessel wall, and 18, or 13.6 per cent, by interposition of a vein graft. All vascular suture was by everting, either continuous or interrupted 5-0 black arterial silk. Vein grafts in all cases were taken from adjacent veins whose internal diameter approximated that of the injured vessel. In no instance was the concomitant vein utilized. As is to be expected, the largest percent of failures occurred in the group which required vein grafting. Since the insertion of vein grafts is technically the most difficult of the three procedures utilized, and since in most instances the most severe extremity wounds were associated with those cases requiring a graft, this is to

TABLE II.

Total no. arterial injuries.....	234
Total no. arterial injuries repaired.....	132
Total no. arterial injuries ligated.....	102
Total no. amputations after repair.....	26
Total no. failures after repair.....	31
(Death, hemorrhage, sympathectomy, amputation)	
% Amputations after repair.....	19.7%
% Failures after repair.....	23.5%

TABLE III. *Types of Repair.*

	No. Cases	% Cases	No. Amputations	% Amputations
Arteriorrhaphy.....	43	32.6	(8) 6	(18.6) 14.0
End to end anastomosis..	71	53.8	(17) 14	(23.9) 19.7
Vein graft.....	18	13.6	(6) 6	(33.3) 33.3
Total.....	132	100.0	(31) 26	(23.5) 19.7

Figures in parenthesis () represent failures as evidenced by death, hemorrhage, sympathectomy amputation,

be expected. As is further to be expected, the best results were obtained in the arteriorrhaphies, since these represented the most minor of the arterial wounds and technically were the easiest to repair. The last column in Table III shows the percent of amputations in each type of repair, while the figures in parenthesis represent the total failure rate of each.

The best means for critically analyzing the results of repair as compared with ligation is by eliminating those injured vessels whose sacrifice would not normally result either in death or amputation. Toward this end, Tables IV and V analyze the results of repair and ligation in these major vessels. As may be noted, a total of 169 major artery injuries (largely consisting of the axillary, brachial, femoral and popliteal arteries, but also including the iliac, carotid and aorta) are found in this series, of which 127, or 75.1 per cent, were repaired, and 42, or 24.9 per cent, were ligated. Curiously enough, 20.5 per cent failures are noted in the repaired vessels as compared with 19.0 per cent failures after ligation. It must be noted, however, that the two series show discrepancies for several reasons. Among these are:

1. The total number of cases in the two groups is completely dissimilar, so that comparison is difficult.

2. Since either ligation or repair of brachial arteries result in a small percent of amputations, the ligations series is favorably weighted by the larger number of brachial arteries in that group. Fifty-four and eight-tenths (54.8 per cent) per cent of the ligations group is composed of brachial arteries, while only 33.1 per cent of the repair group consists of brachial arteries.

3. Again, only six of 29 popliteal arteries were ligated, whereas 23 of 29 popliteals were repaired. Although the amputation rate is lower after repair than ligation, notice there were eight amputations after repair, and three after ligation.

4. In this series, the results have been poorest in those repairs of the femoral artery above the bifurcation of the profunda and yet, as can be noted, no femorals above the profunda were ligated, because all had been repaired.

Note that in comparing the percent of amputations in the two groups that the results of repair are better than those for ligation, except in brachial arteries where the location of the injury is unspecified, in femoral arteries above the profunda, and in axillary arteries. Obviously, in the femoral artery above the profunda group (Table V) no valid comparison exists, since none were ligated and therefore, the percentage of amputations cannot be calculated.

The ideal in traumatic vascular surgery is the re-establishment of circulation to the part as quickly as possible. Unfortunately, under combat conditions, there is an unavoidable time lag between wounding and operation dependent on the tactical situation and other conditions beyond medical control. In addition to these military factors causing a time lag, many of these casualties have suffered other wounds such as penetrating wounds of the abdomen or

chest which must be surgically treated before attention can be turned to arterial repair. Since all the casualties listed in this series had already been evacuated from the Far East at the time this study had been instituted and no record of this surgical lag had been kept, it was necessary to collect this data on casualties with vascular injuries incurred between October, 1952, and February, 1953. It is felt that since there was

period" for traumatic vascular surgery is 0-10 hours after wounding, actually many other factors influence these results, and some of these may be as important within certain limits as the time factor itself. Among these are the following:

1. There is a definite correlation between lack of vascular surgical experience of the operating surgeon and amputation rate. This is so noticeable that a continuing

TABLE IV. Results of Repair—Critical Arteries.

	Total No.	No. Repaired	% Repaired	No. Amputations	% Amputations
Brachial artery.....	40	30	75.0	2	6.7
Above profunda.....	4	3	75.0	0	00.0
Below profunda.....	21	9	42.9	0	00.0
Femoral artery.....	20	16	80.0	4	25.0
Above profunda.....	7	7	100.0	3	42.9
Below profunda.....	24	20	83.3	6†	30.0
Axillary artery.....	13	9	69.2	1	11.1
Popliteal artery.....	29	23	79.3	8	34.8
Common iliac.....	3	3	100.0	0	00.0
Common carotid.....	4	4	100.0	1*	25.0
Internal carotid.....	2	1	50.0	1*	100.0
Aorta.....	2	2	100.0	0	00.0
Total.....	169	127	75.1	26	20.5

*Represents death of casualty.

†One arteriorrhaphy failed after secondary closure of wound and probably due to infection.

no major change in the tactical situation during this period, and since all hospitals remained in the same relative location with regard to the battle line during that time, the surgical time lag of the two periods was the same.

There was a total of 62 injuries of critical arteries collected since October 1, 1952. The average surgical lag for these cases was 9.95 hours, as compared with 15.2 hours for 58 cases reported in World War II by DeBakey and Simeone. In this group of 62 casualties, there was a variation in time lag between ten minutes and 22 hours, and the amputation rate was 17.7 per cent. Of 37 of these casualties operated upon within ten hours of wounding, the amputation rate was 10.2 per cent, whereas the amputation rate for 25 casualties operated upon ten to 20 hours after wounding was 28.0 per cent. Although it appears from these results that the "golden

course in experimental vascular surgery under the direction of an experienced surgeon was conducted in one of the surgical hospitals.

2. Exposure of the casualty to inclement weather, especially cold, prior to being evacuated from the battlefield, likewise affects the amputation rate.

3. As was pointed out in Table III, the type of arterial repair necessary to re-establish continuity of the vessel affects the amputation rate.

Because it was felt that associated orthopedic injury might have some relation to outcome, the January, 1952, to September, 1952, series was broken down into two groups: those with, and those without, associated fracture of the long bones of the involved extremities. Of a total of 33 vascular wounds which were ligated, nine were associated with fractures of adjacent long bones, and 24 were not. Of the nine

TABLE V. Results of Ligation—Critical Arteries.

	Total No.	No. Ligated	% Ligated	No. Amputations	% Amputations
Brachial artery.....	40	10	25.0	0	00.0
Above profunda.....	4	1	25.0	0	00.0
Below profunda.....	21	12	57.1	2	16.7
Femoral artery.....	20	4	20.0	2	50.0
Above profunda.....	7	0	—	0	—
Below profunda.....	24	4	16.7	1	25.0
Axillary artery.....	13	4	30.8	0	00.0
Popliteal artery.....	29	6	20.7	3	50.0
Common iliac.....	3	0	—	0	—
Common carotid.....	4	0	—	0	—
Internal carotid.....	2	1	50.0	0	00.0
Aorta.....	2	0	—	0	—
Total.....	169	42	24.9	8	19.0

extremities with fractures and vascular injuries, three, or 33.3 per cent, were amputated. Of the 24 extremities with vascular injuries which had no associated fractures, three, or 12.5 per cent, were amputated. Seventy-one (71) vascular wounds were repaired, of which 26 were associated with fractures of the adjacent long bone, and 45 had no associated fracture. The amputation rate for those with fractures was seven, or 26.9 per cent, and the rate for those without fractures was 11, or 24.4 per cent. The results are obviously inconclusive, and definite conclusions will have to await wider experience.

The problem of ligation of the concomitant vein has come to the fore once again in this war as it did in World Wars I and II. It assumes a new and different importance this time, however, since more of the critical arteries are now being repaired rather than ligated. All observers in this Theater agree that where the concomitant vein of an extremity is ligated because of injury to both artery and vein at the time of wounding, there is a slower return of that extremity to normal after arterial repair. This is true even with elevation of the extremity and the application of an elastic bandage. That this is due to interference with venous return and edema is unquestioned. On at least two occasions within the author's experience, this has resulted in gangrene and

amputation of an extremity, which on dissection showed a patent anastomosis. It has been felt necessary on this basis to caution all surgeons to avoid destruction of venous channels in dissection and to repair those concomitant veins in which only a small laceration exists in the lateral wall. Because of the fear that thrombosis with pulmonary embolization might occur, complete transections of the concomitant vein have not been repaired. Further study of this interesting phase of vascular repair is to be continued.

CONCLUSIONS

1. Arterial repair by the suture method has been used successfully in the repair of arterial wounds among combat casualties in the Korean War. By this method, the amputation rate has been reduced from 40.3 per cent of World War II to 17.9 per cent.

2. Statistics show that there is an increased incidence of arterial wounds among combat casualties and that this type of wound is of increasing importance among casualties of the Korean War.

3. The effect on the amputation rate of orthopedic injury associated with arterial wounds is questionable.

BIBLIOGRAPHY

¹ DeBakey, Michael E., and Fiorindo A. Simeone: Battle Injuries of the Arteries in World War II. *Ann. Surg.*, 123: 534, 1946.