Early Treatment of War Wounds of the Hand and Forearm in Vietnam

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"There is a close relation between the early and late phases of treatment. The surgeon who deals with these wounds at the battle-front, giving them their first definitive treatment, in large measure predetermines the course of events."

LTC. C. W. CUTLER, JR., 1945[13]

T HE VIETNAM WAR has provided to yet another generation of American surgeons the opportunity of learning first-hand the technics of combat surgery. In the past 7 years many arduously-learned principles of wound care have been reaffirmed.[4,9,11] In addition, the rapid evacuation of casualties by rotary-winged aircraft from relatively fixed geographic areas of combat to stationary medical facilities has created an unprecedented opportunity for surgeons to carry out procedures and achieve results not possible in earlier wars. As a consequence of this orderly and immediate flow of patients from combat to hospitals in Vietnam and finally to the United States, the correlation between immediate care and the ultimate result is probably closer than it has ever been before.

The authors served at the 3rd Field Hospital, Vietnam, between May, 1969 and October, 1970 and treated the majority of patients with hand and forearm wounds admitted to that hospital. The purpose of the present report is to document the technics employed during that period in the immediate management of wounds of the upper extremity, emphasizing those procedures serving to simplify or shorten the future course of reconstruction.

Clinical Data

The records of 147 patients with hand and/or forearm wounds were reviewed. All patients were injured in combat and were transported by helicopter directly to the 3rd Field Hospital. Patients who could be treated in the hospital's emergency room with local anesthesia were excluded from the report. The time interval from wounding to operation ranged from less than 1 hour to as much as 6-8 hours, but rarely more. Longer delays, when present, were usually due to the inability of helicopters to enter areas of active combat to evacuate casualties.

Table 1 lists the wounding agents and reflects the character of the Vietnam War during the period of study. The high number of fragment and blast wounds (73%) illustrates the enemy's reliance on booby traps, rockets, and satchel charges as weapons and agrees generally with other published studies.[25]

Wounds were separated into three general catagories: 1) *Gunshot wounds*—the result of one or more high velocity missiles (greater than 2,000 feet per second) usually fired from the AK-47, the Communist equivalent of the United States model M-16; 2) *Fragment wounds*—the result of high velocity metallic fragments from a device such as a grenade, mortar round, or rocket. Identification of the specific weapon was usually impossible; 3) *"Blast" wounds*—the result of the concussive effect of an explosive device, such as a land mine or "plastic". Such injuries are characterized by multiple wounds with heavy tatooing by dirt and debris.

Associated injuries to other organ systems were frequent (Tables 2 and 3). Three deaths occurred in the series and all resulted from massive trauma to multiple

TABLE 1. *Mechanism of Injury in 147 Patients*

Mechanism	Number	Per Cent
Multiple Fragment Wounds	90	61
Gunshot Wounds	36	25
Blast	18	12
Unknown	3	2

TABLE 3. *Wounds Involving other Major Areas in 75 Patients—51% of Total*

Area of Wound	Number	Per Cent of Multiply-Wounded	Per Cent of All Patients
Lower Extremity	45	62	31
Abdomen	19	26	13
Head and Neck	17	23	12
Back	14	18	10
Chest	10	13	7
Genitalia, Perineum	6	8	4

systems. Management of the extremity wounds was at times dictated by the presence of other injuries.

Table 4 indicates the frequency of injury to various anatomic structures in the hand and forearm. Nerves which were nonfunctional at preoperative examination were reported as injured even if they were anatomically intact at operation. Muscles were listed as injured only if it was felt that the amount lost through wounding and debridement would significantly reduce their function. Tendons were included if they were completely divided.

Table 5 is a listing of the procedures preformed both on the day of wounding and at subsequent operations. All procedures were performed at the 3rd Field Hospital.

Patient follow-up was necessarily short due to the policy of rapid aero-medical evacuation from Vietnam. As a general rule, patients remained at the 3rd Field Hospital for 8–12 days, i.e., until a delayed primary closure of their wounds could be performed and a 3–5 day observation period allowed to elapse. Unusually heavy casualty loads occasionally necessitated earlier evacuation. In accordance with official policy, a patient remained at the 3rd Field Hospital for a mandatory 14-day period if an arterial repair was performed. The majority of patients, therefore, were evacuated from Vietnam 8 to 14 days following wounding. Wounds in this series were treated with the expectation that the surgeon performing the initial operation would have the opportunity of reoperating on the patient. One hundred and twenty-four patients actually underwent a second procedure at the 3rd Field Hospital. Of the remaining 23 patients, a primary closure was performed in three instances, and 20 others were evacuated prior to further operation.

Operative Procedures

The choice of anesthesia was based on the patient's injuries and general condition. Axillary or supraclavicular block, general anesthesia, or intravenous lidocaine were utilized at various times. A pneumatic tourniquet was available in all instances and was usually employed for some portion of the procedure.

TABLE 2. *Location of Wounds in 147 Patients*

	Patients	Per Cent
Limited to Upper Extremity	72	49%
Other Areas or Organ Systems	75	51%

Initial Surgery: Wounds were scrubbed with soap and a surgical brush and copiously irrigated with saline (Fig. 1-A). The importance of this procedure in the reduction of contamination and prevention of infection cannot be over-emphasized. All wounds were then surgically debrided. Except for tangential wounds, it was rarely necessary to debride more than a few millimeters of skin and subsequent wound closure usually posed no problem. Muscle debridement frequently had to be wide and the amount necessary was sometimes difficult to gauge. Bone was not removed unless completely detached from all soft tissue. Frayed tendon ends were trimmed smooth. Hematomas were treated aggressively by wide decompression, evacuation, and drainage. Arteries in the vicinity of wounds were explored and repairs were performed when indicated. Major nerves in the vicinity of wounds were visually inspected and their condition carefully noted. Divided nerves were minimally debrided. Fasciotomies were performed over the flexor and extensor muscle groups of the forearm, the dorsal interossei, and the lumbrical muscles of the hand. The volar carpal ligament was divided if necessary (Fig. 1-B). At the completion of these procedures hemostasis was carefully obtained by ligature and cautery. Fine mesh gauze, absorbable sponges, and a supportive plaster splint were applied and the extremity was elevated continuously until the time of the second procedure.

Reparative Surgery: The surgeon's judgment and the logistical situation determined when this phase of treatment was begun. In the absence of infection or other complications, the patient was usually returned to the operating room 3 to 5 days after injury (Fig. 1-C). At that time further debridement could be carried out if necessary. Definitive alignment and fixation of fractures was also performed. Kirschner wire fixation was the method of choice in hand and wrist fractures, but only external splinting was used for the forearm. In metacarpal fractures without loss of bone substance, fixation was accomplished by crossed wires or by a transverse wire through the metacarpal heads and a vertical wire in the medullary canal to prevent angulation.

The problems associated with loss of bone substance and shortening of the bony framework are all well known to surgeons involved in the late reconstructive surgery

of war wounds. In patients with significant loss of meta-carpal length, a special effort was made to stabilize distal bone fragments to intact adjacent bones or to use Kirsch-ner wire "spacers" to maintain length. This practice has greatly simplified subsequent bone-grafting and re-construction (Fig. 2).

Phalangeal fractures were usually treated with crossed or multiple small Kirschner wires, inserted in standard fashion. A number of patients had all or parts of one or more fingers amputated. Particular care was taken to preserve viable innervated skin in such cases for use in later coverage. In addition, badly damaged fingers were saved if future use of remaining parts seemed likely.[8]

Wound closure was by direct suture, autograft,[12] or local flaps fashioned from the skin of a filleted finger. Homografts were occasionally used for temporary wound coverage. Flaps and skin grafts were left exposed post-operatively to permit frequent observation. Patients were evacuated from Vietnam 3 to 5 days after wound closure if their condition was satisfactory (Fig. 1-D).

Discussion

A large majority of our patients had sustained high velocity missile wounds. The pathophysiology of these wounds has been well-described and is beyond the scope of this report,[1,15,16,18,24] but it should be empha-sized that such wounds characteristically produce marked destruction at great distances from the missile track and are frequently accompanied by massive con-tamination. For these reasons, they do not lend them-selves to the technics employed in the treatment of wounds incurred in civilian life.

War surgeons have appreciated the importance of the early management in the subsequent course of upper extremity wounds.[2,3,4,5,23] In 1944, Churchill identified three stages in the treatment of war wounds: initial surgery, reparative surgery, and reconstructive surgery.[9] This classification has been modified to fit the particular circumstances of the Vietnam War. The term *initial surgery* refers to procedures carried out within a few

TABLE 4. *Injured Structures, Upper Extremity in 147 Patients*

Structure		Number of Patients	Per Cent	
Bone		93	63	
	Hand	70		48
	Forearm	23		15
Nerve		60	41	
	Hand	38		26
	Forearm	22		15
Muscle		49	33	
Tendon		45	31	
Artery		15	10	
	Wrist-Elbow	10		7
	Elbow or Above	5		3

TABLE 5. *Surgical Procedures—Immediate or Delayed in 147 Patients*

Wound Closure	127	
Immediate Suture		3
Delayed Suture		112
Autograft		12
K-Wire Fixation of Fracture		53
K-Wire Spacer for Bone Loss		10
Amputation		23
Evacuation of Hematoma		15
Arterial Repair	15	
Saphenous Vein Graft		4
End-To-End		4
Lateral Suture		3
Ligation		4
Fillet of Finger		6
Decompression	76	
Forearm Fasciotomy		47
Intrinisic Muscle Fasciotomy		17
Volar Carpal Ligament Division		12

hours of wounding and is primarily directed toward preservation of life and limb. Its purpose in the hand and forearm is to preserve and protect all remaining vital structures and prepare them for reparative surgery. Churchill noted that *reparative surgery* "is designed to prevent or cut short wound infection . . . and is per-formed between four and ten days, 'the golden period' to close wounds, reduce and fix fractures, remove retained missiles, and carry out other procedures to prevent or abort infection." *Reconstructive surgery*, such as nerve suture, tendon repair, bone grafts, and pedicle flap cov-erage, was not performed in Vietnam.

In previous wars, the initial operation was carried out near the front, whereas reparative surgery was performed at base hospitals located to the rear. In Vietnam, how-ever, there is no front and the terms, "forward" and "rear" are anachronistic; and it is not uncommon for the initial operation and subsequent reparative work
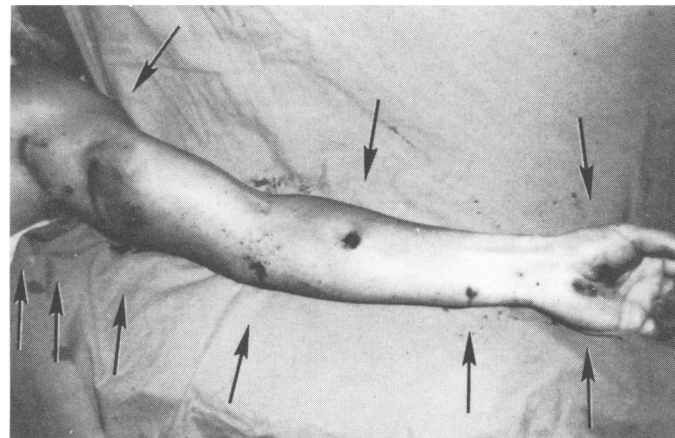

FIG. 1-A. Day of injury. There are multiple fragment wounds. (arrows) Division of brachial and radial arteries, median nerve division, ulnar nerve contusion, fractures of humeral epicondyle and 3rd metacarpal. Wounds will be debrided, arteries repaired, volar carpal ligament excised.
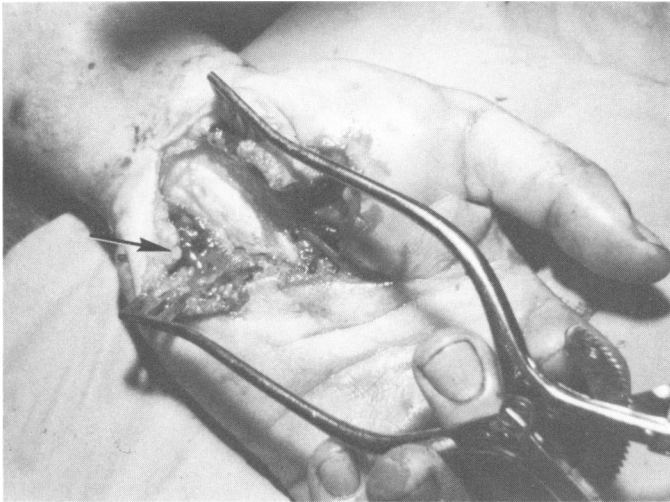
Fig. 1-B. Day of injury. Closeup of hand showing volar carpal ligament excision. Note hematoma (arrow) over ulnar aspect of ligament.

Fig. 1-D. Fourteen days after wounding. Wounds are healing without infection, pulses are present. Note resolving hematoma, upper arm. The patient was evacuated to Japan.

to be carried out at the same hospital and by the same surgeon. This modification in approach to the treatment of war wounds is possible for two reasons: 1) hospitals are stationary and secure and 2) the helicopter and jet transport provide a degree of patient mobility which has not been possible in previous wars.

The staged approach to wound management limits the initial operation to those procedures necessary to 1) restore viability 2) relieve the pressure of hematoma or edema 3) remove non-viable or heavily contaminated tissue and foreign bodies, 4) and inspect nerves or arteries to determine the presence and degree of injury.

At the time of initial operation first priority is assigned to the repair of arterial injuries. The presence of such injuries frequently is suggested by a large hem-

atoma or bright red bleeding, but damage to a vessel may sometimes be present in the absence of these signs. All major vessels in the vicinity of a wound should be inspected, even if a pulse is present distal to the wound.

Injury to an artery may result in either thrombosis (secondary to intimal damage), partial division, or complete division. Resection of the damaged segment and direct anastomosis usually can be performed without difficulty in the first two instances. A completely divided vessel, however, may be best managed by resecting the damaged ends and inserting a saphenous vein graft. This technic allows a tension-free repair and avoids the necessity of dividing collateral branches to gain length.

The large scale repair of vascular injuries by hun-

Fig. 1-C. Five days after wounding. Hand is viable, wounds are open, clean, uninfected. Ideal for fracture fixation and wound closure.

Fig. 2-A. Two months after gunshot wound with comminution and partial loss of second and third metacarpals, extensor tendon loss. Kirschner wire spacers and transverse wire are in position to maintain length.

FIG. 2-B. Three and a half months following wounding. Note slight collapse of third metacarpal head following removal of transverse wire.

FIG. 2-C. Three and a half months. Oblique view showing absence of union —ready for iliac crest bone grafting.

dreds of surgeons has been a major advance in the care of the wounded in Vietnam. Survival and amputation rates have been consistently better than those obtained in other wars.[14,17,25,26] Early thrombosis of saphenous vein grafts in the upper extremity has sometimes been a source of disappointment however.[7] Although the magnitude of injury clearly plays a major role in such failures, it is felt that scrupulous attention to technic may minimize such complications. Particular care must be taken to distend the vein graft with a dilute heparin solution and to dissect away constricting areas of adventitia to make certain that there are no areas of narrowing. Of the 11 arterial repairs performed above the wrist, five were at the elbow or higher and involved the brachial artery. These extremities were potentially nonviable. Four of the patients required saphenous vein grafts, three being at the elbow and one in the upper arm. There was no loss of limb and pulses were present distal to all repairs fourteen days later when the patient was evacuated.

Table 5 illustrates the emphasis placed on decompressive procedures. In addition to standard forearm flexor and extensor fasciotomy, intrinsic muscle fasciotomy and volar carpal ligament division were frequently performed for wounds or edema of the hand and wrist. Burkhalter et al.,[6] have emphasized the value of these procedures in reducing the pressure on intrinsic blood supply, minimizing median nerve compression, and facilitating tendon motion through the carpal tunnel.

Although fasciotomy has been widely advocated for the leg, upper arm, and forearm, fascial releases in the hand have not been stressed adequately. These procedures seem to offer many advantages, are simple, and can be carried out quickly and with little morbidity.

Hopefully, they will be employed more frequently in the future.

Amputations were performed at the initial procedure only when the part in question was clearly nonviable. Only one amputation was performed at the carpal level and none proximally. No complications were noted to result when marginally vascularized flaps of skin were

FIG. 2-D. Fourteen months after wounding, bone graft is healed. Extensor tendon transfer and graft has been performed to index and middle fingers respectively (note small wires).
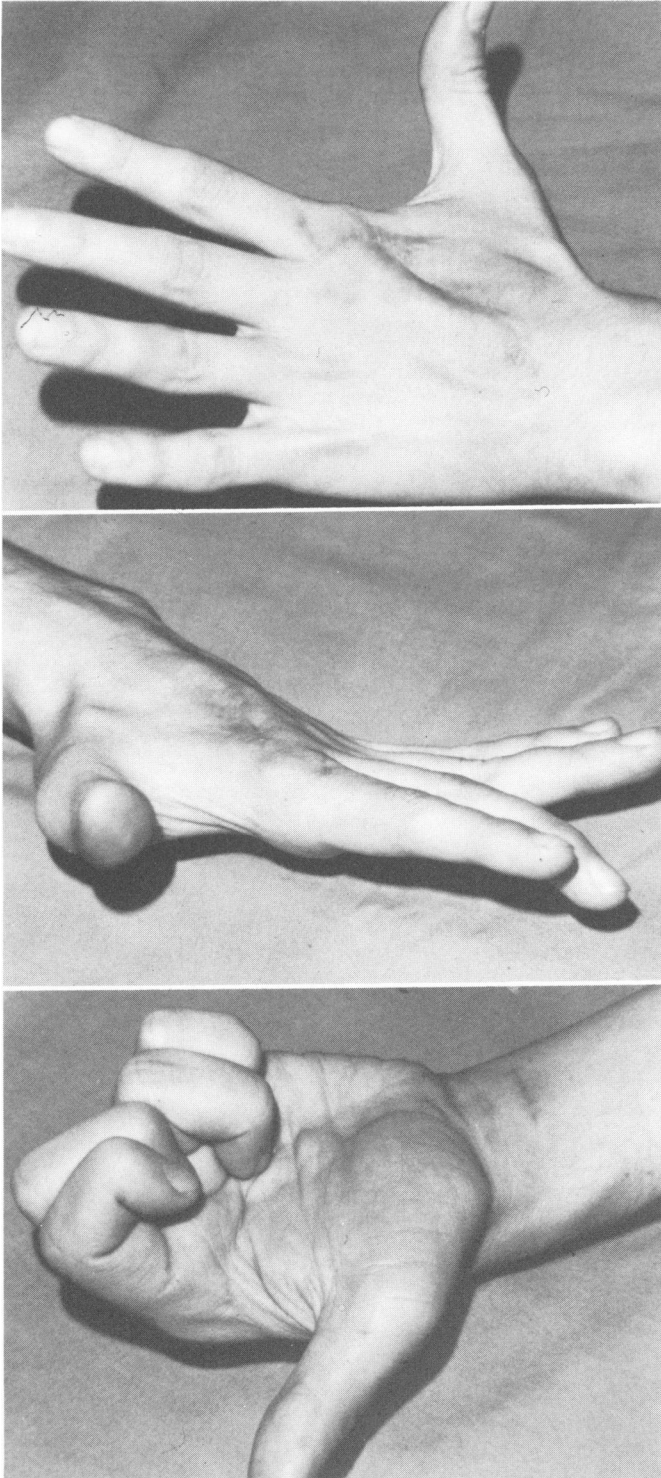
FIGS. 2-E, F, G. Final result, showing appearance of wound, range of motion. 45° flexion and full extension is present at MP joints.

allowed to remain at the first operation, since a second chance to debride them was available. This technic resulted in greater skin salvage.

The initial stage of surgery was always terminated with irrigation and a search for bleeding vessels. The importance of hemostasis is not diminished by the fact that wounds are to be left open. Hematoma and bleeding have produced many wound complications in Vietnam which might have been avoided by more careful hemostasis.

Decisions regarding the use of antibiotics are still largely empiric. The majority or patients wounded in Vietnam are given antibiotics when first seen by a physician. Many of our patients, however, did not receive antibiotics, particularly if there were no associated injuries. Only one patient in this series developed a clinical infection, a rate of 0.68%, and this occurred despite treatment with antibiotics. This success seems to substantiate the philosophy of Mason's excellent discourse on the treatment of open wounds.[20] Infection is prevented by faithful adherence to surgical principles, not bacteriological principles.

There are several advantages to the two-stage method of wound management: 1) A more conservative debridement can be performed at the time of initial operation since the operator knows there will be a second opportunity to remove tissue of questionable viability. 2) Hematomas which accumulate in the wound following initial operation can be evacuated. 3) Time-consuming procedures such as fracture fixation can be performed at a time when the patient's condition is generally more stable than at the time of initial resuscitation and treatment. 4) Wounds are not closed over nonviable or minimally viable tissue. 5) Wound closure is performed at a time when edema is beginning to subside.

There exist differences of opinion concerning the relative merits of primary and delayed primary closure of hand wounds. We have chosen not to distinguish between these two methods but to emphasize that both are *primary*, so long as closure is performed within 4 to 7 days of wounding. There is no evidence suggesting an advantage to closure on the day of injury or a disadvantage to closure within 7 days of wounding. Healing occurs at virtually the same rate, and the final result is unchanged.[19,27] It is the responsibility of the surgeon to "close the wound when it is ready for closure" and this should be done at the earliest possible date. It may occasionally be on the day of injury but a vast experience with high velocity war wounds has shown that wound closure can be more safely performed at a later date. Wound severity notwithstanding, many of the most difficult problems seen in military hospitals in the United States are the result of wounds which have been closed only to disrupt at a later date because of infection, tension, or closure of tissue with marginal circulation. The major issue which thus evolves is not *when* the wound is closed but that once closed it *stay closed* and heal without infection.

The immediate care of war wounds of the hand has

changed considerably in America's last three wars. For most of World War II, the initial surgical treatment of wounds was followed by open treatment. A delayed closure was performed as the patient moved to the rear. As armies advanced and evacuation chains lengthened, however, hand and forearm wounds sometimes remained open for 2 to 4 weeks or longer. This regimen produced infection, stiffness, and fibrosis and resulted in the recommendation that primary closure of hand wounds be attempted. Immediate closure was in fact practiced in the later stages of World War II and initial results were encouraging in a limited series, but several instances of wound breakdown and life-threatening infection were seen.[10] No final conclusions could be drawn at that time about its efficacy. Following World War II and during the Korean War, there was continued interest in immediate reconstruction. McCormack[22] in 1959 pointed out the improved capability of hospitals and surgeons and suggested that immediate reconstruction be performed on selected cases. Mason and Bell,[21] in that same year, advocated "primary closure if at all feasible" but cautioned that "extensive reparative surgery in a hand already badly handicapped by the original trauma may wreck the patient's only chance for a functioning hand. The surgeon must remember that *unless primary healing can be secured,* the later reparative surgery may be unduly delayed and difficult, and may produce a poorer result. Bunnell stated that "the goal of all initial wound care is to obtain healing by first intention with a minimum of tissue reaction." To this we would add, at the earliest possible time and whatever means necessary.

Summary

1. A group of 147 war wounds of the hand and forearm from the Vietnam War is presented.

2. The staged approach, utilizing early debridement followed by reparative procedures and delayed primary closure, is advocated.

3. The more frequent use of intrinsic muscle fasciotomy and volar carpal ligament is recommended.

4. Emphasis is placed on the relationship between proper initial treatment and the ultimate success of reconstruction.

References

1. Adams, R. W.: Small Caliber Missile Blast Wounds of the Hand. Am. J. Surg., 82:219, 1951.
2. Allen, H. A.: Hand Injuries in the Mediterranean (North African) Theater of Operations. Surgery in World War II-Hand Surgery, Office of the Surgeon General, Department of The Army, Washington, D. C., S. Bunnell (ed), Chapter 3, 79–153, 1955.
3. Boyes, J. H.: A Philosophy of Care of the Injured Hand. Bull. Am. Coll. Surg., 50:341, 1965.
4. Bunnell, S.: Suggestions to Improve the Early Treatment of Hand Injuries. Bull. U.S. Army Medical Dept., 88:78, 1945.
5. Bunnell, S.: The Early Treatment of Hand Injuries. J. Bone Joint Surg., 33-A: 807, 1951.
6. Burkhalter, W. E., Butler, B., Metz, W. and Omer, G.: Experiences with Delayed Primary Closure of War Wounds of the Hand in Vietnam. J. Bone Joint Surg., 50-A:945, 1968.
7. Chandler, J. B. and Knapp, R. W.: Early Definitive Treatment of Vascular Injuries in the Vietnam Conflict. JAMA, 202:136, 1967.
8. Chase, R. A.: The Damaged Index Digit: A Source of Components to Restore the Crippled Hand. J. Bone Joint Surg., 50-A:1152, 1968.
9. Churchill, E. D.: The Surgical Management of the Wounded in the Mediterranean Theater at the Time of the Fall of Rome. Ann. Surg., 120:268, 1944.
10. Cleveland, M.: Hand Injuries in European Theater of Operations. Surgery in World War II-Office of the Surgeon General, Department of the Army, Washington, D. C., S. Bunnell (ed), Chapter 4, 155–184, 1955.
11. Cleveland, M., Manning, J. G. and Steward, W. J.: Care of Battle Casualties and Injuries Involving Bones and Joints. J. Bone Joint Surg., 33-A:517, 1951.
12. Converse, J. M.: Early Skin Grafting in Wounds of the Hand. Ann. Surg., 115:321, 1942.
13. Cutler, C. W., Jr. LTC: Early Management of Wounds of the Hand. Bull. U.S. Army Medical Dept., 85:92, 1945.
14. Debakey, M. E. and Simeone, F. A.: Battle Injuries of the Arteries in World War II: An Analysis of 2471 Cases. Ann. Surg., 123:534, 1946.
15. DeMuth, W. E., Jr., and Smith, J. M.: High Velocity Bullet Wounds of Muscle and Bone: The Basis of Rational Early Treatment. J. Trauma, 6:744, 1966.
16. Hopkinson, D. A. W. and Marshall, T. K.: Firearm Injuries. Brit. J. Surg., 54:344, 1967.
17. Inui, F. K., Shannon, J. and Howard, J. M.: Arterial Injuries in the Korean Conflict: Experiences With 111 Consecutive Injuries. Surgery, 37:850, 1955.
18. Krauss, Max: Studies in Wound Ballistics: Temporary Cavity Effects in Soft Tissues. Military Med., 121:221, 1957.
19. Lowry, K. F. and Curtis, G. M.: Delayed Suture in the Management of Wounds. Analysis of 721 Traumatic Wounds Illustrating the Influence of Time Interval in Wound Repair. Am. J. Surg., 80:280, 1950.
20. Mason, M. L.: Treatment of Open Wounds. Bull. Am. Coll. Surg., 42:33, 1957.
21. Mason, M. L. and Bell, J. L.: The Crushed Hand. Clinical Orthopedics., 13:84–96, 1959.
22. McCormack, R. M.: Reconstructive Surgery and the Immediate Care of the Severely Injured Hand. Clin. Orthop., 13: 75, 1959.
23. Omer, G. E., Jr.: The Early Management of Gunshot Wounds of the Extremities. South Dakota J. Med., 9:340, 1956.
24. Puckett, W. O., Grundfest, H., McElroy, W. D. and McMillen, J. H.: Damage to Peripheral Nerves By High Velocity Missiles Without a Direct Hit. J. Neurosurg., 3:294, 1946.
25. Rich, N. M., Baugh, J. H. and Hughes, C. W.: Acute Arterial Injuries in Vietnam: 1,000 Cases. J. Trauma, 10:359, 1970.
26. Spencer, F. C. and Grewe, R. V.: The Management of Arterial Injuries in Battle Casualties. Ann. Surg., 141:304, 1955.
27. Wilson, H.: Secondary Suture of War Wounds. Ann. Surg., 121:152, 1941.