Foreword

The success of any military health care system in wartime is directly related to the number of casualties adequately treated and returned to duty with their units. This must be accomplished as soon and as far forward in the theater of operations as possible.

The Second Battle of Bull Run near Manassas, Virginia, was one of the major engagements of the United States Civil War. Three days after that great battle, three thousand wounded men still lay on the field. Relatives travelled to the front and took their loved ones home for treatment rather than leave them to the uncertainties of military medicine We have made phenomenal progress in the century since that battle occurred.

I have had the privilege of being a physician for nearly forty years. Half of that time was spent on active duty in the military services and the other half was spent in the civilian sector. I have participated in the delivery of health care in every conceivable setting: in a battlefield tent in Korea; on a hospital ship; in an air squadron; from austere county and state hospitals to large, glossy high technology institutions. I have seen people strive for, and achieve, excellence in all those settings. I see it now in the military health care system, and no one is more proud than I of the accomplishments and the quality of that system and of the special type of men and women who make the system work. Our system is not without its problems and its frustrations. It takes a long time for equipment to be delivered; the personnel system doesn't always provide the proper mix of people in a timely manner to get the job done; but with rare exceptions, the medical mission is accomplished in exceptional fashion.

This handbook should serve as a constant reminder that ours is a high calling. We are here to save lives, not to destroy them. We are committed to the future, not the past, and to the primary mission of military medicine, which is to keep the soldiers, sailors, airmen and marines alive and whole: in the words of Abraham Lincoln, to minister to "him who has borne the brunt of battle."

This revised edition represents the contributions of talented and gifted health professionals from the military services as well as from the civilian sector. All who contributed have the grateful appreciation of the editorial board for the enthusiasm, dedication, and perseverance which made this revision possible.

WILLIAM MAYER,M.D.
Assistant Secretary of Defense
(Health Aflairs)

Preface

This edition of the.Emergency War Surgery Handbook is written for and dedicated to the new generation of young, as yet untested surgeons, who may be given the opportunity and the honor of ministering to the needs of their fallen fellow countrymen. What is the likelihood that you will be called to serve? The ancient Plato provided the answer: "Only the dead have seen the end of war!"

Will you be adequate, will you be successful in salvaging the lives and limbs of those comrades by applying the principles of the lessons hard-learned by countless generations of combat surgeons that have preceded you? The answer is a resounding yes, for "I would remind you how large and various is the experience of the battlefield and how fertile the blood of warriors in the rearing of good surgeons" (T. Clifford Albutt).

What sort of wounds will you be expected to manage? The Wound Data and Munitions Effectiveness Team (WDMET) data derived from the Vietnam battlefield provide some insight into the types of wounds and the casualty mix that might be expected. The WDMET data indicate that 100 combat casualties, who survive long enough to be evacuated from the field, could be statistically expected to present the following casualty mix:

Thirty casualties with minor or superficial wounds, minor burns, abrasions, foreign bodies in the eye, ruptured ear drums, and deafness.

Sixteen with open, cornminuted fractures of a long bone, of which several will be multiple and several will be associated with injury of named nerves.

Ten with major soft tissue injury or burns requiring general anesthesia for debridement. Several will have injury of named nerves.

Ten will require laparotomy, of which two will be negative and several will involve extensive, complicated procedures.

Six with open, comminutedfractures of the hand, fingers, feet or toes.

Five will require closed thoracostomies and soft tissue wound management; at least one will have a minithoracotomy.

Four will have major multiple trauma, i.e, various combinations of craniotomies, thoracotomies, laparotomies, amputations, vascular reconstructions, soft tissue debridements, or fracture management.

Three will be major amputations (AK, BK, arm, forearm). In three out of four, the surgeon will simply complete the amputation.

Three craniotomies. Two will be craniectomies for fragments and one will involve elevation of a depressed fracture.

Three vascular reconstructions, half involving femoral arteries. One-half will have associated fractures, or venous or nerve injuries.

Three major eye injuries, one of which will require enucleation.

Two amputations of hands, fingers, feet or toes.

Two maxillofacial reconstructions. Half will have mandibular injuries and most of the remainder will have maxillary injuries.

One formal thoracotomy.

One neck exploration (usually negative).

One casualty statistically is delivered up by the computer as "miscellaneous."

If this surgical handbook is on the mark in achieving its objective, we will have provided you with specific guidelines or general principles governing the management of the foregoing 100 randomly selected battle casualties.

There are some who, as they study the chapters that follow, will perceive this handbook guidance as overly regimented, too rigid or prescriptive, and leaving too little room for the individual surgeon's judgment. On the contrary, these lessons and countless others have had to be learned and relearned by generations of surgeons pressed into the combat surgical environment. These very standardized approaches are necessitated by the echeloned management of casualties by many different practitioners at several different sites along a diverse evacuation chain, as opposed to the civil sector in which an individual surgeon can hold and manage an individual patient throughout that patient's entire course Historically, these standardized approaches have repeatedly provided the highest standard of care to the greatest number of casualties.

Several chapters have been completely rewritten and two new chapters have been added to this edition. In an attempt to maintain perspective and continuity between this and the First United States Edition of the Emergency War Surgery NATO Handbook, Professor TJ. Whelan was asked to write a "bridge" between his and this edition. The advice, counsel, and contributions of this outstanding soldier, surgeon, and citizen are truly appreciated. His prologue to the Second United States Edition follows forthwith.

THOMASE.BOWEN,M.D.
Editor
Brigudier Gnerul, US. Army

Prologue

This is a handbook of war surgery. Its lessons have been learn ed and then taught by combat surgeons — "young men who must have good hands, a stout heart and not too much philosophy; he is called upon for decision rather than discussion, for action rather than a knowledge of what the best writers think should be done."

In a world where multinational forces may be thrown together on one side in a large war, a need was clearly seen for standardiza tion of equipment and techniques among nations expected to fight as allies. In 1957, SHAPE (Supreme Headquarters Allied Powers Europe) published the first Emergency War Surgery Hand book, familiarly known as the NATO Handbook. This was the pro duct of a committee of the surgical consultants of the United Kingdom, France, and the United States, chaired by Brigadier General Sam F. Seeley of the United States. In 1958, the handbook was issued in the United States following suitable amendments. In April, 1959, the NATO Military Agency for Standardization pro mulgated NATO Standardization Agreement (STANAG) 2068, which retrospectively placed a stamp of approval on the Emergen cy War Surgery Handbook of 1957 by agreeing that NATO Arm ed Forces would standardize emergency war surgery according to its contents and tenets. This handbook, in addition to being issued to all active duty medical officers in the U.S. Armed Forces Medical Departments, was also forwarded to medical school surgical departments and libraries. At that time the MEND (Medical Educa tion for National Defense) program war active. This was an ex cellent program, instituted in all university medical schools by the universities and the armed forces, in which a faculty represen tative, normally a surgeon, was selected to be briefed on a regular basis by the medical departments of the armed forces and, in turn, to teach principles of care of military casualties at their respec tive schools. Much of the early exposure of these individuals dealt with the concept of mass casualties and thermonuclear warfare.

In 1970, Dr. Louis M. Rousselot,'Assistant Secretary of Defense for Health and Environment, an outstanding surgeon himself, realizing that, during the Korean and Vietnam conflicts, new surgical information had been learned or relearned and that this new information required broad exposure, tasked the Army Surgeon General to update the Emergency War Surgery Handbook. The editorial board for the new U.S. edition consisted of Rear Admiral Edward J, Rupnick, MC, US Navy; Colonel Robert Dean, MC, USAF; Colonel Richard R. Torp, MC, USA; and Brigadier General Thomas J. Whelan, Jr., MC, USA, who chaired the board. Chapters were rewritten, and the format changed to include chapters on aeromedical evacuation, mass casualties in thermonuclear warfare, and reoperative abdominal surgery. The final paragraphs on mass casualties in each chapter of the original handbook were excluded. At the same time, a NATO Handbook Revision Committee chaired by Colonel Tommy A. Pace, RAMC, and with representatives from the United Kingdom, France, the Federal Republic of Germany, the Netherlands, and Greece has been proceeding with minor chapter changes. The U.S. committee felt that the NATO committee might welcome the more extensive changes. Therefore, in 1973 the completed revision of the U.S. Handbook was presented to the committee. Within 48 hours there was a unanimous decision to accept the new US. edition with certain minor modifications and to use it as the basis of a new edition for NATO nations. These modifications were proposed by the representative from France; they related to a description of an external fixation device for use in open fractures and to a minor change in the management of chest injuries. It seems certain that no NATO accord ever came so swiftly or easily. The goodwill on both sides was exemplary and heartening. In 1975, the new U.S. edition was published, and in 1977 it became the guide for all NAZI0 forces, pursuant to a reissue of STANAG 2068. Now it is time for a third edition.

  War surgery represents no crude departure from accepted surgical standards. A major responsibility of all military surgeons is to maintain these principles and practices as fully as possible, even under adverse physical conditions. The physical requirements are, however, relatively simple:

  1. Experienced surgeon, anesthetist, and operating room personnel.
  2. Simple X-ray facilities.

3. Good lighting and water Supplies.

4. Reasonable accommodations under shelter.

5. Well-trained nurses and other professional administrative staff.

6. Ability to retain post-operative patients in the hospital for at least a few days to allow stabilization.

7. Simple surgical equipment, supplemented by a few items of specialized equipment, such as Bovie units, defibrillators, ventilators, blood gas machines, anesthesia delivery equipment, and vascular and orthopedic instruments.

There are, however, differences betwen war surgery and surgery in the civilian setting:

1. The tactical situation may impose major constraints upon the performance of the indicated operation, and threats to the safety of the patient and medical personnel may make appropriate care inconvenient, if not impossible.

2. The high-velocity weapons of war may produce tremendously greater tissue destruction than the low-velocity weapons producing civilian wounds.

3. There are few civilian wounds which resemble the multiple fragment wounds of artillery or mortar shells, bombs, booby traps, and landmines.

4. Wounds are cared for by many surgeons along an evacuation chain that extends from combat zone to home, rather than by one surgeon and his house staff throughout all phases of wound repair.

5. Casualties are frequently received in large numbers over a short time in combat hospitals. Although an occasional catastrophe of similar magnitude has occurred in a few metropolitan civilian hospitals, this is a commonplace occurrence in forward combat hospitals.

6. During aeromedical evacuation, the casualty will require long flights during which lowered air pressure may complicate abdominal, chest, eye, head, and spinal wounds. The cabins of high-altitude aircraft are pressurized only to about 4,000.8,000 feet above sea level, and not to sea level pressures.

We are now faced with a fast-moving, highly mobile, remote control type of warfare which will require major changes in philosophy and management of war casualties. It may, for instance, be necessary to evacuate casualties much earlier than the organism's physiologic responses to injury dictate as optimal. The initial definitive surgery may be required aloft or on shipboard. Or

because of noxious fumes or 'radioactive dust, we may find it necessary to emulate the mole, remaining underground for protracted periods. We must not ever expect that the protected hospital environments of the Korean or Vietnam conflicts, bought with very necessary air superiority, will necessarily be present in future conflicts. Plans for the care of the wounded must be laced with a generous sprinkling of multiple alternatives and options, ranging from immediate air or surface evacuation with delayed suboptimal definitive surgical care to the more standard, early definitive treatment in a combat hospital with a 4-10 day retention period prior to further evacuation. The latter is optimal; the former, however, may be forced by the tactical situation.

As in any medical endeavor, prevention is far more efficacious than treatment. This is true for wounds sustained in war. Unfortunately, there is no precedent to suggest that man and nations have learned to coexist without armed conflict. Although I, personally, and most military men, who "above all other people pray for peace, for they must suffer and bear the deepest wounds and scars of war" (quoted from General Douglas MacArthur's oration "Duty, Honor, Country"), would be profoundly grateful if this handbook might become superfluous, redundant, and unnecessary, it nonetheless continues to serve a useful purpose in these times. Furthermore, a reasonably standard, phased method of treatment of war wounds, to be enunciated in the remainder of this handbook, is imperative when many surgeons, of multiple national extractions, along long evacuation chains, care for those wounded   in   combat.

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General Considerations of Forward Surgery

Military surgery, a subset within the art and science of surgery, is designed to carry out a specialized and highly significant mission under the adverse conditions of war. The mission of military surgery differs from civil sector surgery in that it is limited to emergency surgery that is performed on a mass production basis in what may amount to severely limiting circumstances. Stated another way, the military medical officer does what must be done rather than what could be done to the casualty before either returning him to his unit or rendering him transportable to the next higher echelon of medical care. To achieve these objectives, the military surgical care system depends upon an organized pre-hospital treatment and medical evacuation system and utilizes somewhat different and successively staged techniques to treat the penetrating, perforating, and blast injuries of the battlefield. These wounds and their method, of management differ from those of a community practice in which the preponderance of surgery is elective and the majority of trauma is blunt. The additional necessity of haste in caring for the continuous flow of bat-de casualties does not mean that military surgery is carried out in an atmosphere of confusion and disorder or that standard principles of treatment are abandoned. On the contrary, as all past military history shows, intelligent planning and appropriate training in anticipation of the needs of the battlefield have resulted in enviable and ever-improving military medical results.

The currently employed, phased concept of wound management was developed, to a large extent, by Colonel Edward Churchill during World War II. *Initial surgery,* if necessary, rendered the casualty *transportuble* via rapid evacuation to a rear hospital for *repurutivesurgery* The initial surgical effort at the forward facility, by definition, was not complete surgery, but rather "that initial effort required to save life and limb, prevent infection and render

the casualty transportable.... Surgical procedures not essential to wound management at that time may make a transportable patient non-transportable and are to be avoided." This concept of wound management allowed forward hospitals to be more mobile and concentrated more resource-intensive casualty care far to the rear in secure base areas where evacuation hospitals were not required to move with changing tactical situations. This phased approach to the management of war wounds has withstood the test of time However, the newer technologies of warfare will inevitably increase the depth and breadth of the modern battlefield. Fundamental changes in the nature of warfare will dictate certain alterations in the way medical assets accomplish their missions.

What are the missions of the combat commander's medical assets? And what are the relative priorities of those medical missions? The conservation of the army's fighting strength is clearly the primary goal. This goal is achieved by accomplishing several interwoven goals, listed not necessarily in rank order of importance: the maintenance of the health of the command, the prevention of loss of the fighting strength to disease, the very positive contribution to high morale and promotion of the individual soldier's willingness to fight by establishing a visibly creditable medical system, the provision of timely and efficient evacuation of casualties from the battlefield, and the preservation of life and limb.

How one structures his combat medical care delivery system will depend in large measure upon the nature of the war, the quantitative and qualitative aspects of the casualty load and the medical personnel, logistical and physical plant capabilities. If the nature of the war allows, sophisticated medical facilities can be positioned very near the wounded soldier. If not, the soldier must be moved considerable distances to the well-equipped, relatively immobile "state-of-the-art" surgical hospital. As a general rule, as the medics increase their technical capabilities, they do so at the price of increased requirements for complex equipment, which in turn requires increased lift. These increased cube and gross weight medical airlift requirements compete with combat arms lift requirements. Combat hospitals are already large, bulky, and difficult to move. Highly sophisticated hospitals in the battle zone could encumber the combat commander, restrict his freedom of movement, and at times become a liability rather than an asset. A battlefield medical system must be a compromise between

what is best for the soldier and what is best for the conduct of the battle The basic objective is the realistic minimization of the loss of life and limb.

Examples of two different approaches to combat casualty care can be drawn from World War II. The medical system of the German Army in Russia in 1941 was designed to evacuate the seriously wounded well to the rear and to care for the lightly wounded at the divisional level. This approach required only half as many medical personnel and achieved higher return-to-duty rates than did the U.S. Army's system in France in 1944, because the German system was intentionally designed for return to duty. The American system, on the other hand, returned proportionately fewer casualties to their combat units, but salvaged many more lives because of the capability to perform lifesaving surgery further forward. The ideal system for the modem battlefield must be optimized to maximize return to duty without sacrificing life or limb.

In the event of a sudden, so-called "come-as-you-are" war, medical channels that return soldiers to duty may be the only functional personnel replacement system during the first few weeks of a lightning war. In this sort of scenario, it is of critical importance to the war effort that lightly wounded soldiers who do not require hospitalization be treated at or returned to their divisional areas if they can be held there without encumbering their combat commanders. We refer here to soldiers who are mobile and quite capable of defending themselves, but not yet ready to return to the fire fight. These valuable personnel assets are already trained, are battle-hardened, and are quickly available as opposed to untried replacements who must be transported from a distant homeland. The combat medical system of the short, lightning war must not be allowed to become a giant evacuation conduit through which trained, blooded soldiers pour out of the theater. The medical officer must "fix forward," for as has been said, "The farther a wounded soldier is evacuated from the combat zone, the greater will be his number of noneffective man-days and the less will be his motivation to return to combat duty? In the near-chaos of the mass casualty situation, medical officers must be ever-vigilant in their search for the lightly wounded, but heavily bandaged, casualty who can be returned to his unit rather than further retrograded through medical evacuation channels.

As alluded to earlier, advances in technology are changing the

nature of modern warfare. The battlefield of the future will be broader, deeper, more fluid, more destructive, and more resource-hungry. The concepts of phased wound management and initial and reparative surgery will certainly persist but the distances between echelons may be significantly increased. Resource-intensive facilities that are staffed to perform reparative surgery will, of tactical necessity, be deployed considerably further to the rear. The same could pertain, although to a lesser extent, to facilities that perform initial wound surgery. The same technology that increases the depth of the battlefield and of necessity forces fixed surgical capabilities further to the rear may also provide practical solutions. A new tiltrotor aircraft, with the vertical take-off and landing capabilities of a conventional helicopter is currently undergoing flight testing. This twin-engined craft, in the air ambulance configuration, is capable of picking up and moving twelve litter cases plus three medical attendants at speeds of up to 300 nautical miles/hour with a range of 1,000 nautical miles.

It is not inconceivable that on a highly mobile battlefield, initial wound surgery may have to be performed very far forward under extremely austere, even primitive, conditions within enveloped enclaves. Surgical teams carrying their equipment in rucksacks on their backs may be tasked to perform only that emergency life-saving surgery required to make the casualty transportable Surgical teams of this sort would be assigned to airborne or air assault units that habitually operate in isolation for short periods of time Other surgical capabilities would be brought forward and deployed as the situation requires and permits.

Another aspect of the recently envisioned "fix forward" ap preach to combat casualty care is the two-track flow of casualties. This system would divide the casualty flow at the division-level medical facility (Figure 1).

Casualties who are not expected to return to duty within the time constraints of the theater evacuation policy are passed through a chain of evacuation hospitals and out of the theater as rapidly as their conditions will permit. Only that surgery which is necessary to permit transport to the next hospital in the chain-generally planned as six-hour bed-to-bed moves-would be performed. These hospitals would serve as trauma centers and be equipped and staffed to stabilize casualties for transport back to a secure base. If that secure base were in the continental United States, the last hospital in the theater evacuation chain would do
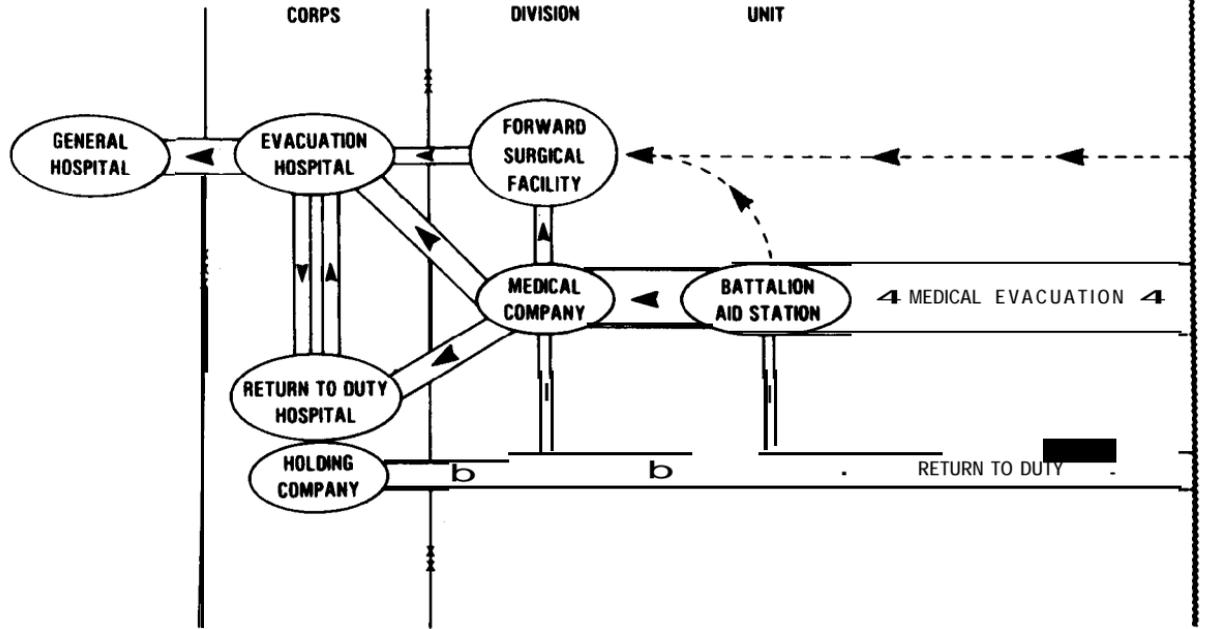
FIGURE I.-Generic organizational diagram for combat casualty care. Width of pathway is proportional to size of CASUAL ty populations. Broken line indicates potential for aeromedical evacuation from the field of the critically injured. Triage identifies three groups of casualties: 1) those needing urgent surgery, 2) those likely to have an early return to duty, and 3) those requiring evacuation from the combat zone.

cn

whatever was necessary for a 24.hour bed-to-bed move. Current evacuation doctrine restricts combat zone hospital stays to seven days and communication zone hospital stays to thirty days. If it appears that the casualty will require more than seven days of hospitalization in a combat zone hospital, he will be evacuated as rapidly as is safely possible to a communications zone facility. If that casualty will not be ready for return to duty within SO days at this level, he is expediently evacuated to the continental United states.

   Casualties on the other track (those whose wounds would allow return to duty within the theater evacuation policy time constraints) would be moved to a hospital facility intended to encourage early return to duty. The expectation in this facility would be that each patient will return to his unit and the war When these soldiers no longer require the daily attention of medical officers or nurses, they would be transferred to medical holding companies. These medical holding companies will be minimal self-care facilities with austere staffing and equipment.

   This model allows the medical planner to better tailor the medical force that must be deployed. The number of resource-intensive hospital beds would more closely match the actual requirements The evacuation policy timeframe could be increased with the only requirement being the addition of relatively inexpensive return-to-duty hospitals and medical holding companies to the theater. The critically injured (those requiring the greatest care) would continue to pass through the evacuation or general hospital chain and be air-evacuated expeditiously. Those casualties retained in the theater under a new, longer evacuation policy would necessarily be the least seriously wounded or ill of the population formerly evacuated. Their wounds or illnesses would require a longer period of time to resolve than those retained under the old, shorter evacuation policy timeframe; however, they would not require the personnel- and equipment-intensive environment of evacuation-type hospitals. They would be shunted to and treated in the return-to-duty (combat support) hospital and convalesce in medical holding companies.

   The medical planner of the future may be faced with a battlefield of such great depth that casualties may have to be moved very great distances to reach secure base areas where reparative surgery can be performed. The feasibility of safely accomplishing prolonged moves of fresh casualties has been demonstrated

several times in the recent past,In the 1973 Arab-Israeli War, more than 4,000 stable casualties were evacuated approximately 150 miles from the Sinai to central Israel for definitive care. Most arrived within 24 hours of being wounded. In the Falklands Campaign, the British evacuated more than 500 casualties to the United Kingdom by way of Uruguay and the Ascension Islands. This 8,000 mile trip required 20 hours. The majority of casualties arrived within 48-72 hours of wounding. Following the 1983 terrorist bombing of the U.S. Marine Barracks in Lebanon, 55 casualties were evacuated directly to USAF medical facilities in West Germany within hours of injury. Although there was some criticism of this move, an examination of patient outcomes sug gest that the results would probably have been the same had they been taken to closer medical facilities.

ECHELONS OF MEDICAL CAKE

A basic characteristic of the organization of modern military medical services is the distribution of medical resources and medical capabilities to facilities at various levels of location and function, which are referred to in formal military parlance as "'echelons". Echelonment is a matter of principle, practice, and organizational pattern, not a matter of rigid prescription. Scopes of function may be expanded or contracted on sound indication; one or more echelons may be bypassed on grounds of efficiency or expediency, and formal organizational structure will differ with time and among various armed forces. The following general pattern; however, is usually apparent.

ECHELONS OF COMBAT MEDICAL CARE

1. At the first echelon (Level 1) a "buddy" (or the trained medical aidman) provides first aid and conveys or directs the casualty to the battalion aid station. The U.S. Army, in an effort to upgrade "buddy aid", provides all basic trainees with 16 hours of first aid training. A more recent initiative identifies one member of each crew-served weapon system (air crew, tank crew, mortar crew, weapons team, etc) with 40 additional hours of first aid training. Because of the proximity of the aid station to the battlefield, its mission is simply to provide essential emergency care allowing the

return of the soldier to duty or the preparation of the casualty for evacuation to the rear. In the former case, this care would be minimal, whereas in the latter case care might include the establishment of an airway the control of hemorrhage, the application of field dressings, the administration of an analgesic, or the initiation of intravenous fluid administration.

2. Second echelon care (Level 2), depending on the circumstances, is rendered at an assembly point, a clearing station, or the brigade medical company. Here the casualty is examined, and his wounds and general status are evaluated to determine his priority, as a single casualty among other casualties, for return to duty or continued evacuation to the rear. Emergency care, including beginning resuscitation, is continued and, if necessary, additional emergency measures are instituted, but they do not go beyond the measures dictated by the immediate necessities. This function is performed typically by company-size medical units organic to the brigade or division. These units have the capability to hold and treat the most lightly wounded.

3. At the third echelon of care (Level 3), the casualty is treated in a medical installation staffed and equipped to provide resuscitation, initial wound surgery, and postoperative treatment. Casualties whose wounds make them nontransportable receive surgical care in a hospital close to the clearing station. Those whose injuries permit additional transportation without detriment receive surgical care in a hospital farther to the rear.

4. In the fourth echelon (Level 4) of medical care, the casualty is treated in a general hospital staffed and equipped for definitive care General hospitals are located in the communications zone, which is the support area to the combat zone or army area. The mission of these hospitals is the rehabilitation of casualties to duty status. If rehabilitation cannot be accomplished within a predetermined holding period, these casualties are evacuated to the Zone of Interior (Level 5) for reconstructive surgery and rehabilitation.

It is important to remember that there is a logistical problem in the care of all battle casualties. Military medical facilities must always be in a state of readiness to receive an influx of fresh battle casualties or to move according to the dictates of the tactical situation, though this necessity in no way lessens the responsibility of the medical service for providing for the medical care and disposition of casualties. Despite the exceedingly unfavorable circumstances of war, movement of casualties from echelon to

echelon in the forward area is usually accomplished within a matter of hours. Distances, which are usually measured in terms of ground transportation or flight time, vary with the local tactical situation, but as a general rule, casualties are moved a distance of many miles between the battlefront and a hospital.

Because the individual who has been wounded in combat is cared for by multiple surgeons at different echelons of medical care and because hospitals at different echelons are usually separated by great distances, the consultant system has been developed. Certain individuals, selected as consultants because of their expertise in a given specialty field, have been utilized to evaluate and correlate end results noted in hospitals of the communication zone with initial surgical care provided in the combat zone The responsibility for evaluating the effectiveness of combat surgery and for feedback to the individual surgeons in forward hospitals resides with these consultants To augment the consultant system, professional meetings of practicing surgeons from both the combat and the communication zone hospitals have been utilized to evaluate the results and to exchange views on methods of surgical care During the Vietnam conflict, annual War Surgery Conferences were held to bring American surgeons at all levels and from all branches of the armed services up to date on the latest information and results in the care of the wounded.

PART1

`ljpes of` *Wounds and Injuries*

Missile-Caused Wounds

INTRODUCTION

Previous contributions to earlier editions of this handbook devoted considerable effort to differentiating between the magnitude of injury caused by "ordinary" versus "high" velocity missile wounds. To a certain extent, as a result of experience gained in recent conflicts and to a greater extent based on wound ballistic research performed over the past decade, new and somewhat different concepts are evolving. One very fundamental concept is that the high-velocity wound is not necessarily a totally different entity, as had been previously thought.

Certain misconceptions continue to be associated with the high-velocity projectile One misconception concerns the very develop ment of high-velocity weapons. The explanation usually encountered is that these weapons were developed to deliver greater wounding power and higher lethality. Proponents offer the kinetic energy formula in support of their position. Weapons developers state that the real reason that certain countries shifted to low-weight, high-velocity projectiles was that their soldiers (who were not the best marksmen) tended to conserve their ammunition and were not discharging their weapons until the enemy was close at hand. It was reasoned that an automatic weapon would obviate some of these shortcomings. From a practical standpoint, the automatic weapon, with its increased requirement for ammunition, necessitated lighter weight ammunition. To compensate for the loss in missile mass, if wounding power was to be maintained, it was necessary to increase missile velocity. These tradeoffs resulted in considerably less recoil, making it easier to maintain the sight picture on repetitive shots, resulting in increased accuracy. The lighter cartridge allowed the individual infantryman to carry the increase in basic load of ammunition (more rounds, same weight) and allowed the maneuver element to present the enemy with greater and more sustained firepower.

These are important considerations as the spectrum of warfare shifts more to the left, such as with guerilla-type warfare in which small units engage one another at isolated points, usually at considerable distances from strong points that offer safe haven and resupply. In circumstances such as these, the ability to carry double or triple the basic ammunition load allows small units to take advantage of the increased and sustained firepower that lighter, higher velocity missiles offer. It was for this reason that the current generation of high-velocity weapons was designed, rather than to develop a weapon that inflicts a more severe wound.

It is vigorously affirmed by some that velocity, almost to the exclusion of mass, is the operative factor in wounding power. From a theoretical standpoint, velocity can be the dominant determinant of kinetic energy (KE); doubling the mass only doubles the KE, whereas doubling the velocity quadruples the KE. However, from a practical standpoint, doubling the velocity is very difficult to achieve The M-16 represents only a 10% increase in velocity over the M-14 it replaced. On the other hand, quadrupling the mass is easy. Switch from a .22 to a . 4 caliber projectile and you immediately square the mass; then double the length of the projectile so that it flies straighter and you now have an eightfold increase in KE at the same velocity.

There are some who mistakenly believe that only the more modern, higher velocity projectiles produce temporary cavitation. The X370-1890 Vetterli deforming bullet, typical of the military rounds utilized at that time, is depicted in Figure 2. It should be noted that in spite of its relatively low velocity, only 1,357 FT/SEC a very substantial temporary cavity is produced. The formation of a temporary cavity is not a new phenomenon associated with modem high-velocity weapons.

VETTERLI **10.4mm** L R N

vv – 1357 fn (414 ma)
W t - 3 0 0 g r **(19.4gm)**

Temporary Cavity

Permanent Cavity

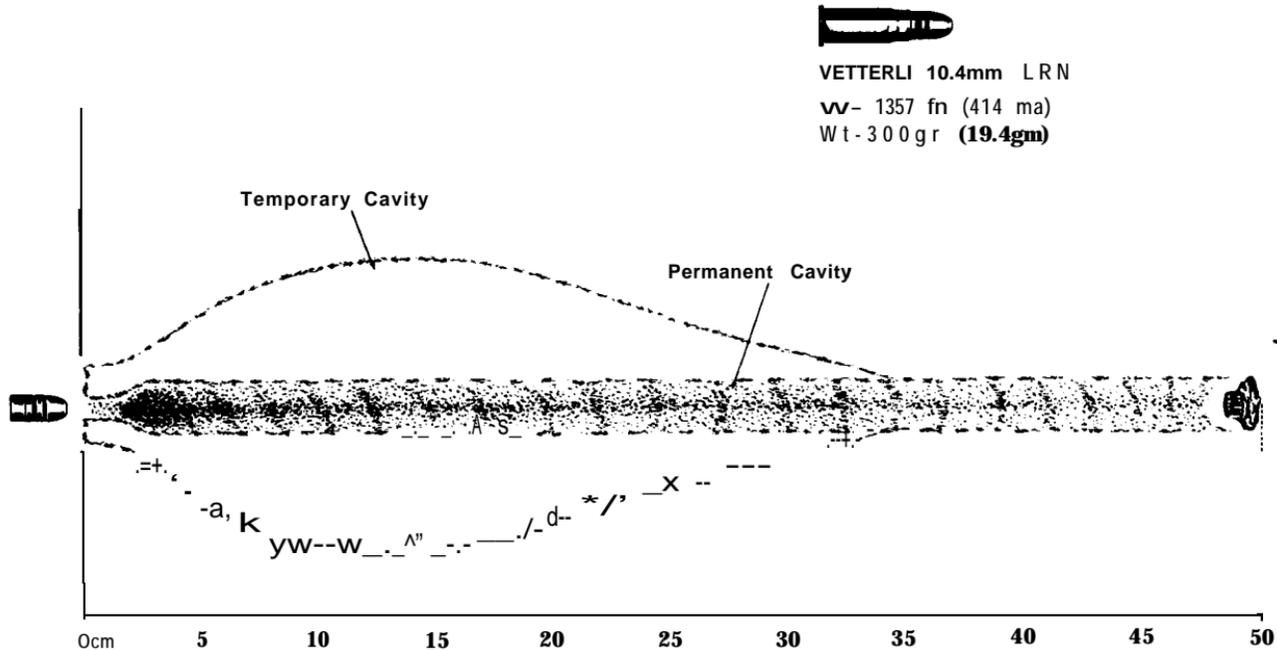Ocm   5   10   15   20   25   30   35   40   45   50

FIGURE P.-Wound Profile. This large lead bullet, used by the Swiss and Italian Armies (1870-1890), is typical of the projectiles used by military forces in the latter half of the 19th century. It produces a very substantial temporary cavity despite its "low" velocity.

Some maintain that a larger-exit-than-entry wound is evidence of the devastating potential of increases in velocity. While this in fact may be the case (and exit wounds are larger than entry wounds in about 60 percent of the cases), the difference in the size of the wound of entry and exit is not per se directly attributable to velocity since the velocity is greater at the smaller entry wound and lesser at the greater exit wound. The larger exit wound, when present, is caused by projectile yaw, by projectile fragmentation, or as a result of multiple secondary bone fragment projectile. Projectile yaw represents a deviation of the longitudinal axis of the bullet from its line of flight. Rifling within the gun barrel impacts a spin to the bullet, which stabilizes the projectile's flight in air, preventing yaw. The stability imparted by rifling is not enough to prevent yaw in tissues or when the missile passes through foliage or other intermediate objects. Tumbling simply represents yaw that has progressed to a full lSO", at which point the center of mass results in stabilized base-forward flight.

The point to be borne in mind is that while the high-velocity projectile has the potential for higher energy transfer with subsequent greater tissue disruption, this may not always be the case. Whereas the military surgeon should have some familiarity with wound ballistics and the "worst case" result of high-velocity missile wounds, the surgeon is better advised to concern himself with the individual wound that confronts him rather than with the variable potential of the weapon. On the other hand, wounds of the brain, liver, and heart caused by high-velocity projectiles are catastrophic in nature.

The study of wound ballistics attempts to predict and to analyze the damage that will be sustained by the different tissue types when struck by missiles of varying sizes, shapes, weights, and velocities. Missiles that penetrate the human body disrupt, destroy, or contuse tissue, invariably resulting in a contaminated wound. Subsequent triage and treatment decisions are based upon an estimation of the type of wound, the location of the wound, and the amount of tissue disruption. Objective data from the physical examination and appropriate roentgenographic studies of the casualty provide the information necessary to make these decisions.

MECHANISMS OF WOUNDING

The penetrating missile or fragment destroys tissue by *crushing* it as it punches a hole through the tissue (Figure 3). This hole or missile track represents the so-called *jwrmanent cavity*. The cross-sectional area of the missile track is comparable to the presenting area of the missile and its dimensions are roughly the same for all soft tissues.
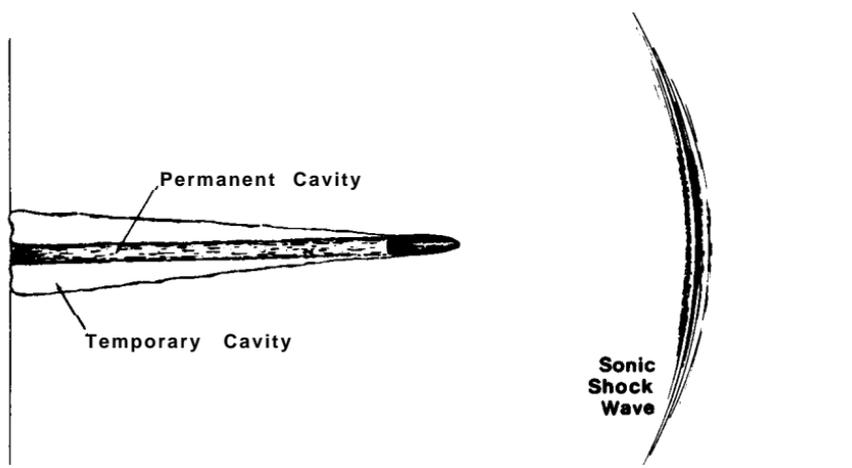

FIGURE 3.-The sonic shock wave and temporary cavity. Diagram of bullet passing through tissue showing sonic shock wave and the formation of a temporary cavity by outward stretch of the permanent cavity.

After passage of the projectile, the walls of the permanent cavity are temporarily stretched radially outward. The maximum lateral tissue displacement delineates the temporuq *cavity*. Any damage resulting from temporary cavitation is due to *stretching* of the tissue Resistance or vulnerability to stretch damage depends mostly on tissue elasticity. The same stretch which causes only moderate contusion and minor functional changes in relatively elastic skeletal muscle, can cause devastating disruption of the liver. The result of temporary displacement of tissue is analogous to a localized area of blunt trauma surrounding the permanent cavity left by the projectile's passage.

The typical wounding potential of a given missile can be assessed by measuring the two types of tissue disruption it produces.

A method developed by U.S. Army researchers captures the entire path of missiles fired through gelatin tissue-simulant blocks. Measurements taken from the gelatin are used to illustrate the location and the extent of both crush and stretch types of tissue disruption on a drawing or "Wound Profile". The scale included on each profile can be used to measure the extent of tissue disrup tion at any point along the path of the projectile. This method allows comparison of the wound profiles of different wounding agents.
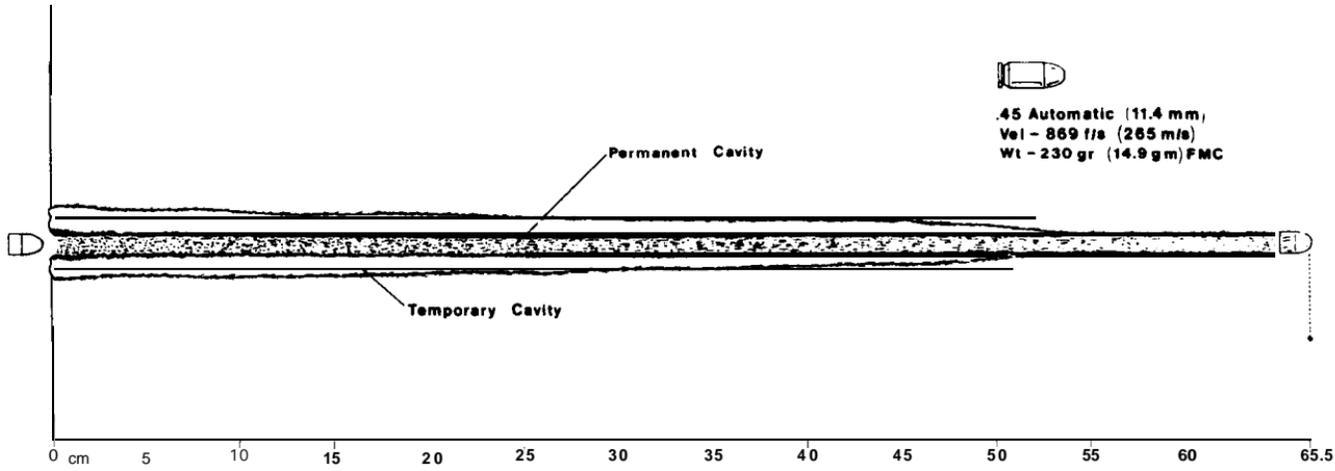
The sonic shock wave seen at the far right of Figure 3 precedes the projectile's passage through the tissue. Although the magnitude of the sonic wave may range up to pressures of 100 at- mospheres, its duration is so brief, about 2 microseconds, that it does not displace tissue. It has no detectable harmful effect on tissues.

PROJECTILES

The following is a compendium of the characteristics of the more commonly encountered small arms projectiles. Note that the projectiles depicted in Figures 4-9 do not deform upon passing through soft tissues, whereas those in Figures lo-14 either deform or fragment, forming secondary bullet fragments. Projectile defor- mation, fragmentation, yaw and individually or collectively in- crease the resultant degree of tissue disruption.

45 AUTOMATIC-This full-metaljacketed military bullet (Figure 4) is one of few that does not yaw (turn the long axis in relation to direction of travel) significantly in soft tissue. Lack of yaw, coupled with the large mass of this bullet, results in deep penetration. The crush tissue disruption remains nearly constant throughout the bullet path. Temporary cavity stretch is maximal near the point of entry, gradually diminishing with penetration, but with this bullet type and velocity the temporary cavity is too small to show a stretch wounding effect.

22 LONG RIFLE-This commonly used rimfire bullet (Figure 5) yaws through 90° and ends up traveling base forward for the last half of its tissue path. The crush tissue disruption increases with yaw angle, reaching its maximum when the bullet is travel- ing sideways. Temporary cavity stretch increases with increasing bullet yaw, much the same as a diver hitting the water.makes a

.45 Automatic (11.4 mm)
Vel - 869 f/s (265 m/s)
Wt - 230 gr (14.9 gm) FMC

Permanent Cavity

Temporary Cavity

| 0 cm | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65.5 |

FIGURE 4.-45 Autumuztic. This was the standard U.S. Army pistol until recently. The short, round.nosed, full-metal-cased bullet does not deform or yaw significantly in tissue but penetrates deeply.

larger splash as his body angle to the water surface increases. Even
at the point of maximum bullet yaw, the temporary cavity produc-
ed remains too small to add a detectable stretch wounding effect.

.22 Long **RIFLE** 5.56 m m
Vol- 1122 ffs (342 m/s)
Wt – 40gr (269 gm) load
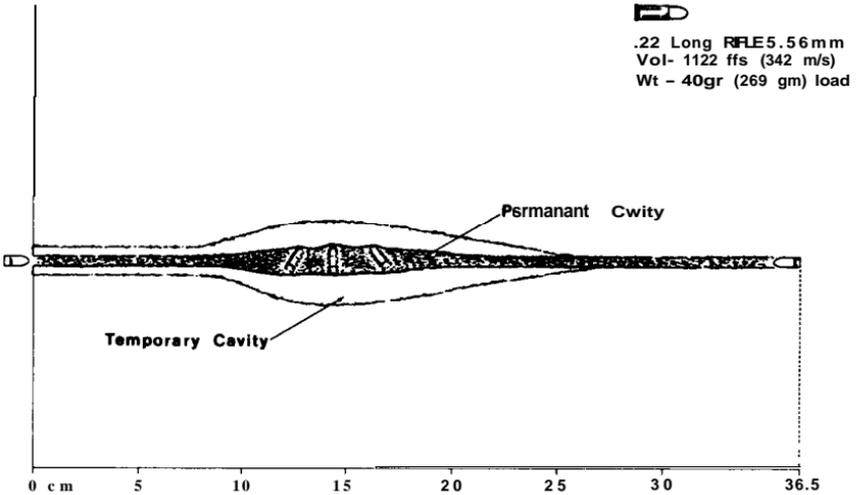
FIWRL 5.-22 Lung *RtJkz* **This solid lead round-nosed bullet yaws through 90° and
travels base-forward for the last half of its tissue path.**

38 SPECIAL-This round-nosed lead bullet (Figure 6), like the
45 Automatic (Figure 4) and the 22 Long Rifle (Figure 5), produces
its wounding almost solely by the crush tissue disruption
mechanism. Although still too small to show an observable stretch
wounding effect, the maximum temporary cavity is of 20% greater
diameter than that made by the 22 Long Rifle despite the fact that
its velocity is 40% less.

9 MM PARBELLUM-This bullet is widely used in both pistols
and submachine guns. As with the full-metal-jacketed bullet type,
it produces a profile that resembles that of the 38 Special (Figure
6), but the maximum temporary cavity is about 2 cm larger in
diameter and will show some stretch effects (radial splits) in less
elastic, more susceptible tissues such as those of the liver.

7.62 NATO FMC-FMC is the abbreviation for full-metal-cased,
which is a synonym of full-metal-jacketed. This refers to the harder
metal covering of the bullet core. This full-metal-jacketed military
bullet (Figure 7) shows the characteristic behavior in tissue
observed in non-deforming pointed bullets. It yaws through 90°
and, after reaching the base-forward position, continues the rest

38 Special f.357 inl LRN
Vel-788 fro (24OmrsI
W I-158gr (10.2gml

Temporary Cavity

Permanent Cavity
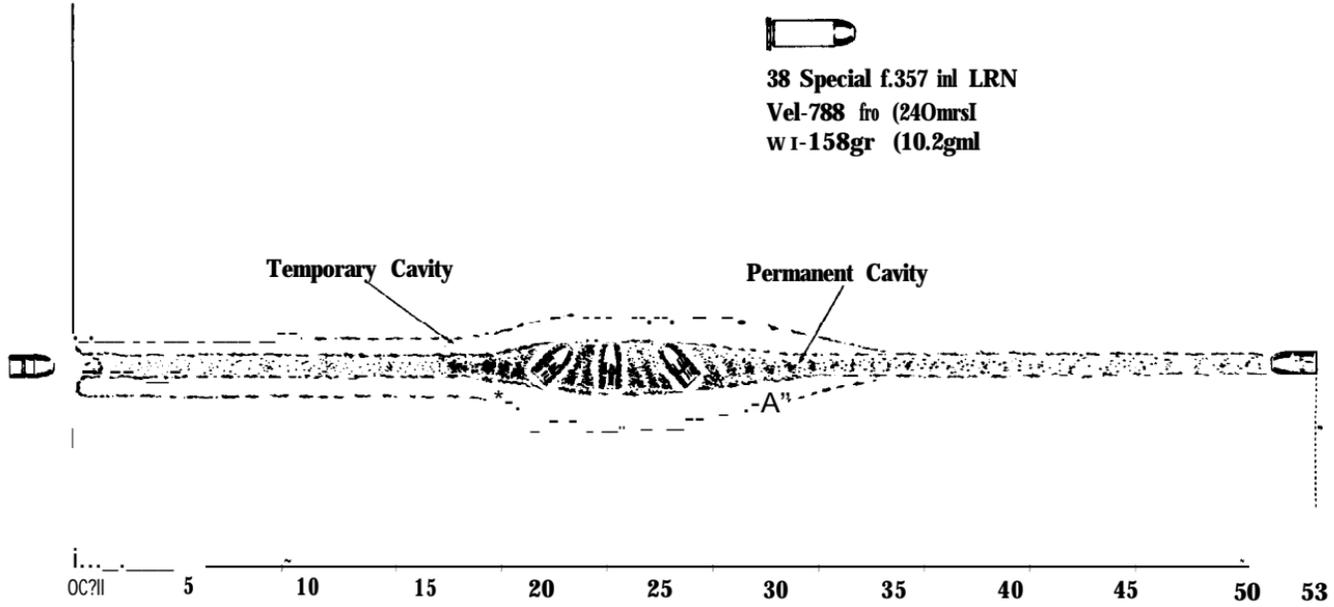
-A"

OC?II 5 10 15 20 25 30 35 40 45 50 53

FIGUKE 6.-38 Special Lead, round-nosed bull&even out of ten of these bullets yawed through 90° and traveled base forward for the latter part of their tissue paths as shown. Three shots yawed to about 803 then straightened out and traveled point-forward for the remainder of their paths.

of its path with little or no yaw. The bullet is stable traveling base first in tissue, since this position puts its center of mass forward. The rotation imparted to the bullet by the rifled gun barrel is sufficient to cause point-forward travel in air, but not in tissue where such factors as bullet shape and location of center of mass outweigh rotation effects. The tissue disruption in the first 15-18 cm of bullet penetration, during which the streamlined bullet is still traveling point forward, is minimal. At 20-35 cm, however, in which bullet yaw is marked, a large temporary cavity is produced. If the bullet path is such that this temporary cavity occurs in the liver, this amount of tissue disruption is likely to make survival improbable

AK-47The Russian Assault Rifle's full-metal-cased military bullet (Figure 8) travels point forward for 25-27 cm in tissue prior to beginning significant yaw. Wounds from this rifle are familiar to surgeons who served in Vietnam and have been documented by the WDMET study of wounds from that conflict.

AK-74This new generation, smaller caliber Russian Assault Rifle (Figure 9) follows the example set by the USA with the M-16. The full-metal-cased bullet designed for this weapon has a copper-plated steel jacket, as does the bullet of its predecessor, the AK-47. A unique design feature of the AK-74, however, is an airspace (about 5 mm long) inside the jacket at the bullet's tip. The speculation that this air-space would cause bullet deformation and fragmentation on impact proved to be unfounded, but the air-space does serve to shift the bullet's center of mass toward the rear. This bullet yaws after only about 7 cm of tissue penetration, assuring an increased temporary cavity stretch disruption, even in many extremity hits. The typical exit wound from a soft-tissue thigh wound (12 cm thick) is stellate, with skin split measuring from 9-13 cm across. The underlying muscle split is about half that size. The bilobed yaw patterns shown in the profiles of the AK-47 and the AK-74 represent what is seen in four-fifths of test shots. In the rest, the bullet reaches 90° of yaw and continues to 180° or the base, forward position, in one cycle. Whether there are one or two yaw cycles does not influence the point of prime clinical relevance-the distance the bullet travels point forward before yaw. The bilobed yaw pattern depicted in Figures 8 and 9 results from initial bullet yaw returning to zero yaw (first lobe), but then yawing a second time (second lobe) to 180' where the center of mass

7.62 mm NATO
Vel- 2830 f/s (862 m/s)
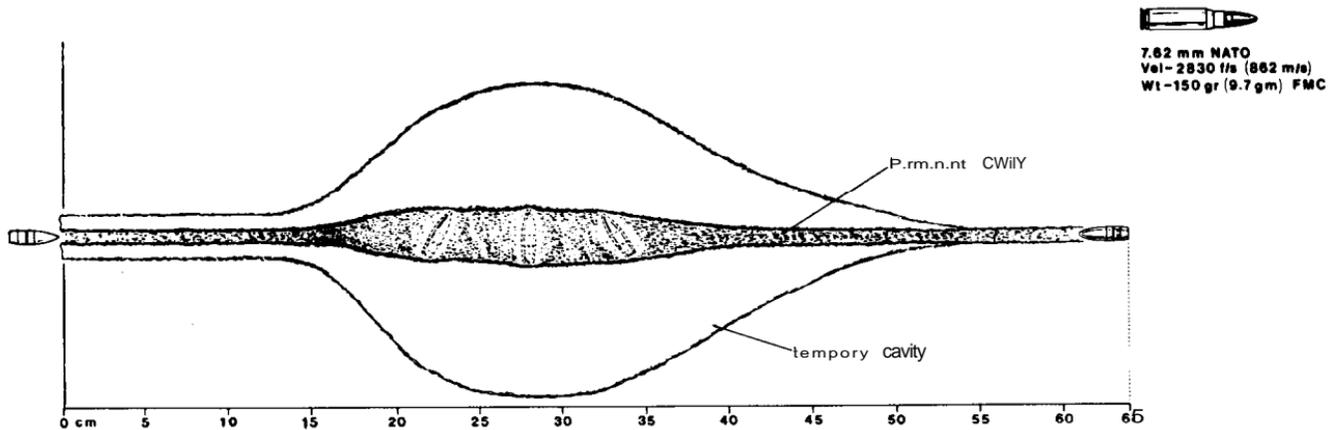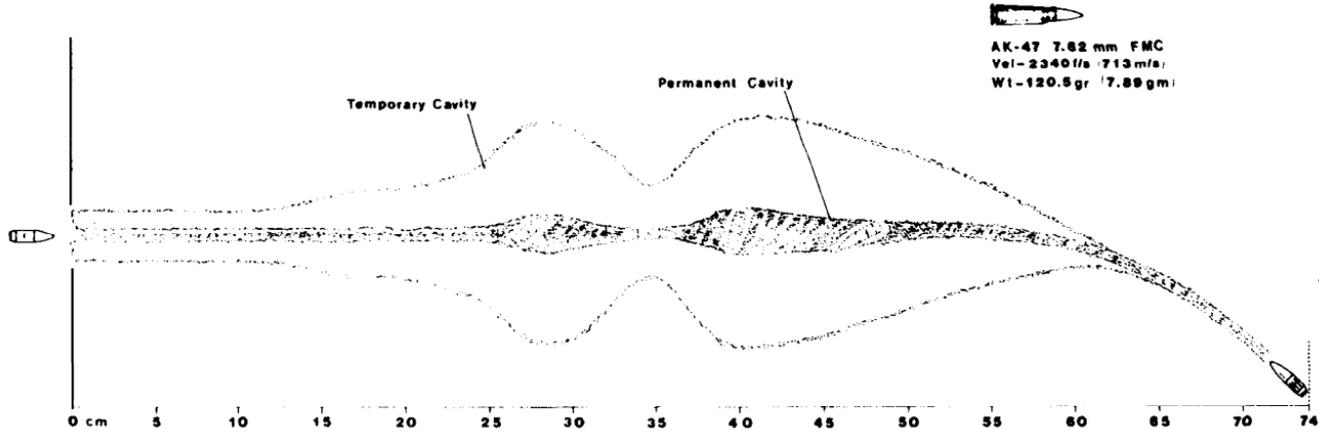Wt-150 gr (9.7 gm) FMC

figure **7.-7.62** *NATV cartridge withjidl-metal-cased militq bullet.* **This was the standard U.S. Army rifle until the adoption of the M-16 in the 1960's. It is still used in snipers' rifles and machine guns. After about 16 cm of penetration, this bullet yaws through 90' and travels base forward. A large temporary cavity is formed and occurs at point of maximum yaw.**

AK-47 7.62 mm FMC
Vel-2340f/s (713m/s)
Wt-120.5gr (7.89gm)

Temporary Cavity

Permanent Cavity

0 cm   5   10   15   20   25   30   35   40   45   50   55   60   65   70   74

FIGURE 8. *A K 47.* **This was the standard rifle used by the communist forces in Vietnam and is used today very widely throughout the world. The long path through tissue before marked yaw begins (about 25 cm) explains the clinical experience that many wounds from this weapon resemble those caused by much lower velocity handguns.**
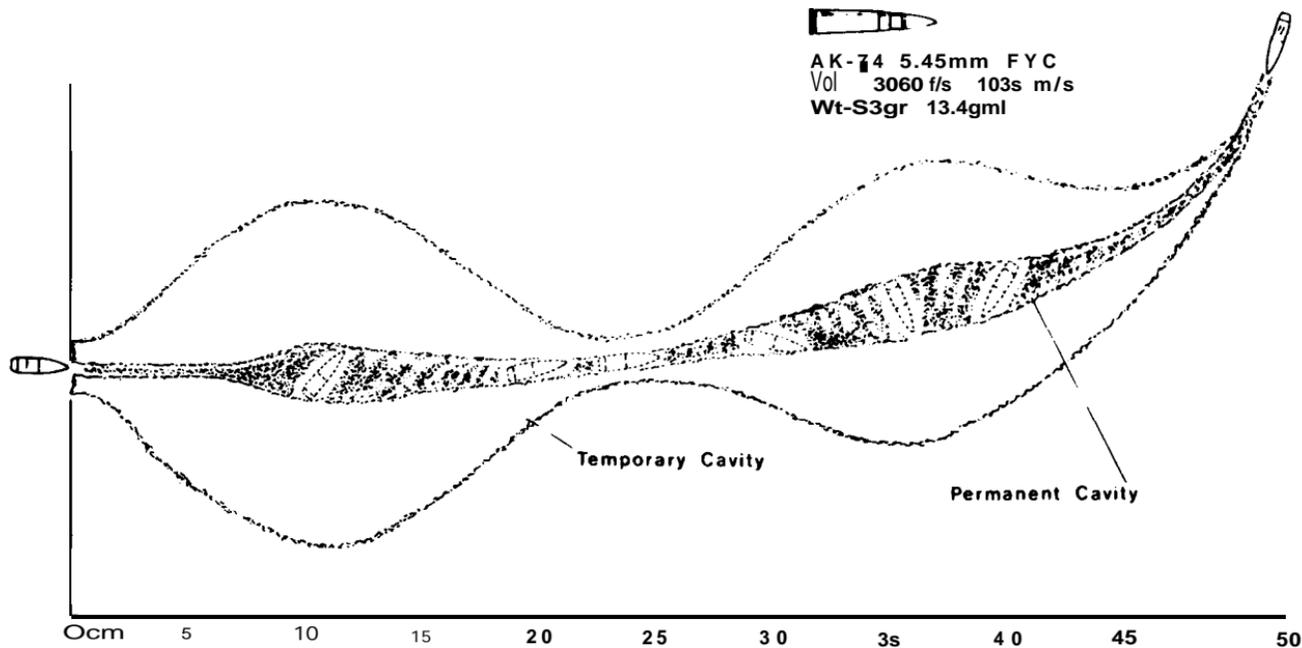
AK-74 5.45mm FYC
Vol 3060 f/s 103s m/s
Wt-S3gr 13.4gml

Temporary Cavity

Permanent Cavity

Ocm   5   10   15   20   25   30   3s   40   45   50

figure: **9.-M 74. This is the Russian contribution to the new generation of smaller caliber assault rifles. The bullet does not deform or fragment in soft tissue but yaws early (after about 7 cm of penetration). As this bullet strikes soft tissue, lead flows forward filling the air space inside the bullet's tip. Xrays of recovered f&d bullets show that this "internal defer mation" produces an asymmetrical bullet which may explain the unusual curve of close to 90° made by the bullet path in the latter part of its penetration.**

stabilizes the projectile in base forward travel.

357 MAGNUM JSP-The jacketed soft-point bullet (Figure 10) and the jacketed-hollow-point bullet flatten their tips on impact. This "expansion" or "mushrooming" (in which the final bullet shape resembles a mushroom) results in a doubling of effective bullet diameter in tissue, and allows the bullet to crush four times as much tissue (n times radius squared equals the cross section area of the bullet which impacts tissue). This conversion of the bullet to a non-aerodynamic shape causes the same sort of increased temporary cavity tissue stretch as does the yawing of a bullet. The maximum temporary cavity produced by the expanding bullet occurs at a shallower penetration depth than that caused by the full-metal-jacketed military type bullet. This soft-point pistol bullet is typical of the type most commonly used by law enforcement agencies in the USA. Its decreased penetration depth, as compared to the depth of penetration of the nondeforming bullets depicted in Figures 2 and 4, decreases the likelihood of the bullet perforating a criminal and going on to injure an innocent bystander.
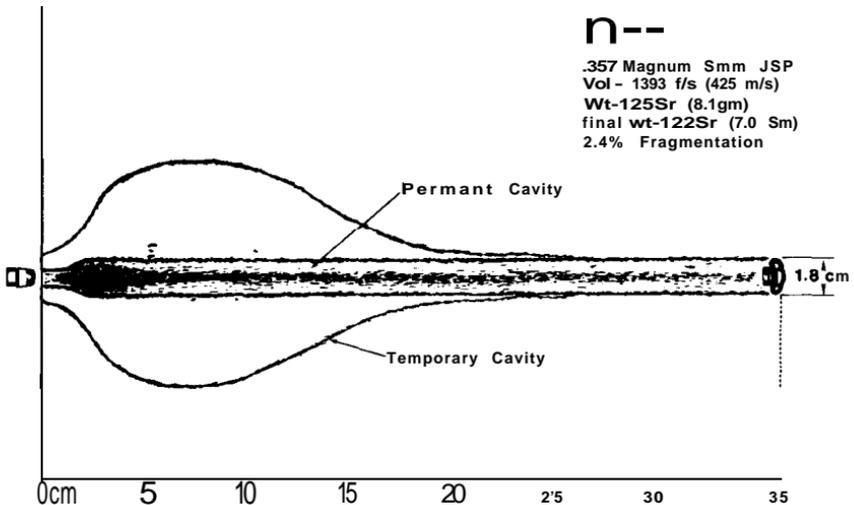
Figure: lo.-357 *Magnum jacketed soft-point pis&ol bullet.* **This expanding bullet is typical of those used by the majority of law enforcement agencies in the USA.**

7.62 SP (SP is the abbreviation for soft-point) The same cartridge case shown in Figure 7, when loaded with a soft-point bullet,

produces the wound profile shown in Figure 11. Changing only the variable of bullet construction causes massively increased tissue disruption compared to that of the full-metal-cased bullet (Figure 7). Bullet expansion occurs on impact as seen with the 357 Magnum pistol bullet (Figure 10); however, the crush in the tissue that results from bullet expansion accounts for only a small part of the large permanent cavity. As this bullet flattens, pieces break off and make their own separate paths of crushed tissue. These bullet fragments penetrate up to 9 cm radially from the bullet path. The following temporary cavitation stretches muscle that has been weakened by multiple perforations. The fragment paths act to concentrate the force of the stretch, increasing its effect and causing pieces of muscle to be detached. This synergistic effect, resulting in the large tissue defect shown in Figure 11, is seen only with bullets that fragment. The 7.62 NATO soft-point is a popular big game hunting bullet, and although shooting accidents are not infrequent with **such rounds, they are rarely seen in the hospital since few victims of torso shots survive.**

22 CAL FMC-This is the M-193 bullet shot from the M-16Al Assault Rifle (Figure 12). The large permanent cavity shown in the profile was observed by many surgeons who served in Vietnam, but the tissue disruption mechanism responsible was not clear until the importance of bullet fragmentation as a cause of tissue disruption was worked out. This military round is fullmetal-jacketed and, as with other bullets of this type, it causes little tissue disruption so long as it remains traveling point forward through tissue. Its average distance of point-forward travel is about 12 cm, after which it yaws to 90°, flattens, and breaks at the cannelure (groove around bullet mid section). The bullet point remains a flattened triangular piece, retaining about 60% of the original bullet weight. The rear portion breaks into many fragments that penetrate up to 7 cm radially from the bullet path. The temporary cavity stretch, its effect increased by perforation and weakening of the muscle by fragments, then causes a much enlarged permanent cavity by detaching muscle pieces. The degree of bullet fragmentation decreases with increasing shooting distance, as striking velocity decreases. At a distance of 80 meters, the bullet breaks in half, forming two large fragments. At ranges in excess of 180 meters, this projectile does not break in two and the wounding capacity and mechanisms are essentially the same as those of the AK-74.

Detached Muscles

Bullet Fragments

Permanent Cavity

7.62 mm SP
Vol - 2923f/s (891 m/s)
Wt-1SOgr (g.7gm)
Final wt -99.7gr (6.46 gm)
35.4% Fragmentation

1.95 cm

Temporary Cavity

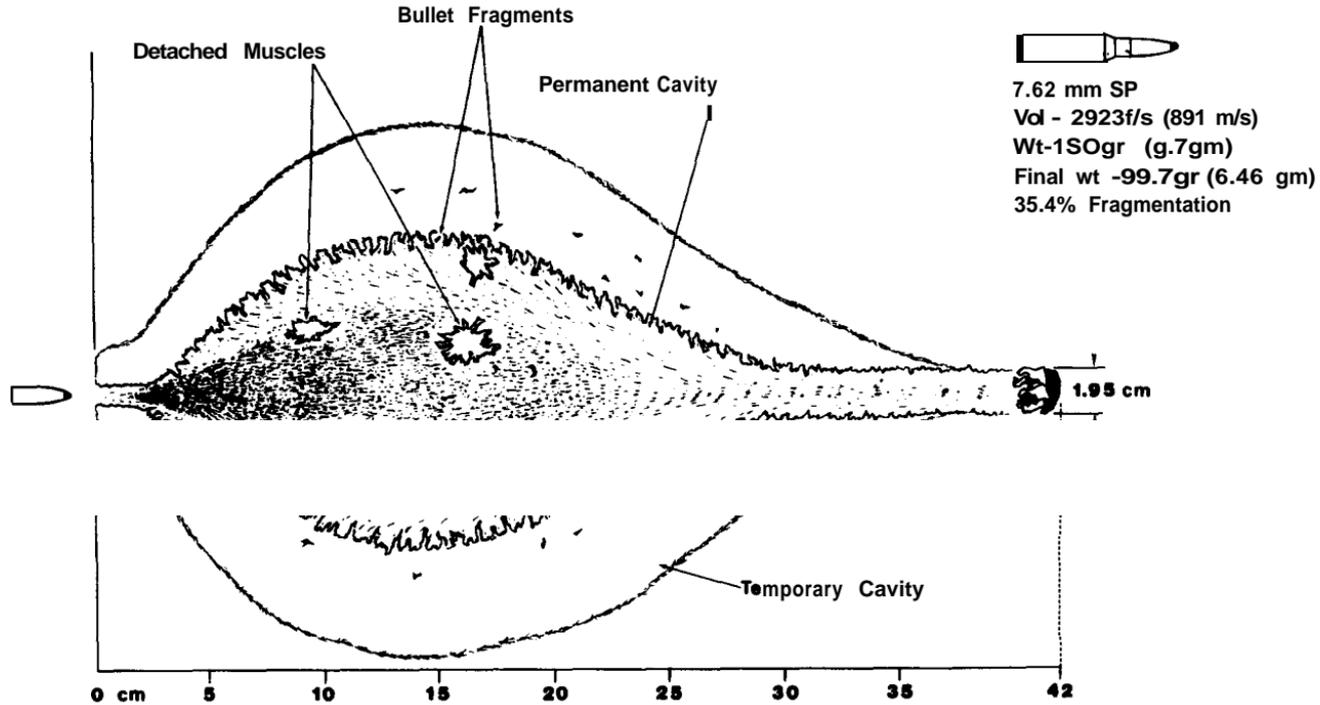0 cm   5   10   15   20   25   30   35   42

FIGURE 11 .--7.62 Soft-point &d&t. **The fragmentation of this bullet is largely responsible for the massive tissue disruption, compared to that produced by the nondeforming military bullet fired from the same cartridge (Figure 7).**
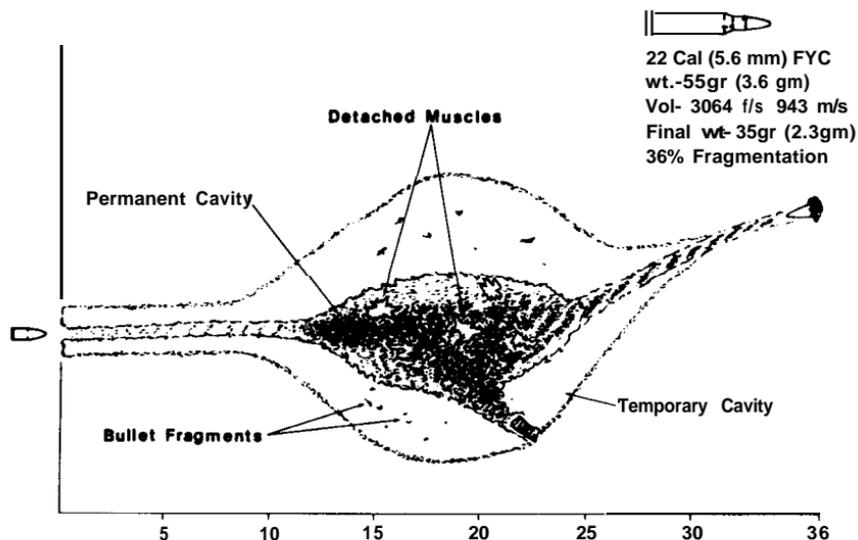
Figure: 12.-22 metal-cased   (M-16   rifle cased M-193 bullet). **This is the standard weapon of the U.S. Armed Forces, although it is soon to be replaced by a new rifle using the same caliber and cartridge but with a longer and slightly heavier (62 grain) bullet.**

M-855 22 CAL FMC-The slightly heavier M-855 bullet shot from the   Assault Rifle will eventually replace the M-193 bullet shot as the standard bullet for the U.S. Armed Forces. The wound profile is similar to that produced by the M-193, although the tip generally does not remain in one piece. The temporary cavity size and location are about the same and any difference in wounds caused by the two would be difficult to recognize.

The smaller bullets of the new generation Assault Rifles (M-193, AK-74, M-855) are susceptible to deflection and disturbance of their point-forward flight by intermediate targets such as foliage. This was not the case with the previous generation of larger and slower projectiles This can result in large yaw angles at impact and a shallower location in the body of maximum tissue disruption. For these bullets that rely on yaw in tissue for their maximum effect, the wound profiles show the average penetration depth at which this yaw occurs.

.224 SOFT-POINT-This 50 grain soft-point bullet is designed for maximum deformation and fragmentation. To produce the wound profile shown in Figure 13, it was shot from the M-16

cartridge case (known as the 223 Remington in civilian shooting parlance). The amount and type of damage caused is about the same as that caused by the military M-193 (M-16) bullet, but the location of the maximum disruption is at a shallower penetration depth.
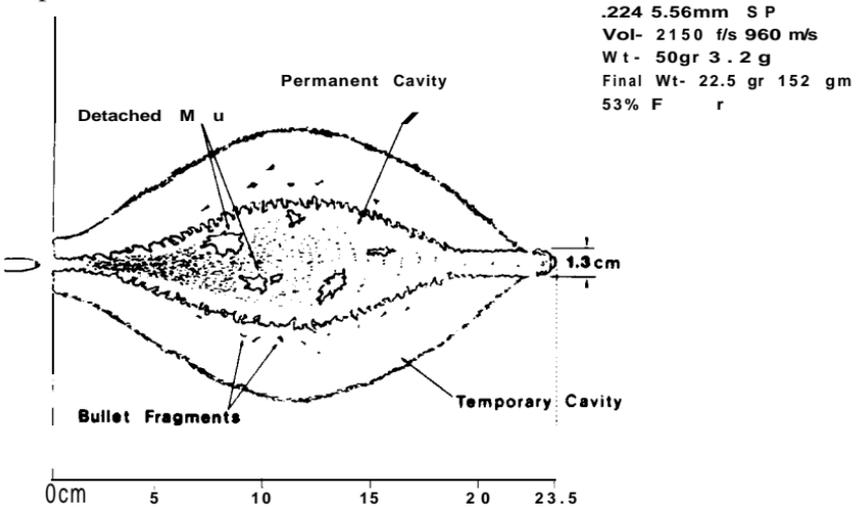

Figure: **13.-.224 Soft-Po bullet. This is a typical 22 caliber center-fire hunting bullet (.224 inches is actual bullet diameter) fired from the same cartridge as the military M-16.**

12 GAUGE SHOTGUN #4 BUCRSHCJI-Loaded with 27 pellets of #4 Buckshot (Figure 14), the 12 gauge shotgun at close range (3 meters in this case) causes massive crush type tissue disruption. At this short range, soft-tissue impact deforms the individual pellets, increasing their original 6 mm cross section to about 10 mm with concomitant increase in tissue crush or hole size. The 27 perforations of this size in a 7-8 cm diameter area result in severe disruption of anatomy by direct crush and in disruption of blood supply to tissue between the multiple wound channels.

The foregoing wound profiles portray an estimate of the maximum soft-tissue disruption expected at short ranges (under 25 meters). A gradual decrease in the amount of bullet deformation, fragmentation, and maximum size of the temporary cavity occurs with distance as the striking velocity of the projectile decreases. When bone is struck by the penetrating projectile, the result is predictable and easily verified on X-ray. Total penetration depth

Cavity

Tem~y   Permane? Cavity

12 Gauge Shotgun
   no choke
#4Buckshot
Vol.- 1351 f/s (412 m/s)
Wt.- 540gr (35gm)
27 pellets of 24 Cal.

Wad

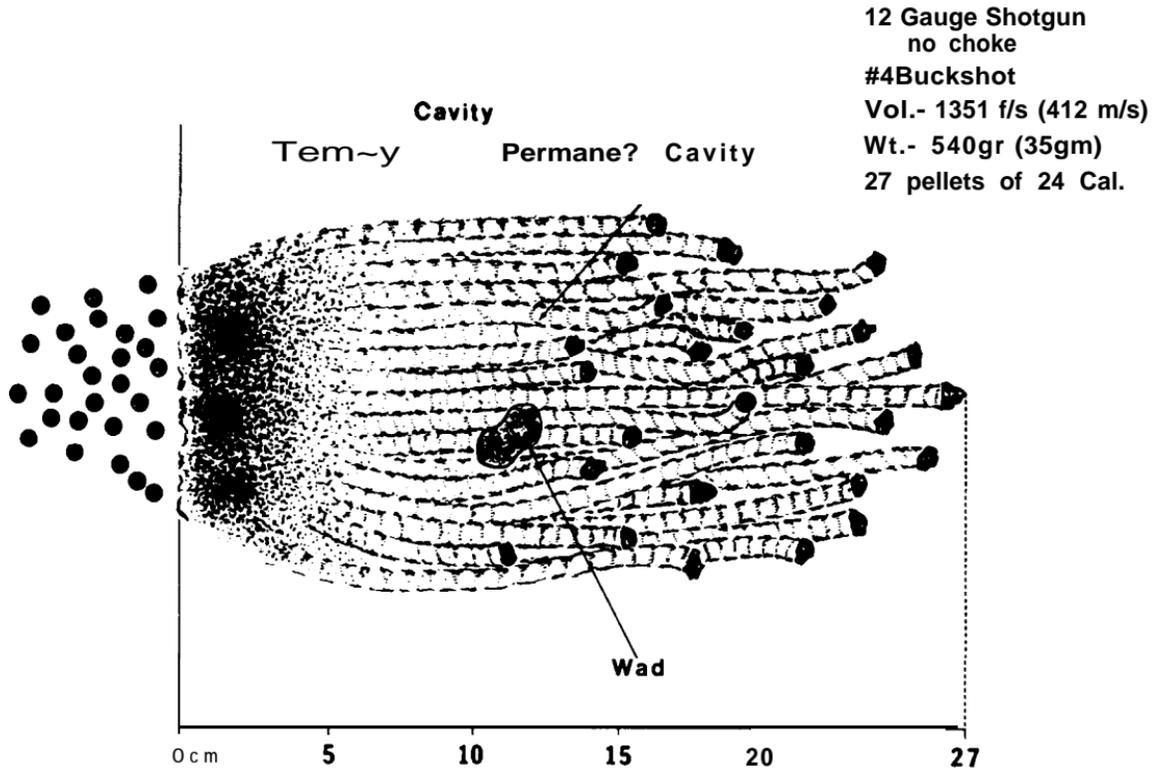0 cm   5   10   15   20   27

Figure: **14.--12 Cuq** shotgwn *with #4 size buckshot.* **This load is used by the military and by law enforcement groups for special situations.**

will be less; however, the degree of tissue disruption will be greater
due to increased projectile deformation and the creation of secon-
dary bone fragment missiles.

FRAGMENTS FROM EXPLOSIVE DEVICES

The great majority of fragments from explosive devices are of
blunt or irregular shape, distinctly not aerodynamic, and of steel
or less dense material. This causes them to lose velocity rapidly
in air with resultant decreases in tissue penetration depth com-
pared to the denser streamlined rifle bullets. Although initial frag
ment velocities in the 5,900 ft/sec (1800 m/sec) range have been
reported for some of these devices, the wounds observed in sur-
vivors indicate that striking velocities were less than 1900 ft/sec
(600 m/sec). For this reason, body armor affords much better pro-
tection against these fragments than against the rifle bullet. The
crush type of tissue disruption predominates in the injury pat-
tern caused by the individual fragment from these devices, with
little evidence of temporary cavity stretch. The projectile track
made by the fragment is consistent with its size and generally re-
mains constant throughout its path. It is analogous to the wound
from a single shotgun pellet. In cases where a survivor was close
enough to the device to be struck by multiple fragments in a
localized area, such as stepping on a landmine, the injury pattern
is similar to that produced by #4 buckshot at close range (Figure
14). In this situation, the crush mechanism results in the massive
tissue disruption one encounters when many permanent wound
paths in close proximity to one another totally destroy anatomic
integrity.

DISCUSSION

It becomes apparent from observing of data on the Wound Pro-
files that a projectile's striking velocity and mass determine only
the *potential* for tissue disruption. For example, a shot through soft
tissue of the average human thigh by a 7.62 NATO round loaded
with the soft-point bullet (Figure 11) could result in an exit wound
up to 13 cm in diameter with massive tissue loss. The same poten-
tial is available in the 7.62 NATO FMC military bullet (Figure 7),
but the exit wound it causes in a comparable shot would most like-
ly not exceed 2 cm in its largest dimension.

If one presented at the average large city hospital with a gun-shot wound in the thigh (entrance and exit holes of less than 1 cm in diameter) and gave the history of being shot with a 22 Long Rifle bullet, the surgical treatment rendered would be minimal. The same would probably apply if the history were of a wound from a 38 Special or a 45 Automatic. If, however, the history was given that the wound had been made by an M-16, the victim would most likely be subjected to an excision of the entire bullet track and possibly even several cm of tissue on all sides of the track. Comparing *the first 12cm of penetration* on the M-16 wound profile (Figure 12) with that of the other examples mentioned (Figures. **4-6),** shows that *in such a wound the* M-16 *is unlikely to cause any more tissue disruption than the* 22 *Long Rifle.* The reason for this is that the M-16 round does not fragment or yaw in the first 12 cm of soft tissue it traverses, nor does it develop its very significant temporary cavitation effects prior to 12 cm of penetration. The widespread belief that each and every wound caused by "high-velocity" pro-jectiles must be treated by "radical debridement" is incorrect and results from failure to recognize the role of other variables, such as bullet mass and construction, in the projectile-tissue interaction.

Serious misunderstanding has been generated by looking upon "kinetic energy transfer" from projectile to tissue as a mechanism of injury. In spite of data to the contrary, many assume that the amount of "kinetic energy deposit" in the body by a projectile is directly proportional to the damage it does. Such thinking stops short of delving into the actual interaction of projectile and tissue that is the crux of wound ballistics. Wounds that result in a given amount of "kinetic energy deposit" may differ widely. The nondeforming rifle bullet of the AK-74 (Figure 9) causes a large temporary cavity which can cause marked disruption in some tissues (liver), but considerably lesser disruption in others (mus-cle, lung, bowel wall). The temporary cavitation produced by the M-16 (Figure **12),** acting on tissue that has been perforated by bullet fragments, causes a much larger permanent cavity in tissues such as muscle and bowel wall and a similar disruption to that caused by the AK-74 in liver. A large slow projectile will crush a large amount of tissue (permanent cavity), whereas a small fast missile *with the same kinetic energy* will stretch more tissue (tem-porary cavity) but crush a proportionately smaller volume of tissue.

The "temporary cavity/energy deposit mystique" has spilled over into the field of weapons development and evaluation, where one

large study rates handgun bullets based upon the unfounded assumption that the degree of incapacitation a bullet causes in the human target is directly proportional to the size of the temporary cavity produced by the bullet. Many soft tissues (muscle, skin, bowel wall, lung) are flexible and elastic, having the physical characteristics of a good energy absorber. The assumption that tissue **must** be damaged by the temporary displacement of cavitation makes no sense physically or biologically. Not surprisingly, law enforcement agencies are finding increasing numbers of cases in which handgun bullets chosen on the basis of such studies fail to perform as predicted.

In the missile-wounded combat casualty, determination of the missile's path through the body is a major concern. Since the majority of penetration projectiles follow a relatively straight course in tissue, an estimate of the missile's path can be made from the location of the entrance wound and the location of the exit wound or the position at which the expended projectile comes to rest within the body. In most **cases, physical** examination and biplanar X-rays establish these two points and allow clinical estimation of structures that might have been damaged. In some cases, oblique X-ray views will be needed and it may be impossible to determine with certainty whether penetration of a body cavity has occurred. When the question arises as to whether or not the peritoneal cavity has been perforated by abdominal wall wounds, experience has clearly demonstrated that it is better to look and see (by laparotomy) than to wait and see

Bullet fragmentation and its correlative severe permanent tissue disruption (Figures 11 - 13) are especially useful roentgenographic signs. **Rifl** e wounds of the chest wall in which a large disruption has occurred in the muscles of the shoulder girdle (M-16, AK-74, or AK-47 if it strikes bone) may be expected to have pulmonary contusion even without penetration of the pleural cavity. This may not be evident on X-rays taken shortly after wounding. The surgeon must be aware of this potentially life-threatening situation and assure adequate follow-up observation and treatment. This is one of the more common situations in which occult damage from temporary cavity "blunt trauma" results in a clinical problem.

A point worth reiterating is that the surgeon is best advised to treat the wound and not the weapon!