# EFFECTS OF SMALL ARMS ON THE HUMAN BODY

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The type, location, and amount of tissue disruption caused by a projectile is the critical information needed to evaluate its effect. The "Wound Profile" illustrates these data. The profiles provide a standardized starting point, but some understanding of anatomy and physiology must be added to predict accurately the effect of a given projectile penetrating the human body.

## INTRODUCTION

Historically, weapon development has made use of the most advanced and sophisticated methods available to science. However, the chemistry of internal ballistics, the physics of the projectile's flight, and the determination of terminal effects on hardware (such as armor), have far outdistanced the study of terminal effects on the living human target.

In 1981, a wound ballistics laboratory was established at the Letterman Army Institute of Research in San Francisco to study treatment of war wounds. Measuring the effects of penetrating projectiles on the living body is obligatory prior to any meaningful comparison of treatment methods. Knowledge of what consequences can be expected from wounds caused by various weapons is also vital to planning the overall surgical support for troops in battle. Furthermore, designing protection to prevent or minimize injury from penetrating projectiles must begin with well-established known wound effects.

## WOUND PROFILE

The Wound Profile method (1,2) was developed to measure the amount, location, and type (permanent cavity CRUSH and temporary cavity STRETCH) of disruption produced by a given projectile. Calibration of ordnance gelatin against living muscle revealed that a 10% gelatin solution shot at 4 degrees C reproduces the projectile penetration depth as well as projectile deformation and fragmentation pattern. Additionally, a close approximation of the location and amount of tissue stretch from temporary cavitation can be determined by measuring the radial cracks it causes in the gelatin (1,2). The width of the projectile's path in the gelatin indicates its approximate yaw angle. In cases where the projectile fragmented, biplanar X-rays of the gelatin blocks are used to map the fragmentation pattern. The characteristic wound produced by a projectile is thus presented, in illustrative form, as a Wound Profile (Figs 1 - 4). A centimeter scale is furnished at the bottom of each wound profile to aid measurement of any dimension on the profile and to facilitate comparisons. Each profile pictures the approximate tissue disruption pattern as it might be expected to appear in living muscle (See Figures).

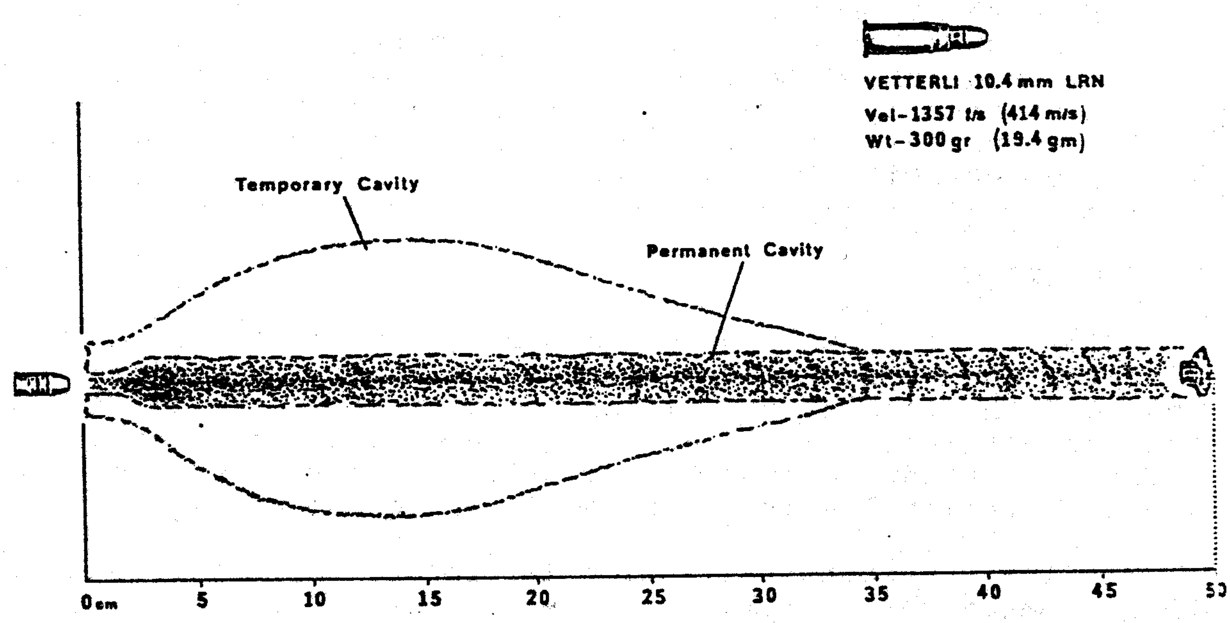
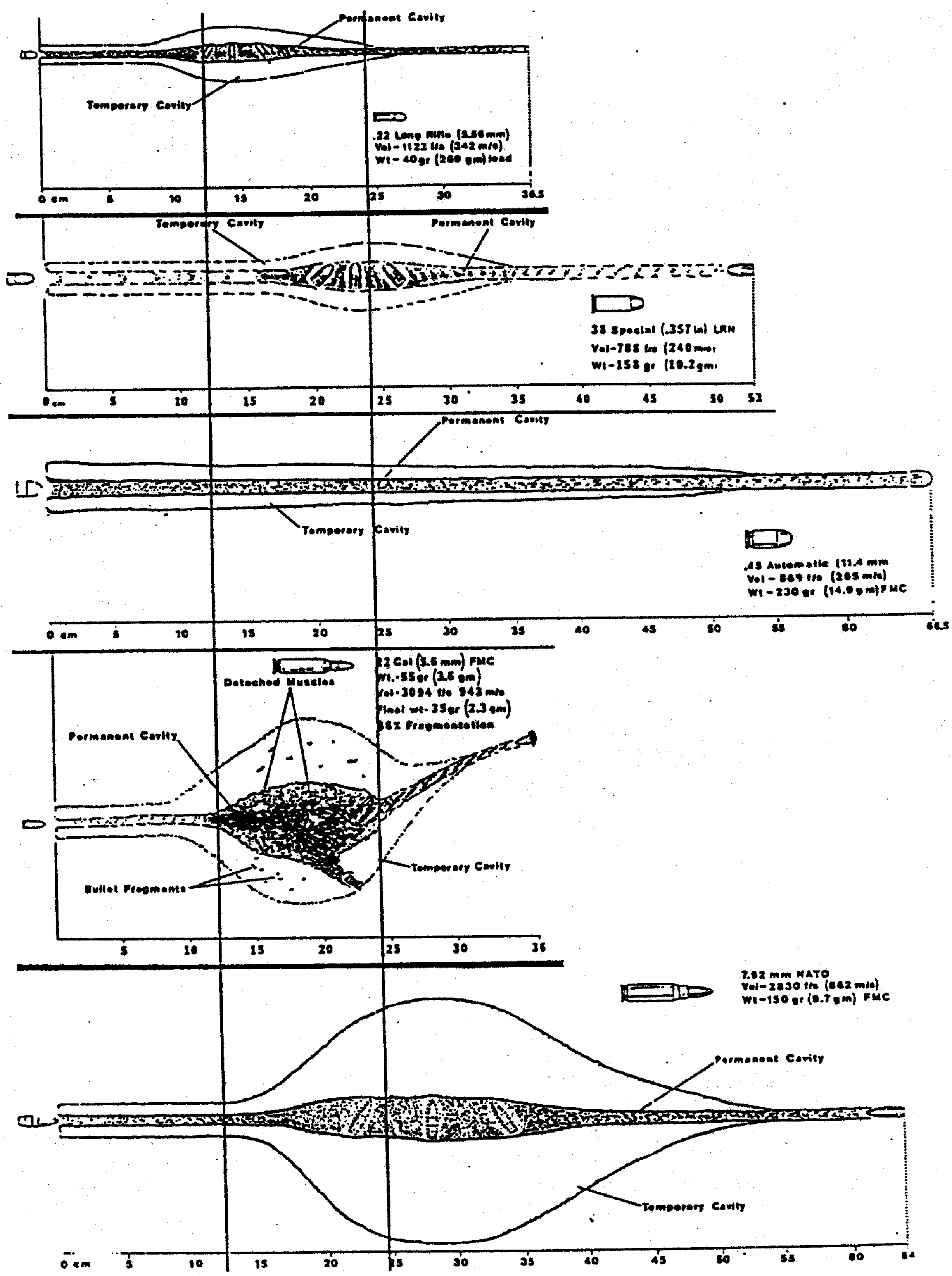



Figure 1 The lead Vetterli bullet, used by the Swiss and Italian Armies (1870-1890), doubled its diameter ("mushroomed") on impact with tissue. Despite its "low" velocity it produced a temporary cavity as large as the present-day 5.56 mm military rifle bullets (see Figs 2D and 4). The generation of military rifle bullets following the Vetterli was of smaller caliber (6.5 mm Carcano, 30-40 Krag, etc.), jacketed, and of 50 to 80 percent higher velocity. Despite the greatly increased velocity (and more than doubled kinetic energy) possessed by the new jacketed bullets, reliable historical accounts are unanimous in their observations that the tissue disruption and overall effect they caused was far less than that produced by the earlier and slower lead bullets (3).




<u>Figure 2</u> Five wound profiles are compared. They show the disruption pattern caused by the following bullets: (A) 22 Long Rifle solid lead bullet; (B) 38 Special round nosed lead bullet; (C) 45 Automatic full-metal-jacketed bullet; (D) M-16A1 full-metal-jacketed bullet; and (E) 7.62 NATO full-metal-jacketed bullet (USA version). The line drawn

at 12 cm represents the thickness of the adult human thigh, and the line at 24 cm represents the adult human torso diameter from front to back. Note that these are the measurements from shots at right angles to the part hit. Angled shots can have greatly increased tissue path lengths.

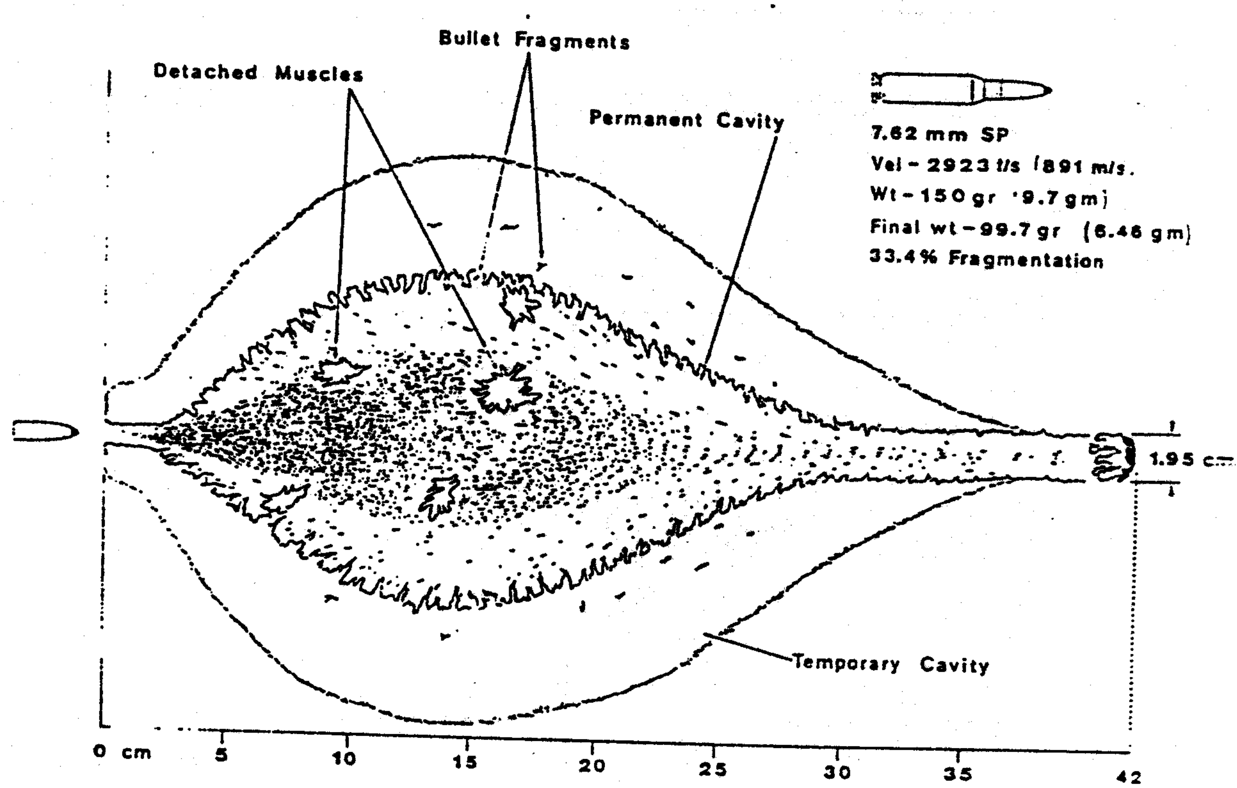



Figure 3 Wound profile produced by the 7.62 NATO cartridge case loaded with a typical hunting type soft-point bullet of the same mass as the bullet that produced the wound profile shown in Figure 2E. Note the greatly increased permanent cavity. Tissue pieces are detached by the synergistic effect of bullet fragmentation and temporary cavitation.

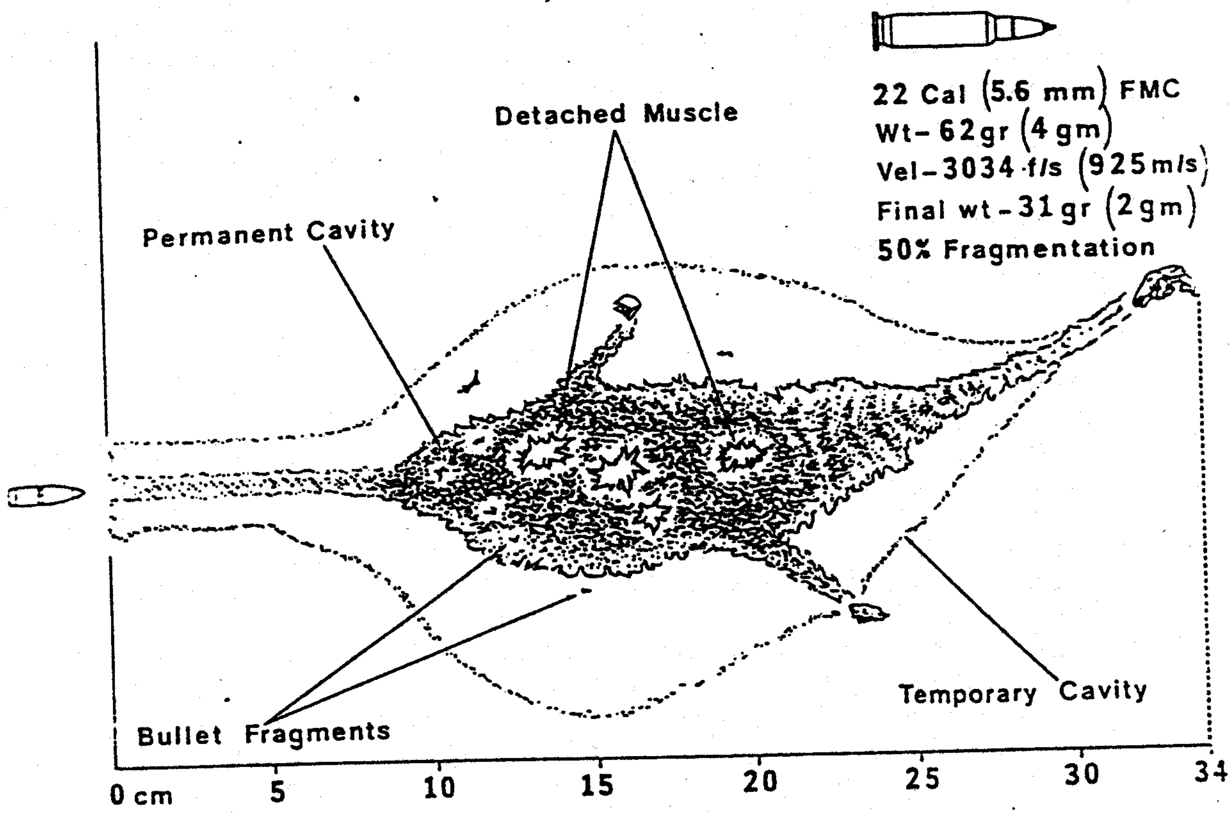



Figure 4 The wound profile produced by the newer SS-109, shown here, does not differ significantly from that produced by the M-193 bullet of the M-16A1 shown in Figure 2D.

APPLIED WOUND BALLISTICS

The wound profile provides a standardized starting point for estimating projectile terminal effects in the living body. To ascertain the effect of a particular projectile path through the living body one must consider the characteristics of the anatomic structures impacted. The crush disruption remains relatively constant in most body tissues, but the effect produced by the stretch of temporary cavitation varies greatly with tissue flexibility, and anatomic location. For example, liver does not stretch as well as muscle, and is damaged much more severely by temporary cavitation (4,5). A projectile striking bone is likely to deform and/or fragment more than usual, and its penetration depth will decrease. Just how much the damage pattern changes from that predicted by the wound profile, however, can vary greatly, depending on the anatomy of the bone struck (its thickness, hardness, etc.). Passage through the abdominal cavity in which the organs perforated contain liquid and gas might be expected to give less resistance to penetration than muscle, so the length of penetration would be expected to be longer and more variable. Projectile passage through the chest, where a large part of the volume is occupied by low density lung, might be expected to yield an even longer penetration. Experimental observations from adult human sized animals confirm these expectations (Fackler ML, Breteau JPL, unpublished data, 1988).

In addition to animal experiments, the analysis of actual wounds from the battlefield and civil strife, and their consequences, has provided solid confirmation of the wound profile predictions. Measurements taken from autopsies have provided much additional data on the relative variation of damage patterns caused by anatomic differences in various parts of the body. Clearly, an understanding of anatomy and physiology is mandatory for any serious study of weapon effects on the human body.

Autopsy measurements of the physical disruption produced in cases where the weapon, bullet, and range of fire were known, has correlated so uniformly with the disruption shown on the wound profiles that they have become a useful tool for the forensic scientist in determining such things as projectile characteristics, range of fire, and the effects of intermediate targets on projectile effects in the human body (6). The Firearms Training Unit of the FBI Academy, Quantico, VA, USA, has recently initiated a program to determine bullet effects using the techniques described in this paper (7). Their testing includes shots through common intermediate targets such as automobile windshield glass, automobile body steel, plywood, wallboard, and layers of clothing. The shots are then captured in gelatin and compared with shots made under identical conditions in which the projectile impacted the gelatin directly. This same methodology used with body armor, armor plate. etc. can give the pertinent information that has been almost universally overlooked in the past. Requirements that a projectile must perforate a particular protective device at a certain range of fire miss the crux of the matter. Should not the real concern be what is the projectile's capacity to wound after passing through the protective device? This is the pertinent question. If tests are to provide a valid answer, the projectile must be captured, after it perforates the protection, in a standardized tissue simulant calibrated against living tissue.

## THE KINETIC ENERGY FALLACY

The erroneous assumption that the amount of kinetic energy "deposited" by a projectile is a measure of the damage it produces continues to mislead (5,8,9).

Wounds that result from the same amount of "kinetic energy deposit" can differ widely, depending on the predominant tissue disruption mechanism (crush or stretch), and the anatomic location of the disruption (compare Fig 2E with Fig 3).

Projectile fragmentation can greatly augment temporary cavity effects by providing points of weakness on which the stretch is focused rather than being absorbed evenly by the tissue mass (Figs 2D, 3, 4).

A large slow projectile will crush a large amount of tissue, whereas a small fast missile with the same kinetic energy will stretch more tissue but crush less (2,9). If the tissue crushed includes the wall of a large blood vessel, far more damaging consequences are likely to result than if this vessel absorbs the same amount of energy in being stetched or temporarily displaced by cavitation.

Simply considering the dimensions of the human torso exposes the fallacy in bullet performance claims based on shots done in a 15 cm block of tissue simulant (10).

It is not surprising that attempts to teach wound ballistics using formulae or tables of velocity and kinetic energy have been counterproductive. This diverts attention from the actual tissue disruption and makes the subject appear unnecessarily complicated.

The kinetic energy fallacy is a smokescreen which hides the actual ways in which the projectile interacts with tissue. Authors who use "kinetic energy transfer" as an explanation of how a projectile causes a particular injury are missing the crux of wound ballistics, as well as spreading the worst kind of misinformation; that which induces complacency by masquerading as knowledge. How much better off this field would be if the words "kinetic energy" were erased from its vocabulary; then one would be forced to look into the mechanical interactions of projectile and tissue wherein lies the key to understanding.

## CONCLUSION

Both those who produce weapons and those who treat the wounds they cause need valid information on <u>how</u> projectiles affect the human body. In this regard, <u>both groups have been seriously misled</u>. The body of science in wound ballistics has been badly contaminated to the detriment of all. Some of the misconceptions have resulted from well-meaning attempts by those who forgot the basic precepts of scientific method (8,9), and others from politically motivated exaggerations and distortions masquerading as "science" (11).

Recognizing that the penetrating projectile simply crushes tissue to form its hole and that the walls of certain parts of this hole may be dilated or stretched outward for a few milliseconds after the projectile passes, provides the basic foundation needed to understand the effects of projectile on tissue. The characteristic wound produced by a given projectile is most accurately described by illustrating both crush and stretch tissue disruption along the entire tissue path. This foundation can be built upon by those who need more detail, but it must remain the logical basis for understanding. It is the common ground to bridge the "knowledge gap" between the physical and biological sciences. In no field is the admonition "back to the basics" more necessary to continued fruitful work than in wound ballistics.

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