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Fundamentals of Wound Ballistics

by Lawrence E. Heiskell, M.D.

Introduction

The science of wound ballistics is the study of the natural laws governing projectile missiles and their predictable performances after striking the target. A review of a few basic principles is helpful in understanding the pathophysiologic process of gunshot wounds.

Over one million American civilians have died from gunshot wounds since the turn of the century, and the present population in the United States is the most heavily armed in history. Current statistics show an annual death rate as a result of projectile injuries exceeding 50,000. With the increasing incidence and prevalence of gunshot wounds, it is essential for not only the emergency physician but also the tactical officer to become familiar with wound ballistics.

The identification of a projectile producing a wound is important for two reasons. The first is medical; the emergency physician must have knowledge of the wounding capacity of the weapon involved to help determine the extent and type of injury. With this information, the physician can provide the victim the most effective treatment. Secondly, the officer on scene can aid the physician by collecting certain facts that can contribute tremendously to the evaluation of the victim.

These include the type and caliber of weapon used, its distance from the victim when shot, the quantity of rounds fired, and the amount of blood loss at the scene. From the tactical point of view, the goal of immediate incapacitation is the rationale for decisions regarding ammunition, training, and the selection of special weapons to be used in the tactical environment.

The science of wound ballistics is complex and has been clouded by the previous lack of accurate and credible research in the field. Misconceptions and errors in the scientific method have persisted for years, and attempts to explain wound ballistics using mathematical formulas of kinetic energy and velocity have not been helpful and has even been counterproductive.

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Energy

For years, the most widely accepted theory stated that the wounding capacity is related to the kinetic energy (mass x velocity squared). Based on the hypothesis that tissue damage is then proportional to the difference between the kinetic energy the projectile has on impact and exit of the target, the design of ammunition was directed toward maximizing this difference to increase tissue damage. The literature is full of material proposing that the amount of kinetic energy delivered to the target by a projectile is a measure of the damage. This is not totally correct, because it does not take into consideration a number of variables. These include velocity, bullet shape, construction, mass, and most important of all, the type of tissue

involved; for example, muscle, lung or bowel. It is this interaction of tissue type and projectile that is the crux of wound ballistics.

Velocity

Projectile velocity is categorized as low (less than 1000 feet/sec), medium (1000 to 2000 feet/sec), and high (greater than 2000 feet/sec). Some experts define a high-velocity projectile as one that travels faster than 2500 feet/sec. The impact velocity on the target depends on several variables. They are the distance between the weapon and the target, the muzzle velocity, and certain characteristics of the projectile such as mass, shape, and construction.

Low-velocity projectiles are relatively unstable compared with high-velocity projectiles because of their lower kinetic energy. After entering the skin, even less energy exists to further damage tissue or vital organs. This instability results in the belief that low-velocity projectiles have a tendency to not continue into the body in a straight line but to follow tissue planes and may even move around structures such as veins, arteries and nerves. They commonly are found in locations of the body completely unsuspected from the point of entry. However, low-velocity projectiles can have tremendous wounding capacity if the projectile has sufficient mass (weight) to penetrate the body deep enough and destroy vital structures. At medium and high velocities, the projectile has, but not always, an explosive effect which creates within the body a temporary passage or cavity in the tissue along its course. The size of this passage or cavity is directly proportional to the density of the tissue penetrated. It is this sudden formation of a cavity that displaces tissue, organs, blood vessels and vital structures, which may be torn or injured without actually being struck by the projectile. Bowel, lung, muscle, and blood vessels are all capable of substantial stretching with minimal damage. However, inelastic tissue, such as the brain or liver, can suffer severe damage secondary to temporary cavitation.

Projectile Tumbling

It was once believed there were other modifying factors that contributed to an increased wound profile as the projectile imparts the target. These are referred to as yaw and tumbling. Yaw is defined as the deviation of a projectile's longitudinal axis from the straight line of flight, thus causing the projectile to tumble in flight and increase wound damage by striking the target at a large angle.

Ballistic studies have consistently shown that projectiles yaw only a few degrees in flight regardless of their velocity. The rifling of the barrel generates spin to the bullet along its longitudinal axis providing gyroscopic stability until the bullet

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strikes the target. However, once the projectile enters the body, bullets can yaw as much as 180 degrees in their path through tissue, increasing the amount of tissue disruption and enlarging the permanent cavity. This is determined by the length of the bullet, with maximum tissue destruction occurring at 90 degrees of yaw. Thus, projectile yaw is important in tissue wounding, but is negligible in flight when studying wound ballistics.

Mechanics of Projectile Wounding

There are four basic components of projectile wounding, and not all of them are directly related to incapacitation. However, each component must be considered in the understanding of wound mechanics. The first is **PENETRATION**. This is the tissue through which the bullet passes. It may crush tissue during penetration or push surrounding tissue outward from the bullet's path, producing the second component, the permanent cavity.

The **PERMANENT CAVITY** is the space that was once occupied by tissue and now has been destroyed by the passage of the bullet. This is a function of the penetration and the frontal surface area of the bullet. In simpler terms, it is the hole left by the passage of the bullet. The expansion of the permanent cavity by stretching due to the transfer of the bullet's kinetic energy is known as the **TEMPORARY CAVITY**. These two components are the sole wounding mechanisms.

As bullet fragments are impelled outward during the formation of the permanent cavity, they can further damage tissue by disrupting blood vessels, muscle or vital organs. This component is known as **FRAGMENTATION**, and does not necessarily occur in every bullet wound. Therefore, it is usually considered a secondary effect.

The Human Target

It is important for the tactical officer to understand that the human target is very durable and complex, and a combination of physiological and psychological effects have tremendous variability in the goal of incapacitation. Wound placement is the only factor within the control of the tactical officer. Only well-placed hits to the upper spinal cord or brain can produce immediate incapacitation of an adversary. Even repeated hits to the torso which penetrate the heart or major blood vessels resulting in circulatory collapse will not result in immediate incapacitation. This is because the brain can store enough oxygen to maintain full body function for up to 15 seconds. An adversary that is influenced by drugs, alcohol, fear, or the sheer will to survive may not be incapacitated even if mortally wounded. Pure adrenalin alone can keep a mortally wounded adversary functioning. The critical wounding factors are: **PLACEMENT, PENETRATION,** and the **PERMANENT CAVITY**. Factors such as "knock-down power" and "shocking power" are a myth. Mathematical calculations like the relative incapacitation index (R.I.I.), the temporary cavity size, and kinetic energy transfer are misleading and erroneous. Proper placement is a hit in the center of mass of an adversary, regardless of the angle. Penetration must be of sufficient depth to pass through vital organs, regardless of anatomy and body frame, and the permanent cavity must be of sufficient size to maximize tissue and organ destruction with rapid bleeding.

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Conclusion

Wound ballistics combines the sciences of biology, physics and medicine. The failure to take into consideration all of the variables in the projectile tissue interaction has led to much inaccuracy in the literature. Failure to adhere to the scientific method, misinterpretation of battlefield experience, and the use of an improper tissue simulant in the laboratory have all led to error and misconceptions. Every shooting is a unique sequence of events, and because of the large number of variables that exist within the human body, anything that can happen, will. Unfortunately, there is no correlation between the number and location of hits and incapacitation. Some individuals are predisposed to fall down when shot, while others continue to fight despite multiple hits. One should understand that the projectile tissue interaction is nothing more than a simple mechanical collision combined with the type of tissue disrupted. This concept, based on objective data and scientific fact, helps the tactical officer to make an informed choice of ammunition and special weapons for deployment in the tactical environment.

About the Author

Lawrence Heiskell is a Senior Emergency Medicine Resident in the Department of Emergency Medicine, Kern Medical Center, Bakersfield, California. Doctor Heiskell has been with the Kern County Sheriff's Department for two years. He has completed the California Commission on Peace Officer Standards and Training basic course and is currently assigned to the Special Weapons and Tactics unit as the team physician.