Gunshot wounds: A review of ballistics, bullets, weapons, and myths

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In the United States, someone experiences a gunshot wound every 4 minutes 44 seconds, and a person dies as a result each 16 minutes. Annually, this means that approximately 111,000 Americans are shot and 33,800 die as a result of these injuries, which equates to 93 deaths caused by firearms every day.[1,2] In contrast, the war in Iraq and Afghanistan has resulted in less than 200 deaths per year from gunshot wounds during the height of the conflict (Table 1). Gunshot wound injuries are a preventable epidemic in the United States. This silent epidemic is largely deaf to the American public because we are so accustomed to these injuries that they rarely make the news. Gun violence leading to homicide may get some attention, but an even greater toll is placed on the survivors who must live with the loss of loved ones or are burdened by the costs associated with the temporary or permanent disability caused by these wounds. Gunshot wounds not only hurt the body and mind of the victim but also burden the family of the victim and the society, both mentally and from a financial perspective. It is not unusual to have survivors accumulate hospital costs of more than $1 million per year, and some have total hospital and recovery costs of more than $10 million. Since most do not have the money to afford these enormous costs, the burden then falls on the society and ultimately the taxpayers. Additional societal costs that are harder to quantify are the costs associated with the permanent disabling and unemployment seen not infrequently in the victims of gunshot wounds. Whether these injuries are intentional or unintentional, the patients are in our health care system. These costs have been estimated to range from $100 to $174 billion annually.[3]

Furthermore, there has been an alarming escalation in the numbers of mass shootings throughout the United States (which leads the world in mass shootings), with 265 individuals killed and 269 wounded in the past 16 years[4] (Table 2).[5] Recent terrorist-related mass shootings have reignited vigorous and volatile public debate over access to weapons designed for inflicting mass casualties.[6] The predictable reflex response to these mass shootings has been in several forms, of which one is in the call for reviving and funding research on gun violence and inadequate recognition and treatment of mental illness that warrants federal and state tax support.[7,8] As health care providers for trauma care, we have witnessed the ravages of gun-related violence and, thus, should become proactive in the ongoing national debate as it is our duty.

The numbers of gunshot wounds are increasing in the United States, although the gun-related homicide rates remain relatively stable.[9] Guns are ubiquitous in the United States, and it is known that where there are guns, there will be gunshot wounds.[10,11] In other countries, it has been shown that gun law reforms were associated with a decrease in the numbers of mass shootings and firearm deaths.[12–14] Canada, with their strict handgun control, has one-third fewer gunshot wounds than the United States. Australia and the United Kingdom have less than half of the deaths from gunshot wounds seen in Canada.[10] The United States, which constitutes approximately 5% of the world's population, owns between 35% and 50% of its guns. Legislation regarding firearms differs within the United States, but what is certain is that gunshot wounds are a daily part of our society and will remain a part of it for a very long time. While any topic relating to firearms remains volatile in our country, the fact is that where there are guns, people will be shot. The real tragedy is that with as many gunshot wounds occurring daily in the United States, even collection of the basic data, scientific inquiry, policy formation and analysis, and rigorous evaluation are limited. Firearm research is difficult because of politically motivated constraints. A blue ribbon commission appointed by the National Academy of Sciences concluded that very little is currently known about effective ways to reduce gun violence and injury within the United States because it is rarely studied.[15] While mortality rates from every major cause of death have declined dramatically during the past half century,[16] the homicide and gunshot wound rates in America are the same as those in 1950. Without challenging the Second Amendment of the Constitution, we can still work toward some semblance of regulation and control. The costs of inaction are more gunshot wounds to both intended and unintended victims. The cost of total freedom to bear arms is measured not only in terms of the financial burden to the society but also in terms of lives and lives ruined. The cost to life and the society is too enormous to ignore. The costs are generally to the taxpayers because it is costly to the court system, police system, and health care system. By promoting discussions on this topic and synergy of collaboration, we can at least attempt to make effectual progress.

Despite gunshot wounds being an epidemic, many health care providers' understanding of ballistics, bullets, and guns

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TABLE 1. US Military Combat Casualty Deaths

	Total Deaths	Deaths per Year	US Population	Deaths per Year per 100,000
Revolution (1775–1783)	8,000	1,000	3,929,884	25.6
War of 1812 (1812–1815)	2,260	565	7,036,509	8.0
Mexican War (1846–1848)	1,733	577	17,019,678	3.4
Civil War (1861–1865)	213,000	42,400	30,383,684	139.5
Spanish-American War (1898)	385	385	61,116,815	0.6
World War I (1917–1918)	53,402	58,258	91,641,186	29.1
World War II (1941–1945)	291,557	81,080	130,962,661	44.5
Korean War (1950–1953)	36,574	9,144	149,895,183	6.1
Vietnam War (1964–1975)	47,424	4,311	178,554,916	2.4
War on Terror (March 19, 2001–2015)*	5,281	352	321,216,397	0.11
2014 US firearm deaths	32,800	32,800	321,216,397	10.2

*The Iraq War excludes the nonbattle injury deaths, and firearm deaths are approximately 50% of the battle-related deaths.

TABLE 2. Mass Shootings in the United States 2000 to 2015

Date	Location	Killed	Wounded
December 26, 2000	Wakefield, Massachussetts; office	7	0
March 5, 2001	Santee, California; school*	2	13
October 28, 2002	Tucson, Arizona; university	3	0
July 8, 2003	Meridian, Mississippi; workplace	5	9
March 21, 2005	Red Lake Indian Res, Minnesota; school*	9	7
January 30, 2006	Goleta, California; post office	6	0
October 2, 2006	Nickel Mines, Pennsylvania; school	5	5
February 12, 2007	Salt Lake City, Utah; shopping mall*	5	4
April 16, 2007	Blacksburg, Virginia; university	32	17
December 5, 2007	Omaha, Nebraska; shopping mall	8	4
February 14, 2008	Dekalb, Illinois; university	5	16
April 3, 2009	Binghamton, New York; immigration services center	13	4
November 5, 2009	Fort Hood, Texas; military base	13	32
February 12, 2010	Huntsville, Alabama; university	3	3
August 3, 2010	Manchester, Connecticut; court	8	2
January 8, 2011	Tucson, Arizona; shopping center	6	13
October 12, 2011	Seal Beach, California; hair salon	8	1
April 2, 2012	Oakland, California; university	7	3
July 20, 2012	Aurora, Colorado; movie theater	12	58
August 5, 2012	Oak Creek, Wisconsin; temple	6	3
September 28, 2012	Minneapolis, Minnesota; offices	6	2
October 21, 2012	Brookfield, Wisconsin; salon	3	4
December 14, 2012	Newtown, Connecticut; school	27	1
June 7, 2013	Santa Monica, California; home	5	0
September 16, 2013	Washington, District of Columbia; Navy yard	12	3
April 2, 2014	Fort Hood, Texas; military base	3	16
May 23, 2014	Isla Vista, California; neighborhood	6	7
June 18, 2015	Charleston, South Carolina; church	9	0
July 16, 2015	Chattanooga, Tennessee; military centers	5	3
October 1, 2015	Roseburg, Oregon; college	9	9
November 29, 2015	Colorado Springs, Colorado; planned parenthood clinic	3	9
December 2, 2015	San Bernardino, California; workplace	14	21
	Total	265	269

*Teen shooters. Total number of mass shootings defined as more than two victims and does not count the assailant whether they were killed or committed suicide. In comparison with the previous 16 years, from 1984 to 1999, the total number of deaths was 135, and wounded was 156.

are falsely propagated because of media, uneducated beliefs, and urban legends.[17–19] Therefore, the purpose of this review was to provide the fundamental facts regarding gunshot wounds, ballistics, bullets, and weapons.

BALLISTICS

Ballistics is defined as the science of mechanics that deals with the flight, behavior, and effects of projectiles discharged from guns. The severity of a bullet wound depends on the characteristics of the bullet (mass, velocity), orientation of the bullet, and the tissue that is impacted. Ballistics is broadly classified into three categories as follows: internal ballistics, external ballistics, and terminal ballistics. Firearms can be weapons, but not all weapons are firearms. However, for the purposes of this review, they will be used interchangeably, and guns and firearms may be referred to as weapons, and vice versa.

Internal Ballistics

Internal (initial) ballistics is the study of the propulsion of a projectile within a weapon from the propellant's ignition until the projectile exits the barrel. In addition, it involves understanding the acceleration of the bullet within the weapon and the related processes. Internal ballistics is of importance to designers of weapons. It is determined by the type of propellant (gun powder), the chamber (where the cartridge rests before it is fired), and the barrel (rifling and length) of the weapon. Rifling or the groove carved inside the barrel determines the amount of spin imparted to the exiting bullet, which stabilizes flight.

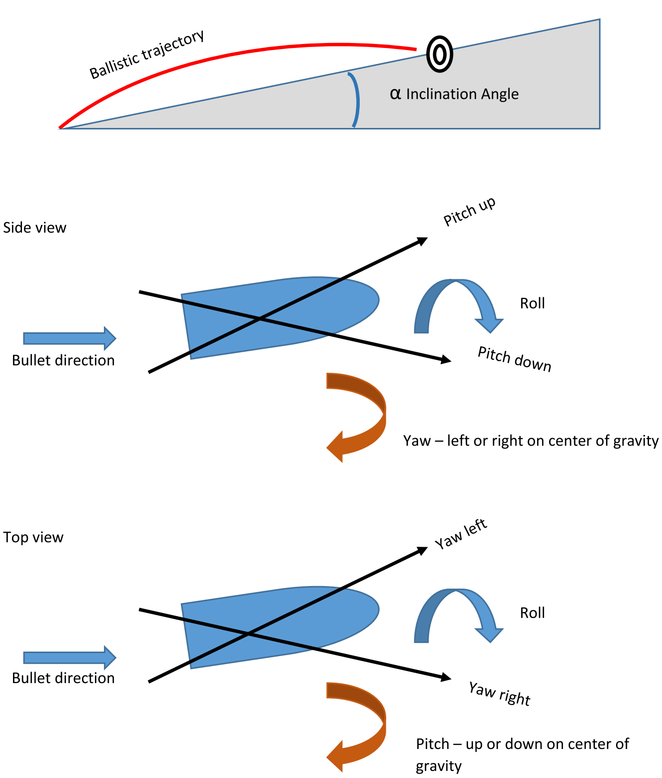

Figure 1. Ballistics and trajectory of bullet including pitch, roll, and yaw of the bullet.

External Ballistics

External ballistics addresses the path (trajectory) of a projectile in flight. It includes the time frame from when a projectile is fired until it reaches its target. Intrinsic factors depending on the type and size of both bullet and weapon along with extrinsic factors such as wind and gravity are key components of external ballistics. After a bullet is fired, the flight of the bullet determines the amount of energy transferred to the object upon impact of the bullet. Gravity and bullet drag caused by friction are the main forces acting on the projectile during its path through the air. Both gravity and friction cause the projectile to lose energy during flight, which in turn affects the ultimate path of the bullet.

The effect of gravity on the trajectory of the bullet in space is commonly known as bullet drop. A bullet commonly travels in a parabolic shaped trajectory whose vertex and distance are determined by the energy of the bullet. As a result, bullets fired at a longer distance need to be fired at a positive angle of elevation (inclination angle) to the line of the target. The path followed by the bullet in space is commonly termed *ballistic trajectory*, which is determined by the energy potential at which the bullet exits the barrel of the weapon (muzzle energy), gravity, and the aerodynamic resistance (ballistic coefficient) on the bullet. Shooters routinely use the knowledge of bullet drop trajectory to accurately hit an intended target at distance. The bullet in flight also experiences yaw, roll, and pitch (Fig. 1).

Terminal Ballistics

The effects of a projectile on a target are known as terminal ballistics. The type of weapon, type of bullet (size, shape, material), and the type of tissue injured are the most important factors, which determine the terminal ballistics of a weapon.

UNDERSTANDING THE BASIC PHYSICS BEHIND FIREARM BALLISTICS

There are several important laws of physics that should be considered when discussing the ballistics of firearm injuries.

Law of Kinetic Energy

The kinetic energy of an object is defined as the ½ mass times the velocity squared

$$KE = \frac{1}{2}mv^2$$

Thus, both mass and velocity contribute to the energy of the projectile. Mass or size of the bullet is directly proportional to the resulting energy, while the square of its velocity is directly related to the overall energy of the projectile. As a result, for a constant velocity, if the mass is doubled, then the energy is doubled. However, the velocity of the bullet is a more important determinant of tissue injury because if the velocity of the bullet is doubled, the energy increases four times (Table 3). Gunshot wounds are classified according to the speed of the projectile, as low, medium, or high velocity. Generally, a low-velocity projectile is defined as 1,200 ft/s, medium as 1,200 ft/s to 2,500 ft/s, and high as greater than 2,500 ft/s.[20] Bullets from handguns are

TABLE 3. Typical Bullet Characteristics of Handgun Rounds and US Big Game Hunting Rifles

Caliber	Bullet Weight, Grains	Velocity, ft/s	Muzzle Energy, ft lb
.22LR	38	1,000	100
.380	90	1,000	200
.38 special	115	900	220
9 mm	115	1,200	400
.357	125	1,500	624
10 mm	155	1,265	550
.40	115	1,180	479
.44 mag	180	1,550	850
.45 ACP	185	970	386
.45 colt	225	800	250
.308	150	2,820	2,648
270 Win	150	2,900	2,801
30-06	150	2,920	2,839
7 mm	165	2,950	3,190
300 Win Mag	180	2,960	3,500
300 WBY Mag	180	3,190	4,005
375 H + H Mag	300	2,830	4,265
458 Win Mag	2,380	2,380	5,030

generally less than 1,000 ft/s, while bullets from rifles exceed 2,500 ft/s. The US military commonly uses 5.56-mm bullets, which have a relatively low mass as compared with other bullets; however, the speed of these bullets is relatively fast (Table 4). As a result, they produce a larger amount of kinetic energy, which after contact with the target is transmitted to these tissues.

Muzzle velocity is defined as the speed at which the bullet leaves the barrel of the weapon and is used to calculate the muzzle energy, which equates to wounding potential. It is important to keep in mind that bullets do not accelerate after leaving the barrel of the weapon. A bullet discharged downward does technically accelerate because of forces of gravity, but friction has more of a negative effect on the bullet than the positive effect of gravity. Thus, the kinetic energy of the bullet generally decreases after firing at a logarithmic rate. As a result, the energy of impact on the target object is also determined by the distance of the target object from the muzzle of the gun. The farther an object is from the muzzle of the weapon, the less energy is imparted to that object.

The ballistic coefficient is the efficiency of a bullet in delivering potential energy through the air to its target. Variables that affect the ballistic coefficient include the bullets mass, cross-sectional diameter, density of the bullet, and shape of the bullet, which all determine bullet drag. The bullets' ability to have yaw, pitch, and roll also has some effect on this coefficient. Factors involved in determining the path of a bullet toward its target are many and varied.

Newton's Third Law of Motion

According to the Newton's third law of motion, for every action, there is an equal but an opposite reaction. When a person is shot at point blank range, the energy felt by the person being shot is the same as the energy of the gun during its recoil. The effect of Newton's third law is on the person shooting the gun who gets a "kick" or "recoil," which is equal and opposite to the direction of the muzzle energy. Typically, in movies, directors often depict the person being shot as absorbing more energy than the shooter (by flying backward through the air) and that is physically not possible.

AMMUNITION

A round, shell, or cartridge is ammunition for the gun. Modern-day rounds consist of a casing, a primer, propellant, and a projectile. The anatomy of the projectile consists of its material and shape and if it has an outer lining or jacket. The nomenclature of a cartridge is variable and often based on the unique characteristics; for example, the .30-06 Springfield is a 0.30-in-wide military round that was designed at Springfield, Arsenal, Massachusetts, in the year 1906.[21] However, there are considerable variations in the cartridge nomenclature based on the country of use, type of organization, and company manufacturing the cartridge. Generally, in the United States, the caliber (diameter) of a round is measured in hundredths of an inch (0.30 cal = 30/100ths of an inch), whereas in the rest of the world, it is measured in millimeters (5.56 cal = 5.56 mm). Modern-day ammunition thus typically has a brass casing with a primer that detonates upon impact with the firing pin and results in a small explosion. This in turn causes the smokeless powder in the cartridge to burn very quickly, thus producing pressurized hot gasses, which propel the projectile or bullet through the barrel of the gun and out of the muzzle (the open end of the barrel).

TABLE 4. Typical Military Weapons and Their Ammunition Specifications

Military Weapon	Caliber	Bullet Weight, Grains	Velocity, ft/s	Muzzle Energy, ft lb
M1 Garand	.30-06 Springfield	150	29,100	2,820
M14	7.76 NATO	144	2,749	2,437
M16	5.56 × 45 NATO	62	3,251	1,303
M4	5.56 × 45 NATO	62	3,251	1,303
AR15	5.56 × 45 NATO	62	3,251	1,303
AK47	7.76 NATO	144	2,749	2,437
AK74	5.45 × 39 NATO	53	2,900	979

M1 Garand was preplaced by the M14, which was replaced by the M16, which was replaced by the M4. The M4 is similar in capability and function to the M16, but the stock is collapsible. The AR15 is the civilian version of the military assault rifles and does not come from the manufacturer with autocapacity or the three-round burst option. AK47 is Avtomat Kalashnikova. The prototype was developed in 1947 in the Soviet Union by Major Mikhail Kalashnikov, and he also developed the AK74—Avtomat Kalishikov developed in 1974.

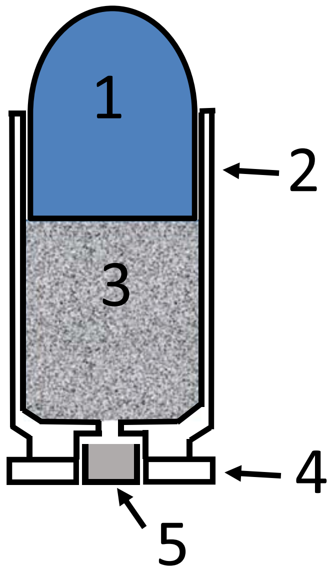

Figure 2. Ammunition, round, shell, or cartridge. 1 indicates bullet; 2, casing; 3, propellant; 4, rim; and 5, primer cap.

Casing

The casing is typically made from brass, steel, aluminum (or plastic in the case of shotgun shells) containing a propellant, which is a smokeless gunpowder, and the projectile or bullet, which is fit tightly at the end. The neck size, overall length, case body diameter, rim type, case body tapering, bullet weight, and caliber are critical specifications that are specific for a particular type of cartridge. Cartridges are available in various sizes or shapes but are commonly cylindrical with a taper toward the head of the cartridge.

Primer

Opposite the projectile, the primer is a type of a blasting cap that ignites the smokeless gunpowder when struck by a small metal firing pin (Fig. 2). This initial spark causes a conflagration that results in rapidly expanding gasses and the propulsion of the bullet down the barrel of the weapon. Centerfire and rimfire are the two common designs of a cartridge based on the location of the primer in the cartridge. In a centerfire cartridge, the primer is located in the center of the cartridge in the back of the cartridge, while in a rimfire, the primer is located on the edge. Centerfire cartridges are safer, are more reliable, and can withstand higher amount of pressure without disintegrating in comparison with rimfire cartridges.

Propellant

The discovery of gunpowder was revolutionary and directly related to the evolution of firearms. Black powder (the first type of gunpowder) was made from mixing sulfur, charcoal, and potassium nitrate. This invention forever changed the civilized world. Black powder was initially used for the creation of fireworks first described in the seventh to the ninth century.[22] The explosive power was used in many ways but soon found its way into weaponry and the creation of guns, cannons, and rockets. In the 13th century, the first primitive firearm was the fire lance, which was made from bamboo or a metal tube that shots projectiles such as metal objects, pieces of broken porcelain, or darts and arrows. The Chinese used it against the Mongols who then spread the use of gunpowder across Asia, and soon, it spread worldwide through the Middle East and eventually into Europe.

Gunpowder is the most important component of a cartridge that determines the power or energy. Gunpowder was difficult to use because it was messy and dangerous. Large plumes of black smoke had obvious disadvantages, especially for the shooter, as reloading was not very efficient. In 1846, Christian Schönbein,[23] a German chemist, was conducting experiments at his home (against his wife's wishes) when he spilled a mixture of strong nitric and sulfuric acids in his kitchen. He wiped up the mess with his wife's cotton apron and hung it over the stove to dry. This apron ignited and disappeared almost instantly, leaving behind no ashes. What he discovered was nitrocellulose. This material provides less heat and smoke and has much more explosive force per gram compared with black powder. This new "guncotton" was notoriously unstable and thus underwent several generations of changes. During this evolution, scientists also developed the primer, which when compressed, would explode. This invention enabled the modern cartridge to be developed. In 1887, Alfred Nobel obtained a patent for a smokeless gunpowder that he called *Ballistite*.[24] It is believed that the criticism Alfred Nobel bore because of his leading role in the manufacture and sales of weaponry spurred him to donate his wealth to science, both creating the prize that bears his name and simultaneously improving his reputation.

Projectile/Bullet

The projectile or bullet is the part of the cartridge that exits the weapon and comes in every imaginable shape and size. Bullets are an important part of the damaging potential of a weapon because they affect the kinetic energy imparted to the target tissue. It depends not only on the size and weight

Figure 3. Various sizes of bullets and rounds. Variety of cartridges or rounds, from 0.22 cal handgun round, 9-mm hollow point handgun round, 5.56-mm rifle round, 7.63 rifle rounds, 0.50 cal rifle round, average pen for comparison.

Figure 4. Fully jacketed bullets, on the top row, retain their shape when traversing tissue. Partially jacketed bullets are designed to expand upon entering tissue and thus deliver more of their potential energy to their target.

(density) of the bullet but the on composition of the bullet. The center of the modern bullet is typically made of soft lead because it is cheap, easy to work with, and readily available. The modern-day bullet comes in precise diameters, lengths, mass, shape, and outer jacket, all of these factors help determine the energy and tissue damage imparted to the target (Fig. 3).

Jacket on the Bullet

The bullet is often covered by a metal jacket that is typically copper, cupronickel, or steel alloy. A full metal jacket round typically refers to the bullet with a soft lead inner core where the front and sides are completely covered by a thin metal. Full metal jacket bullets reduce lead vapor generation, which is better suited for indoor firing ranges. A full metal jacket results in less expansion, fragmentation, and deformation of a bullet when the target is hit reducing tissue injury.[25] The design of the outer jacket of the bullet is central in determining the magnitude of tissue injury and has been a focus of international, military consensus meetings during the past 120 years. The jacket is essential for the bullet traveling more than 2,000 ft/s to prevent deformation and melting from the high temperatures in the barrel. Full metal jacket bullets also reduce vapor generation, which is important for indoor firing ranges. Conceptually, a full metal jacket bullet with less expansion, deformation, and fragmentation may traverse tissue imparting only a portion of its kinetic energy, whereas a partially jacketed bullet deforms and fragments upon entering tissue, increasing retention and transferring more kinetic energy to the tissue (Fig. 4). This concept is relevant because bullets are used in wide circumstances from police handgun bullets, to assault rifles, to small game and big game hunting. Handguns often have semijacketed, hollow point, ballistic tip bullets, which are discussed later in this review. On the other hand, military experts have agreed to minimize devastating tissue injuries by prohibiting bullets that are not fully jacketed. Often attributed to the "Geneva Conventions," the Czar of Russia proposed and arranged a meeting at The Hague in 1899 that included representatives from 26 nations (including the United States). The result was a "Declaration Respecting the Prohibition of the Use of Expanding Bullets" that is, "abstaining from the use of bullets which expanded or flattened easily in the body." The Hague Convention of 1987 reaffirmed forbidding projectiles that "cause unnecessary suffering."[20]

Shape

The shape of the bullet determines the flight character, penetration capability, and the behavior of the bullet once it enters the target. The bullet penetrates the body easily due to the laws of physics as the point of the bullet is relatively small. The bullet shape and surface area of the bullet are what determines penetration. Although a pointy bullet or "Spitzer bullet" (from the German word Spitzgeschoss, which means "pointy bullet") confers an aerodynamic advantage, at short range, this is less of an issue. The pointy bullet has a lower drag coefficient, decelerates less, and is more accurate because it is less affected by crosswinds and is more stable in flight. For rifle bullets, there are many configurations such as flat nose, Spitzer, and boat tails, which affect how the bullet acts during flight and in the tissue, as the ballistic coefficient variables such as sectional density and drag are affected by the shape and material. Instability in flight is also important because bullets do have some tendency to pitch and yaw during flight and once in the tissue. The roll or the spin caused by rifling in the barrel helps reduce the instability and highly affects the flight characteristics. Boat-tailed bullets have a sloping end narrowing gently at the base, which reduces the vacuum behind the bullet and thus reduces drag. This reduction in drag will help retain velocity because it is more aerodynamic and is used for long-range shots. Although it is mainly designed to affect the flight characteristics, some falsely believe that it increases the tumbling of the bullet once the target is hit.

Another important variable of shape is the hollow point bullets designed for handguns (Fig. 5). Handguns are for short range, and thus, the flight characteristics are less important. One of the design intents of hollow point bullets is that the hollow point will result in more deformation of the bullet on impact, and thus, more tissue injury will occur, but the main design characteristic is that the deformed bullet is less likely to pass through the body, minimizing the potential of bystander injury.[26] If the bullet deforms and does not pass through the victim, then the entire kinetic energy of the bullet is imparted

Figure 5. .380 caliber round next to 9-mm hollow point round next to 9-mm round next to .380 round. When compared side to side, the rounds are different, but when comparing them from the back, the diameter of the rounds is similar.

TABLE 5. Caliber of Bullets in English and Metric

Caliber in inches	Conversion to Millimeter	Similar Metric Round	Type of Firearm
.22	5.59		Handgun and rifle
.223	5.66	5.56	Rifle
.30	7.62	7.62	Rifle and machine gun
.357	9.07	9	Handgun
.38 special	9.65		Handgun
.380 ACP	9.65		Handgun
.40	10.16	10	Handgun
.44 mag	11.18	11	Handgun
.45 ACP	11.43		Handgun
.45 colt	11.43		Handgun
0.50	12.7		Rifle and machine gun

ACP, Automatic Colt Pistol.

to the victim. The goal of transferring all of the kinetic energy is in hopes of knocking down the person or "dropping" the person. This is known as "stopping power." Some hollow point bullets are so well designed that the expansion is precise and reproducible such as the "black talon" bullet. This type of modification to enhance wounding capacity is not modern. One of the earliest reports was in 1897 when the British scored the bullets externally to promote fragmentation to stop fanatical Indian Tribesman. The "dum-dum" bullet was developed by the British by removing the jacket at the nose of the bullet to expand (mushroom) on impact to limit penetration and produce a larger-diameter wound for increased incapacitation. At the British military facility, Captain Neville Bertie-Clay developed the Mark IV cartridge, the so-called *dum-dum bullet* (Dum Dum is a city in West Bengal, India). These were the types of bullets that have been banned in warfare by the Hague Convention. During World War I, the Germans also similarly altered their ammunition. A more recent modification highlighted by the shooting of President Regan is the explosive bullet, designed to detonate after the bullet was imbedded in the victim's tissues.[27] The earliest report is attributed to the British in 1822, who designed the bullet with delayed ignition of powder magazines, and these bullets were used in the Civil War. The modern version of this concept is referred to as "Devastator" brand cartridges, which contained small aluminum and lead azide explosive charges designed to explode on contact, and this was used by John Hinckley when he tried to assassinate President Regan in 1981.[28] Hinckley used a Rohm RG-14 0.22 long rifle blue steel revolver and fired six rounds in 1.7 seconds.

Caliber

The outer diameter of the bullet is the caliber. It can be confusing because nomenclature is large. The system is somewhat cumbersome because English or metric systems are used. The English system measures bullets in hundredths of an inch, and the metric system uses millimeters. A .22LR, L, or S caliber bullet is 22/100th of an inch in diameter. The abbreviations after the diameter stand for long rifle, long, or short, respectively, and denote the power charge and size of the casing behind the bullet. The .22lr caliber handgun round (the most popular of the .22 caliber cartridges) can be shot in revolvers or semiautomatic handguns or rifles and is a very low-energy round with a very small bullet. In contrast, the typical round used in military assault rifles are the .223 round (metric system, 5.56 mm). The rifle rounds are either 22.3/100th of an inch or 5.56 mm in diameter (Table 5). Although the caliber of the .223 assault rifle round is similar to the .22 handgun round in diameter, the bullet mass and length are larger and contain much more propellant or smokeless gunpowder. The result is that the assault rifle round has more than four times the muzzle velocity compared with the handgun round and more mass and thus significantly more kinetic energy, even though the calibers are similar (Tables 3 and 4). Similarly, the 9-mm bullets from the most common handgun are 9 mm in diameter. The .380 and .357 bullets (using English dimensions) are similar in caliber to the 9-mm bullet (Fig. 6). Table 1 shows various sizes of the bullets in inches with comparable metric equivalent.

The common English nomenclature handgun rounds are the .22, .38, .357, .40, .44, and .45. Grain is an older standard measure of mass and can refer to the amount of propellant behind the bullet and also denotes the weight of the bullet. One grain is equal to 64.79891 mg. Although the .38 special is a common round used in revolvers by the police in the 1960s and 1970s, this round is vastly different from the .357 magnum because of the amount of propellant, even though the diameter of the bullet is similar. President Lincoln was assassinated with a .44 caliber Derringer revolver, President Garfield was assassinated with a .44 caliber Webley Bulldog revolver, and President McKinley was assassinated with a .32 caliber Iver Johnson "Safety Automatic" revolver that was purchased for $4.50.

The .380 is a round used in a semiautomatic handgun that is most well-known for its use by James Bond in the 007 movies. The .380 bullet is similar in diameter to the 9-mm semiautomatic handgun used by law enforcement and the military. Although the diameter may be similar among various bullets, the length and weight of the bullet and the amount of propellant are not normally distinguished in the nomenclature. Ultimately, this equates to the muzzle kinetic energy being different between the .380 and the 9-mm round (Fig. 5).

Figure 6. Handgun ammunition is considered low velocity and designed for short-range targets. The bullets vary widely in design; the left is a 50 cal magnum; the right, a 22 cal short.

It seems that in recent modern era, the kinetic energy of handguns continues to increase.[29]

THE ANATOMY OF WEAPONS

Modern-day firearms are available in a variety of shapes and sizes and are routinely classified based on their caliber (bore diameter) and the type of used action (revolver, semiautomatic, automatic, bolt action, muzzle loader, etc). Guns are traditionally defined as low velocity and high velocity. Most handguns are considered low velocity, and most rifles are considered high velocity.

Handguns

Handguns are designed to be handheld. They were conceived as compact weapons primarily to be used for self-defense. Legally, handguns are considered concealable and governed by strict legislations across various states in the United States. Handguns are also considered low velocity. Single-shot pistols, revolvers, and semiautomatic are the three common types of handguns.

Single-Shot Pistols

Single-shot pistols are capable of holding only a single round of ammunition and are required to be reloaded after each shot. These are a very simple type of handguns that were used regularly in the 19th century. However; currently, these have been largely replaced by revolvers.

Revolvers

Revolvers have a revolving cylinder containing multiple chambers[5,6] that are capable of firing multiple rounds with a single load. Revolvers are of two types, namely, single action and double action. The single-action pistol requires the hammer to be manually pulled back against a spring with the thumb with the first action. The second action of the trigger being pulled sends the hammer forward striking the firing pin, which strikes the primer of the round in the chamber causing the bullet to fire. Every time the hammer of the revolver is cocked, the revolving cylinder realigns itself to the next chamber and is ready to fire the next round. The double-action revolver enables the shooter to pull the trigger (long pull), which cocks the hammer and fires the gun, performing a double action with just one pull of the trigger. A double-action revolver can also function as a single-action revolver when the hammer is cocked back against the spring and the pull of the trigger (short pull) sends the hammer forward striking the pin.

Figure 7. This is a 44 magnum revolver handgun, also known as ''Dirty Harry,'' and known for its relatively high muzzle velocity.

Figure 8. Semiautomatic pistols. Top gun is Baretta 92FS Brigadier, similar to the weapon used in the military. Bottom gun is Walther PPK, which is small and concealable, popularized in Ian Fleming's novels featuring James Bond 007.

The modern-day revolver such as the .44 magnum (Fig. 7) is a double-action handgun, and all six bullets can be fired with only six pulls of the hammer. In comparison, the single-action revolver such as the Colt 45 peacemaker western style gun used in western movies requires the cocking of the hammer in between every pull of the trigger. Revolvers are simple in design, are cheaper to manufacture, have less moving parts, and are more reliable in performance and operation as compared with semiautomatic handguns. On the other hand, revolvers are limited to five or six cartridges when fully loaded.

Semiautomatic Pistols

Semiautomatic pistols are a third group of handguns that have a single fixed firing chamber that is located in the rear of the barrel and a magazine so they can be used to fire multiple rounds without the requirement of reloading after each round (Fig. 8). This gun requires a manual chambering of the first bullet to be fired, which is stored in the magazine or clip. The magazine can typically hold 7 to 17 rounds stacked one on top of the other and have a spring to push the rounds upward. The slide of the gun is pulled back against a spring, and this cocks the hammer and loads the first round into the chamber of the gun. When the trigger is pulled (short pull), the hammer strikes a pin that strikes the primer of the round. With the expansion of the gas caused by the conflagration of the propellant, the bullet is propelled forward through the barrel and sends the slide backward, cocking the hammer again, ejecting the expelled

Figure 9. Bolt action rifle, 300 Weatherby magnum rifle, typically used for wapiti hunting.

shell, and loading the next round into the chamber and barrel. Modern-day semiautomatic pistols have a double-action capability. If a round has been chambered already and the hammer is in the uncocked position, a long pull of the trigger in one action will cock the hammer and send it forward with one long pull. After discharging the first round, the gun is then ready to be fired with a short pull as the discharging and recoiling process cocks the hammer and loads the next round simultaneously. Thus, with a semiautomatic handgun, all the rounds in the bullet can be fired as fast as the trigger can be pulled until the rounds in the magazine are spent. High-capacity magazines that can hold more than 10 rounds were federally banned from manufacture in the United States in 1994, but this ban was allowed to expire and has not been legislatively renewed at the federal level. Eight states currently have bans on these magazines. Consequently, most pistols sold in the United States can hold 7 to 17 rounds, but high-capacity magazines holding up to 30 rounds are easily available.

Long Arms

Long arms are the category of firearms with longer barrel. These weapons are required to be fired using both hands braced against the shoulder or hips. The barrel length commonly ranges between 10 in and 36 in and is mounted on a stock (wooden, plastic, or metal) that provides the grip while firing the gun. Long arms provide the user more hand grip because of the longer barrel and also higher precision and stability while aiming at a target in comparison with handguns. Rifles and shotguns are the two most commonly available types of long arms.

Rifles

A rifle is a type of long arm that has helical groove or a distinct pattern of grooves (rifling) cut into the barrel walls. As a result of this pattern of grooving, the term *rifle* was coined to this design of a long arm. Within the barrel, a rifle has raised areas of the rifling commonly called as lands. These lands after coming in contact with the projectile impart a spin or roll to the projectile around an axis corresponding to the orientation of the gun. This provides gyroscopic stability to the projectile in space and minimizes the projectile from tumbling or deviating from its ballistic path. In addition, this also allows for aerodynamic efficiency of the projectile and helps improve range and accuracy of the gun. The rifling typically is one full twist per foot. This is termed 1:12, but the modern-day assault rifles will come with 1:7 to 1:14.

Rifles come as single shot, bolt action, or semiautomatic or automatic. Traditional hunting rifles were loaded at the breach and had to be reloaded after each shot. Newer hunting rifles and sniper rifles are typically bolt action rifles (Fig. 9). They have a bolt with a handle that is lifted to allow the bolt to come back exposing the chamber, and the round can be placed into the chamber from either above or below with the use of a magazine holding the rounds in a stacked fashion. Each round fired requires a manual process of reloading by manually pulling the bolt back, which also cocks the striker against a spring and the forward push of the bolt, and then, twisting and locking the bolt into position readies the rifle to be fired with a short pull of the trigger. Hunting rifles are designed to kill big game animals with ideally a single shot, and thus, the ammunition is relatively bigger compared with handgun ammo (Fig. 10). Muzzle loading rifles are single shot, usually with a .45 or .50 caliber slug (bullet) that is loaded via the end of a barrel.

The semiautomatic rifle, like the semiautomatic handgun, uses the recoil of the fired round to load the next round into the chamber. The semiautomatic rifle fires a round each time the trigger is fired until the magazine or clip is empty. Assault rifles are semiautomatic or fully automatic. An assault rifle is shoulder fired and uses intermediate-sized cartridges in a clip or magazine and may have selective fire between semiautomatic,

Figure 10. Big game hunting and military ammunition are high velocity and designed to retain bullet stability for delivering major destructive kinetic energy at longer distances. The top row is typical big game hunting ammunition, ranging on the left a 300 Weatherby magnum to the right a 30.06 Springfield. On the bottom row is typical military ammunition, on the left, an AK47; the middle, an M-4; and the right, an AR15 with a Teflon jacketed bullet.

automatic, or even burst fire, which is typically three rounds. Burst fire was developed to save ammunition because typically only the first three rounds will be near the intended target as the recoil aims the gun elsewhere than intended (Fig. 11). A *machine gun* typically refers to an automatic rifle that has its ammunition belt fed. This rifle will shoot continuously as long as the trigger is pulled and stops when the trigger is released or the rounds have been expended. A *submachine gun* is an automatic, magazine-fed weapon that is typically bigger than a handgun but shoots handgun rounds. The effect of being shot with a submachine gun is the same as being shot with a handgun.

Shotguns

Shotguns are a smooth bore long arms that fire a variety of projectiles from small spherical pellets (birdshot) to large spherical pellets (buckshot) to solid lead projectiles (slugs). Shotguns have an external appearance similar to rifles but differ in the lack of rifling inside the barrel. They exist in breach load, pump (rounds are ejected and the weapon rearmed from a magazine with a pump of the forearm mechanism), lever action (works much like a pump shotgun but uses a lever to extract and chamber shells), and semiautomatic varieties. These have a wide caliber range, from 5.5 mm to approximately 2 cm (Fig. 12). Gauge is the caliber of the shotgun. It is determined by the number of lead balls of equal size that make one pound. A 12-gauge shotgun is the most popular hunting weapon that has a bore diameter equal to the size of 12-lead balls that add up to one pound. As the gauge of the shotgun increases, the caliber

Figure 11. *A*, Semiautomatic assault rifle with adjustable stock, scope, heads up sighting system, and laser targeting device. *B*, Same rifle with a different handguard, lighting system, and sling.

Figure 12. *A*, Shotgun ammunition usually contains multiple pellets, varying considerably in number and size, which are designed for short-range targets. On the right are 50 cal lead slugs used in muzzle loading rifles. *B*, Sears-Roebuck semiautomatic shotgun.

of the barrel decreases (Table 6). The most commonly used shotgun shell is the "birdshot" consisting of hundreds of small lead pellets. "OO" double ought buckshot contains only nine pellets, and each has the potential wounding equivalent of a small handgun round, and a "slug" is one large projectile.

Tissue injury is dependent on the kinetic energy of the shotgun shell and the distance between the weapon and the victim.[30] When shotgun wounds occur at close range (<3 yards), the pellets act as a single large projectile. These injuries can be devastating mainly because of the transfer of energy.[31] The energy of the pellets is reduced dramatically over relatively short distances. Compared with the energy measured at the muzzle, at 50 yards, this energy is reduced to approximately 30% to 50% and even more when pellets are used. Shotgun pellets are not aerodynamically efficient or stable. In intermediate range shotgun injuries (3–7 yards), the pellets will spread apart and no longer act as a single projectile. Typically, at this distance, spread will be approximately 12 in, and fascial penetration and multiple solid and hollow viscus injuries are typical. Long-range (>7 yards) shotgun injuries with bird (small) shot will present with many skin wounds over a large area (the whole back, or the entire abdomen and chest) and do not often penetrate the fascia.[32]

Given the relatively large amount of energy imparted to each pellet in a buckshot cartridge as compared with the small amount of energy imparted to each pellet in a birdshot cartridge,

TABLE 6. US Shotguns

Caliber	Pellet/Grains	Velocity, ft/s	Muzzle Energy, ft lb
.410	88	1,825	650
20 gauge	273	1,600	1,565
16 gauge	383	1,500	2,000
12 gauge	545	1,330	2,145
12 gauge	700	1,320	2,725

patients shot with buckshot should be thought of as having been shot multiple times with a low-velocity weapon (Table 6). The vast majority of these patients will have visceral injuries requiring surgery even after a long-range buckshot injury, and conservative management is not recommended.[33] Shotguns are commonly used for hunting fast moving birds and smaller animals at intermediate ranges.

TISSUE DAMAGE

Overall, the effect of tissue injury depends not only on the muzzle kinetic energy, the distance from the muzzle to the victim, and the dissipation of the kinetic energy, that is, whether the bullet is retained or passes through the tissue, but also on the type of tissue encountered by the bullet.

As the bullet hits the target object, the kinetic energy of the bullet is transferred to the target tissue. In addition to the characteristics of the bullet, the type of tissue is key in determining the extent of injury. Skin and lung tissue has low density but is elastic and therefore is injured less compared with muscle, which has higher density and only some elasticity. Similarly, the liver, spleen, and brain have minimal elasticity and thus are more severely injured by a bullet of similar energy. Fluid-filled organs such as the bladder, heart, great vessels, and bowel can transmit kinetic energy more because they are not compressible and can result in bursting the organ. Bullets usually cause fracture and fragmentation of bone because they have minimal to no elasticity and may even produce secondary fragments, which can act as another missile resulting in injury to adjacent tissues.

Types of Tissue Damage

Laceration and Crushing

Laceration or crushing type of injury patterns are generated by shear forces. Bullets do not typically follow a perfect straight line to the target. Rotational forces keep the bullet off a straight axis of flight. Yaw angle is the angle between the longitudinal axis of the projectile and the path of the projectile. When the bullet is travelling with its front end forward, the yaw angle is zero. However, if the bullet yaws 90 degrees, the entire longitudinal axis of the bullet crushes a larger tissue area at point of impact.[34] There are myths that bullets tumble in tissue and that all wounds have undergone similar distortions of gelatin blocks exploding. The tissue that is injured determines the path of the bullet and what it does in the body. It is highly variable.

In contrast to popular opinion, bullets also do not bounce around in the body. In general, bullets do not tumble when the skin is pierced, but high-energy rounds may begin to tumble as energy is dissipated upon travel through deeper tissue. The natural tendency is that the high-energy bullets will become unstable as they decelerate. These bullets may pitch and yaw, and the back end of the bullet may become the leading edge. During this distance, the energy of the projectile is absorbed by the surrounding tissue, causing stretching and tearing of tissue.

In contrast to high-velocity rounds, handgun bullets will generally travel in a relatively straight line and will either traverse the body in a straight line or make one turn if a bone is hit, in which case the bullet will typically fragment, and trail of fragments and bone can be seen in the general direction of the resulting path. Lacerations are also highly dependent on the deformation of the bullet as with hollow point bullets, which can be designed to splay out with multiple sharp edges, which can slow the bullet down to stop in the tissues, thus transferring all of the kinetic energy and causing more tissue injury because of the sharp edges (Fig. 4).

Cavitation

A bullet with sufficient energy will have a cavitation effect in addition to the penetrating track injury.[35,36] As the bullet passes through the tissue, initially crushing then lacerating, the space left by the tissue forms a cavity, and this is called *the permanent cavity.* Higher-velocity bullets create a pressure wave that forces the tissues away, creating not only a permanent cavity the size of the caliber of the bullet but also a temporary cavity or secondary cavity, which is often many times larger than the bullet itself (Fig. 13). This temporary cavity depends not only on the energy imparted by the bullet to

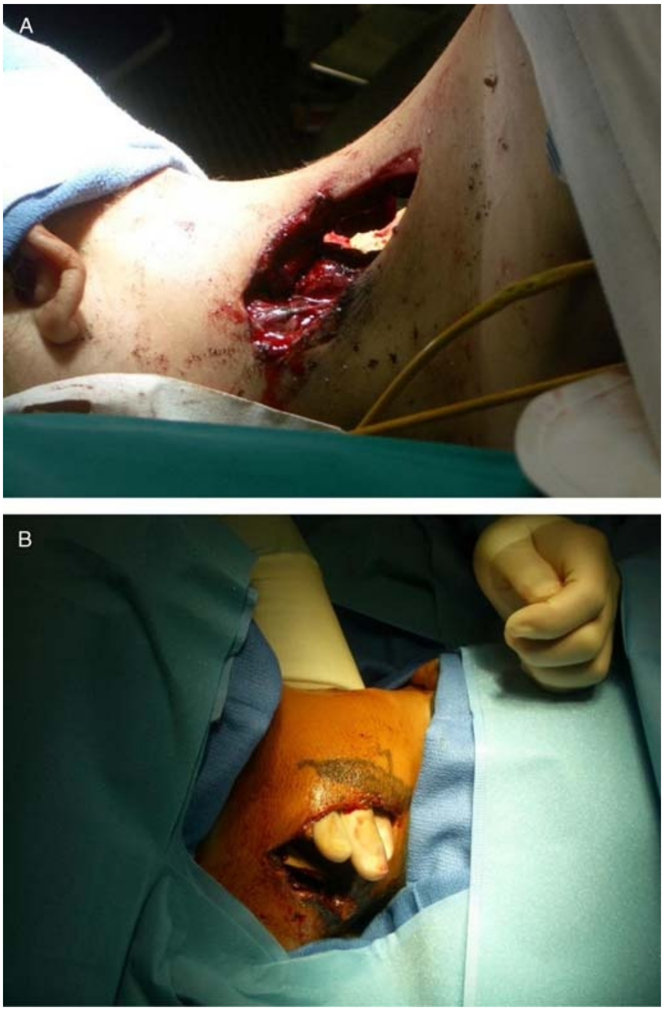

Figure 13. *A*, Gunshot wound to the posterior neck with large tissue defect. *B*, Wound with surgeons hand in it.

the tissues but also on the density and elasticity of the tissue that it passes through, causing stretches and tears.[37] This is commonly referred to as blast injury, but the correct terminology is cavitation injury. Skin, muscles, and intestines are absorbers of energy and hence are highly resistant to the development of secondary cavitation. Organs such as the liver, spleen, kidney, and brain, which have relatively low tensile strength, are likely to split or shatter because of the development of temporary cavitation.[38] If the muzzle of the weapon is close enough to the skin (close range), gases from the conflagration of the propellant gunpowder can be blown into the tissue causing additional cavitation with expansion of tissues. High-velocity rounds are much more likely to have significant cavitation injury (Fig. 13). Although the distance traveled by the bullet is relatively short, this high-velocity wound to the back of the neck results in a large tissue defect. Most agree that the more solid and less elastic the tissue, the more profound is the cavitation. Thus, an injury to the thorax will have less cavitation than an injury to the liver. In injuries to the thorax, severe lung injury, when seen, is most likely caused by secondary missiles created by bullet impact and shattering of ribs and the resulting bleeding around the bullet track. When a chest computed tomography is obtained in cases of a gunshot wound to the chest, the fluid-filled tract is caused more by hemorrhage than by cavitation injury. Figure 14 is a transaxial abdominal gunshot wound with a high-velocity weapon; on the patient's right side, the entry wound is barely noticeable, but the exit wound on the left side of the abdomen was approximately 3 cm, and the cavitation effect resulted in evisceration of bowel.

MYTHS AND FACTS

Stopping Power

Stopping power is the ability to wound enough to incapacitate the victim where they stand. This is in contrast to lethality, which is killing power. A lethal gunshot wound may take seconds, minutes, or days to kill a person. It is obvious that rapid lethality is determined by what is injured by the bullet such as the brain, heart, or major vessels. Injuries to the spinal column can be lethal if the injury is high enough on the spinal column.[39] Lethal wounds do not necessarily incapacitate immediately. In general, the bigger the bullet, the bigger the gun. However, even the largest handgun does not have the kinetic energy to knock down an average adult. If a person was shot and the bullet did not exit, then all the kinetic energy of the bullet is transferred or absorbed by the person. The energy of the bullet simply does not have enough energy to knock back a person significant distances as portrayed in movies. Because of Newton's third law of physics, if the energy of the bullet was sufficient to cause a victim to be blown backward after being shot, then similarly, the shooter would also be blown back because for every action, there is an opposite and equal reaction. The Hollywood examples of people being shot out of a window as they are blown back are fiction and propagated by continued Hollywood productions. The stopping power of a weapon depends more on where the target was hit than on the energy of the bullet.[40] Videos of people being shot during common convenient store robberies show that the robber or clerk shot through the chest or abdomen can be shot numerous times but can still run a distance before falling. A bullet fracturing a femur would drop a person no matter the size of the bullet. The thought that bigger bullets will have a better stopping power is most likely for the larger-caliber bullets being used in civilian urban settings.[29]

Figure 14. Evisceration of bowel through 3-cm exit wound on the left side of the abdomen created by high-velocity weapon (AK47), probably caused by cavitation effect.

Big Guns Kick, Little Guns Don't

The "kick" of the handgun (known as recoil) does not knock down the shooter. In general, weapons with larger muzzle energy kick more than lower-energy weapons. However, the kick of the gun depends both on the round that is shot as well as on the weight of the weapon (heavier weapons kick less.) The kick or recoil of the weapon is dissipated as this energy is transmitted in a spring-like fashion to the arms and joints of the shooter. When a hunter shoots a rifle, the energy felt by the shooter is dissipated because of the body's ability to absorb this shock. In addition, most hunting rifles have recoil pads to absorb some of this energy. The shooter of the rifle who shoots a round from standing absorbs the energy, and the energy or recoil is felt in the shoulder. If lying down in a prone position, the energy in the shoulder is higher and felt more than when the shooter is standing because the forces of friction between the shooter and the ground as well as the weight and position of the prone shooter does not allow for as much movement of the body. Thus, a stronger impact on the shoulder is felt. If the hunter were to stand against a big tree or a wall to stabilize themselves with the shoulder against the stationary stabilizer (not recommended), the hunter shooting the rifle would feel the entire force of the energy imparted to the rifle. The effect will be like a hammer impacting an anvil. The shooter who discharges the rifle with his shooting shoulder against an immovable object can have enough energy to cause injury to the shoulder. This type of injury to the shoulder with dislocations and fractures is seen in inexperienced hunters. Handguns dissipate the energy of recoil of the gun at the hands, wrist, elbow, and shoulder and will not have as noticeable a kick as a rifle or shotgun.

Large-Caliber Weapons Are More Lethal Than Small-Caliber Weapons

Lethality depends more on the number of "rounds on target" rather than what gun you are shooting.[41,42] Most experienced trauma surgeons will testify that what part of the body is hit by that gun is more important than the size of the gun. Some enthusiasts believe that a smaller bullet and power can deliver more precision and accuracy. This equates to more "rounds on target." More rounds on target equates to more chances of "knocking down" someone. The larger handguns that impart more energy will generate more recoil as well and thus require more effort to aim and thus affects the number of "rounds on target" with precision and accuracy compared with a smaller weapon with less recoil. The 44 magnum, the gun used by "Dirty Harry" gun (popularized by the actor Clint Eastwood), has a bullet with a diameter of .44 in (Fig. 7) and is similar to the 45 but normally comes with much more grains of gunpowder in the cartridge and has one of the highest amounts of recoil because it has one of the most amount of muzzle energy in a handgun (Table 3). Knock down power thus is affected by what is hit and how many times much more than the caliber of the weapon. It is conceivable that a person charging at the shooter that is shot in the heart may continue with their charge until the cardiac output from the heart is sufficiently reduced. To stop or incapacitate a person immediately, the person has to be shot in the brain, high spinal cord, or bones of the leg, resulting in the person being knocked down or stopping the person in their tracks.[43]

The Ideal Home Defense Weapon Exists

Much controversy exists regarding which weapon is best for protection. The optimal home defense weapon would incapacitate the desired target yet never cause collateral damage. This weapon does not exist. The typically used 9-mm handgun has been continually challenged as experience has shown that a person shot with this gun does not necessarily stop immediately. The military for years issued a .45 caliber handgun known as the Colt 1911. This gun was made by the Colt firearms company in the year 1911, and thus, the synonym commonly used is the 1911-.45. This handgun was the standard issue during World War I, World War II, Korean War, and the Vietnam Conflict. The Colt 45 or the "peace maker" is a revolver with the same caliber used in most western movies. It is the single-action 45 revolver. This is the gun used by "Billy the Kid" and "The Lone Ranger." The diameters of the western revolver and the semiautomatic pistol are the same and so are the kinetic energy in general as shown in Table 4. Approximately three decades ago, the US military opened up to handgun manufacturers to compete for the contract to replace the Colt 1911 semiautomatic. The winner of the bidding process was Beretta who won the competition with the semiautomatic 9-mm handgun called the *Brigade*. Complaints followed, but many feel that the key issue was that the Beretta was not a US-owned company. However, Beretta 9-mm Brigade has passed the test of time and has been an extremely reliable handgun. Some felt that the gun was not big enough, and many law enforcement including the Federal Bureau of Investigation and the military's Special Forces experimented with the 10 mm, which is equal to the 40 caliber. Although the muzzle energy is greater in the 10-mm round, the difference is not significant enough to change the stopping power. The ability of the bullet to enter but not exit is dependent to a degree on the bullet shape such as the hollow point bullets, but even if retained, it does not have the energy to stop a person.

In military and law enforcement, shotguns are used as close-range combat weapons or as a weapon for self-defense. In fact, it could be argued that the shotgun is the optimal weapon for home defense for individuals with less experience with guns. A shotgun at short range is easier to aim and hit a target, and the delivered wound can be equivalent to an assault rifle (Tables 3 and 4).

Trauma Surgeons Are Experts in Ballistics and Should Be Expert Witnesses in Court

As seen in this lengthy article, ballistics is an ever-changing and difficult field to master. For example, defining the entrance versus exit wounds of a bullet or multiple bullet injuries can be difficult. Study with trauma specialists found that fatal or exiting gunshot wounds were misinterpreted 52% of the time.[44] Thus, when describing gunshot wounds, it is important to characterize the wounds but not label them as entry and exit wounds (Fig. 14). If the bullet fragments, it is possible that only one part of the fragmented bullet may exit the patient. In these cases, the exit may be smaller than the entry. In scenarios when the bullet enters the skull, the entry may be large, depending on how close of a range the person was shot. It is common that, if the energy of the bullet is sufficient, the entry of the bullet into the brain causes fragmentation of the skull, and this impact causes cavitation, and the entry wound may be larger than the diameter of the bullet.

In addition to entrance and exit wound errors, trauma surgeons often use the word "shrapnel" to describe bullet fragments. This is a misnomer. Shrapnel injuries technically refer to those injured by a Shrapnel shell. These shells, invented by Major-General Henry Shrapnel (1761–1842), a British Army officer and inventor, have not been used since World War I. Thus, no one has been injured by shrapnel in almost 100 years. The shrapnel shell was an antipersonnel artillery munition that has individual bullets or balls that are ejected out of the front when close to the target. There are variants of this used currently such as the beehive munitions and the antiballistic missiles.

SUMMARY

Gunshot wounds are, by any definition, an epidemic in the United States. We as health care providers need to know about the truths regarding guns, their ballistic bullets, and gunshot wounds. We have to address this silent injury as we seem to ignore it because of its common daily occurrence. Suicides by guns are a major factor in the number of deaths from guns. People attempt suicides everywhere in the world but are particularly successful in the United Stated because guns are ubiquitous.

The statement "*Guns don't kill people, people kill people*" may be true; however, it is difficult to kill with an ineffective weapon. Availability of a potentially lethal weapon will increase injury severity. The United States has more guns available than most of the other countries in the world and has more gunshot wounds per annum than any other country in the world not involved in a war within its borders. It is indisputable that where there are guns, there will be gunshot wounds, and where there are more guns, there are more gunshot wounds than where there are no guns. More than 33,800 deaths are reported because of firearm-related injuries in the United States per year, making it one of the top 10 causes of mortality in our country. The rate of firearm ownership per capita in the United States is the highest in the world, which is almost double that of the second highest country on earth.[45,46] In addition, firearm-related injuries also negatively burden the financial system, costing US citizens approximately $100 billion annually. A relative lack of firearm legislation in the United States has been thought to contribute to the burden of firearm-related injuries. The understanding of why our country has so many firearms and what the effects in comparison with other countries and societies is hampered by the (some would say intentional) lack of funding on this topic. Because of concerns regarding increased government controls on freedom and guns, federal-funded research that attempts to understand this problem, firearm injury, epidemiology, violence, and injury prevention is minimal. Pressure exerted by the National Rifle Association, the gun lobby, and even some gun owners apparently is highly effective in preventing research to study or any effective legislation to help understand and perhaps change the course of this epidemic.

People do kill people, but guns are a major factor in this ability. We have to address numerous issues to prevent gunshot wounds including the costs, regulation of weapons, mental health issues, and better enforcement of current regulations while balancing these needs with citizen's rights. As firearms are ubiquitous in our country, knowledge of their wounding power is paramount in the care of the wounded patient.

DISCLOSURE

The authors declare no conflicts of interest.

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