While projectile injuries are not uncommonly encountered in veterinary practice, many clinicians are not very familiar with the various weapons and projectiles that may be involved or with the types of injuries that can occur. Whether or not an individual has an interest in firearms, a basic knowledge of projectiles and ballistics can help a clinician to predict the types of injuries expected in a given case, as well as direct him/her toward an appropriate treatment regimen for the patient. Additionally, an understanding of the legal process as it relates to cases of projectile injury allows a practitioner to appropriately collect and process evidence to assist with successful prosecution in cases where malice is suspected. Gaining in-depth understanding of these topics would require specialized training that is beyond the scope of this discussion. However, the goal of this presentation is to provide practitioners with a basic review of projectile injuries seen in small animals and to increase comfort level with appropriate diagnostics and therapies in these types of cases.

Projectiles

A projectile is defined as “a body projected or impelled forward, as through the air.” This can include missiles, arrows, rocks, and just about any other object that one can propel. In small animal practice, we generally see wounds secondary to bullets, pellets, or arrows, though veterinarians treating animals on the field of battle may have to deal with much more destructive projectiles such as rockets or grenades.

Projectile injuries encountered in veterinary medicine may be associated with a variety of different situations, including criminal activity, accidental wounding, and self-defense. Clinics may experience a variable caseload of these types of injuries, often dependent on their geographic location. Clinics located in urban areas tend to see more injuries related to handguns and crime-related shootings. Clinics in the suburbs may see more injuries from air-powered firearms and also from arrows, which may result from mischief of adolescents. Not surprisingly, rural clinics tend to see more injuries from rifles, shotguns, and arrows secondary to the increased prevalence of hunting in rural settings.
Anatomy of a Cartridge

Some people use the terms “cartridge” and “bullet” interchangeably; in reality, a bullet is only one of several components of a cartridge. The cartridge, or round, also consists of a primer, powder, and an outer case. A cartridge casing is most commonly constructed of brass, though aluminum or steel are occasionally used. As its name implies, the case functions to keep the various other components of the cartridge contained until the time of firing. The primer is a small explosive charge located at the base of the cartridge. Cartridges are classified as centerfire or rimfire based on the location of the explosive charge at the center of the cartridge or around the edge. When the primer is struck by the hammer of the gun, it explodes and creates flames to ignite the gunpowder in the adjacent compartment. Upon ignition of the gunpowder by the primer, a large amount of gas is released, and the resulting pressure propels the bullet out of the casing and toward the target.

The composition of a bullet is quite variable and often depends on the intended use. Most bullets are 90% lead, though they may be constructed from a variety of materials. One important characteristic of a bullet is its jacketing. “Jacketing” of a bullet refers to covering of the bullet with a metal that has a higher melting point than the bullet itself. This is done in order to reduce deformation of the bullet during firing and during impact with the target (the significance of which will be discussed later). Bullets may lack a jacket completely, may be partially covered, or may be completely surrounded by a jacket. Bullets in the latter category are referred to as “full patch” or “full metal jacket.”

Two modifications of the traditional cartridge include air-powered projectiles and shotgun shells. Unlike bullets fired from traditional handguns and rifles, air-powered projectiles are fired using compressed air rather than exploding powder. The shotgun shell is a modification of the traditional cartridge, consisting of a paper or plastic casing fused into a metallic cup. While shells can contain a single large slug, they more often contain a variable number of smaller projectiles that are released upon firing. Traditional shotgun shells contain lead or steel spheres, though shells containing rubber pellets, pepper balls, and even rock salt are available. Wads of plastic, felt, paper, or cork are inserted to compartmentalize the shell and separate the shot charge from the gunpowder. This wadding material is also expelled from the cartridge during firing and can serve as a secondary projectile source in the event that shooting occurs at a close range.

Projectile Naming/Sizing

Most commonly, projectiles are named or sized according to the diameter of the bullet itself or that of the weapon from which the slug is fired. This is most commonly expressed in terms of millimeters, as is the case with a 9mm handgun, or in terms of caliber, which is measured in hundredths or thousandths of an inch (e.g. “30 caliber”). Shotguns are an exception, and are often sized in terms of gauge or bore. Gauge developed from the 19th century method of measuring cannon balls; the gauge of a shotgun is the number of lead balls with the same diameter required to weigh 1 pound (so the diameter of a 28 gauge shotgun equates to the diameter of a lead ball weighing 1/28 of a pound). Confused yet? Just remember this: as gauge gets larger, diameter gets smaller (think of hypodermic needles or orthopedic wire).
Unfortunately, naming is very inconsistent between manufacturers, and names of firearms or projectiles may also reflect other characteristics. And it goes without saying that size is not the only determinant of a projectile’s function and potential for damage. The wounding capacity of projectiles can vary greatly according to weight, velocity, shape, and composition, among other things.

**Ballistics Basics**

Ballistics is the science that looks at the motion and potential wounding capacity of a particular projectile. The study of ballistics is broken into 3 major categories: interior, exterior, and terminal. Interior ballistics is the behavior of a projectile within the firearm itself; exterior ballistics concerns the flight of the projectile through the air; and terminal ballistics examines the interaction of the projectile with its target.

Most modern handguns and rifles have spiral grooves cut into the bore or barrel. This is referred to as “rifling,” and serves to impart a gyroscopic spin along the bullet’s longitudinal axis. The rotation of the bullet serves to stabilize it during flight. This is not the case with shotguns and some air-powered firearms, which are smooth-bored (no rifling). Even with rifling of a firearm, forces present in the air often cause a bullet to deviate from its longitudinal axis during flight. This instability increases the likelihood of severe tissue damage and bullet fragmentation upon impact.

The most important determinant of a projectile’s wounding capacity is its kinetic energy. The kinetic energy of an object is determined by the equation: KE = \( \frac{1}{2} \) (mass) x (velocity\(^2\)). Therefore, doubling the mass of a projectile will double the kinetic energy, but doubling the velocity of the projectile will quadruple the kinetic energy. So a smaller, lighter projectile moving rapidly may actually cause more damage than a larger, heavier projectile moving at a slower speed. In general, rifles tend to fire projectiles at higher velocities than handguns.

The wounding capacity of a shotgun is determined by the size, velocity, and distribution of the shot charge. When a shotgun is fired, the shot spreads in a conical fashion as determined by the constriction, or choke, at the end of the barrel. As was mentioned earlier, the number and size of shot in a given shell will vary depending on the intended use. Larger numbers of shot will give a better chance of hitting a target, but smaller numbers of large shot will likely do more severe damage. One will also see different types of injuries depending on the range at which a person or animal is shot. At close range, the shot practically acts as a single mass; at a longer distance, there is wider dispersal of the shot, but each individual projectile possesses less energy.

Once a projectile reaches its target, tissue trauma is caused primarily by the transfer of kinetic energy from the projectile to the target tissue. Specifically, projectiles damage tissues directly via tissue laceration and crushing, and indirectly via shock waves and cavitation. The more a projectile deforms and expands as it travels through the tissues, the larger the tract created and the more energy absorbed by the target tissue. This brings us back to the topic of jacketing. High-energy rounds that are jacketed maintain their kinetic energy and have the ability to
penetrate deep into tissues. This can be good or bad depending on how you look at it. If a jacketed bullet strikes only soft tissues, it may pass right through and cause much less damage than a similar round that is unjacketed; however, if a jacketed round strikes bone or a tissue with high resistance, results can be catastrophic because of the energy that the projectile retains at that point. Conversely, unjacketed bullets tend to deform, or mushroom, on impact. Therefore, while they don’t penetrate as deep into tissues, the wounds resulting from unjacketed bullets may be up to 40 times as large as wounds resulting from a similar jacketed bullet. For this reason, all military bullets are required to be fully jacketed. Hunting bullets, though, are often only partially jacketed and may cause significant soft tissue trauma.

Initial Assessment and Treatment of Patients

On initial examination, it may not be evident that a patient’s injuries are secondary to being shot. For example, projectile injuries may be confused with bite wounds or vehicular trauma. In most cases, though, patients are treated much like any patient presenting after sustaining trauma. In general, all patients should have some degree of basic lab work performed for screening and to serve as a baseline for future tests. An abbreviated ultrasound (FAST scan) can be performed to evaluate for free fluid in the chest or abdomen, and any fluid present can be sampled for analysis. ECG, pulse oximetry, blood pressure measurements, and additional testing can be performed as necessary. Once the patient is adequately stabilized, 2-view radiographs should be obtained of the region of injury. If the path of the projectile is ill-defined or if there are multiple wounds, surrounding areas should also be radiographed. Further imaging, such as ultrasound, contrast studies, endoscopy, and myelography or CT scan may be required on a case-by-case basis.

Some clinicians will try to characterize wounds as being caused by low-velocity or high-velocity projectiles, as this may help to direct treatment. When compared to low-velocity projectiles, high-velocity projectiles cause more damage to structures outside of their direct path. As a result, wounds resulting from high-velocity projectiles may require more extensive exploration than similar-appearing wounds resulting from low-velocity projectiles. If the type of firearm and/or projectile is unknown, determination of velocity can be difficult. In general, however: If a projectile impacts only soft tissues and remains within the body, it was likely a low-velocity round; if a projectile impacts bone and still exits the body, it was likely a high-velocity round. Once again, shotgun wounds are graded differently, and are classified (in increasing severity, based on a scheme by Sherman and Parrish) as type I, II, or III depending upon pattern of distribution and depth of penetration.

After initial stabilization and diagnostics, more definitive treatment of the patient can begin. While specific treatments required will depend on the nature of the injury, patients should generally be given analgesics and sedatives as appropriate, and most patients will benefit from IV fluid support. Contrary to popular belief, bullets are not sterile! Gunshot wounds are inherently contaminated, as projectiles drive and drag hair, dirt, and bacteria as they pass through tissues. As such, antibiotics are indicated in cases of projectile injury. Organisms of significance primarily consist of gram positive skin flora unless the gastrointestinal tract or perineal region are involved, in which case gram negative bacteria and anaerobes become more important.
Involvement of Specific Body Systems

Skin/muscle: If a gunshot wound involves only skin and muscle (such as on an extremity), it is often managed much like any other wound. Hair surrounding the wounded areas should be clipped liberally and the area around the wound cleansed. Wounds are explored and copiously lavaged. Small wounds associated with low-velocity projectiles are generally left open to heal by second intention. If closure of a large defect is required, adequate drainage must be maintained. Bullets that are easily and safely accessible are often removed. However, aggressive exploration for the purpose of removing a projectile is discouraged in order to limit tissue damage and infection. Projectiles that are left in the body are generally walled off by connective tissue. An exception to this rule is a bullet or fragment located within a joint, which must be removed to prevent degradation and systemic absorption of lead. Projectiles may also require removal if they compromise a major structure, will cause discomfort, or are needed for legal reasons.

Fractures: Preservation of bone fragments and minimal disruption of blood supply during debridement and repair of fractures will help to promote fracture healing. Simple fractures with minimal soft tissue injury may be amenable to primary repair, while high-energy fractures with more significant soft tissue injury may require extensive wound management in addition to fracture repair. Use of external fixation is popular in these cases because it can allow for immediate, definitive fracture stabilization and concurrent wound management. In cases of severely comminuted fractures, severe soft tissue injury, or financial constraint, amputation may be considered as an alternative to fracture repair.

Abdomen: Projectiles that penetrate or perforate the peritoneal cavity have the potential to damage a wide array of structures including the GI tract. Due to the risk of septic peritonitis, exploratory surgery is indicated in any case of a penetrating abdominal wound. Careful examination of all structures is necessary, and while small defects may be able to be repaired, resection of devitalized tissue is often required. In those patients with peritonitis, appropriate abdominal drainage should be maintained, either through use of closed suction drains or by management with an open abdomen technique.

Thorax: In cases of penetrating thoracic wounds, varying degrees of pneumothorax and hemothorax may be encountered. Surprisingly, though, many of these patients can be managed without surgery. Air and fluid can be removed from the pleural cavity by means of a thoracostomy tube, which can be intermittently aspirated or attached to a continuous suction source. Exploratory surgery is indicated in cases where damage to the esophagus, heart, or tracheobronchial tree are suspected; as well as in cases where hemorrhage or air leakage cannot be controlled with a thoracostomy tube.

Neurologic: Brain surgery is uncommonly performed in veterinary patients, as those with significant neurologic damage are often euthanized. In patients with minimal neurologic deficits, supportive care and broad-spectrum antibiotic therapy may be sufficient to allow recovery. For patients with suspected spinal cord trauma, appropriate restraint is important to prevent further injury. Neurologic status should be determined as completely as possible prior to sedation. As is the case with any type of spinal trauma, radiographs and CT scan can be used to determine whether fracture stabilization and/or decompressive surgery are required.
Arrow Injuries

While we classically think of firearms when referring to projectile injuries, arrows also have the capability of causing significant injury to our patients. Arrows lack the destructive capacity of bullets, and as such rely on striking vital structures to produce injury. Arrows are available with several different heads, or points, depending on their use. The two general categories of points are field points and hunting points. Field points have a pointed or dull tip and are generally used for target practice or hunting small game. Hunting points, also known as broadheads, possess cutting blades for hunting larger game. Field point arrows are generally easy to remove, as they will slide out of tissues with little effort. In contrast, hunting point arrows can corkscrew into tissues, making removal difficult, and their cutting blades may lacerate vital structures if withdrawal is attempted. It is recommended that arrows be left in place until surgical exploration can be performed; owners can cut and remove the external portion of the arrow to make transport of the patient easier. As is the case with gunshot injuries, radiographs of the injured area are performed, followed by surgical preparation and exploration of the wound. Because arrows travel at relatively low velocity, damage to surrounding structures is often minimal and wide debridement of wounds is often unnecessary. However, appropriate lavage and drainage of the wound are important, and as is the case with gunshot wounds, penetration of the peritoneal cavity necessitates exploration.

Legal Considerations

Some incidents may result in, or even require, legal action. In order for a legal case to be prosecuted successfully, proper handling of both the case and the evidence are needed. In potential legal cases, a complete set of quality radiographs should be obtained to highlight the patient’s injuries. Photographs should also be taken of the entire animal and of the individual wounds. A metric ruler should be included in photographs for size comparison. All photographs should be labeled with the date, case number, and initials of the clinician involved. If possible, projectiles should be photographed in situ prior to removal; detailed photographs are then taken after retrieval. Bullets should be washed with water and alcohol to remove blood and tissue, and then allowed to air dry. Projectiles are placed individually in containers that can be sealed with tape. Containers should be marked with the date, time, case number, owner’s name, and initials of the attending clinician. If a patient injured by a projectile does not survive and legal action is possible, a thorough necropsy should be performed, preferably by, or in consultation with, a board-certified pathologist. Evidence in a potential legal case should be transferred only to a law enforcement officer, never to the owner. While details of evidence collection and handling may seem silly, they must be followed in order to guarantee admission in court.

Selected References/Recommended Reading


http://library.med.utah.edu/webpath/tutorial/guns/gunintro.html
