Sister's Last Shot

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Introduction

Gunshot trauma is classified as a focal, penetrating type of traumatic injury.[3,8] While gunshot trauma is an uncommon cause of injury for equine patients, the indiscriminate nature of where projectiles strike, especially when shotgun pellets are used, creates a diverse range of potential outcomes for patients that clinicians should be cognizant of in order to understand the true nature of the injury and to subsequently provide the appropriate treatment.[3,6,8] Projectiles not only disturb the skin and other surrounding superficial structures, but musculoskeletal tissues, internal organs, and neovascular structures may also be affected. More importantly, depending on the elasticity and cohesiveness of the tissues affected, some, such as bone, may be less likely to survive the trauma, ultimately resulting in a graver prognosis for the patient.[6]

The physical appearance of entry wounds is often circular, with relatively clean margins and likely a hyperemic edge surrounding the wound due to local inflammation or carbon monoxide damage from the barrel if shot at close range.[8] High-velocity impacts create a vacuum-like effect as the projectile passes through tissue, causing foreign material to be pulled into the wound.[6,9,17] Moreover, the projectile itself is not sterile.[14,17] As a result, gunshot wounds should be considered contaminated, so primary closure of these wounds is generally not recommended and instead, should be managed as open wounds. If surgical intervention is warranted, it is recommended that they be corrected with delayed primary closure techniques.[6,8,11]

Most of the damage from gunshot trauma is hidden below the surface of the skin.[6] Only after the initial assessment and stabilization of the animal should the wound be explored to evaluate the extent of the damage.[15] Treatment includes thorough identification of all structures involved, establishing and maintaining adequate drainage, and debriding the permanent cavity, if necessary.[6,8,10,15] Broad spectrum antibiotics, including those with anaerobic spectrum, are highly recommended, and depending on secondary complications, such as peritonitis, long-term

administration is often warranted.[3,6] Musculoskeletal injuries are the most common result of gunshot trauma in horses and usually carry a good prognosis for survival and return to function.[8,9]

History and Presentation

Sister, a 2-year-old, Quarter Horse filly, presented to MSU-CVM Equine Emergency Service on Saturday, December 14th, 2019, at 11am for an emergency evaluation. Around 7:30am that same morning, while Sister was out in her paddock with her herd mates, she was shot with a shotgun in a drive-by shooting. Remnants of the ammo casing were found approximately 30 yards from where Sister was standing, and it was determined to be Winchester Long Beard turkey load ammo (12 gauge, 3 inch, 1200 velocity, 5 shot), which is classified as high velocity shotgun ammo.[8] Sister's primary veterinarian was immediately notified, and he arrived at the farm around 8am. Sister was administered a dose of Banamine intravenously; however, due to the extent of her injuries, she was referred to MSU-CVM for further evaluation.

On presentation to MSU-CVM, Sister was quiet, alert, and responsive. She was slightly irritable and uncomfortable. When asked to walk, she was graded to have a mild 4/5 right hind lameness. She had an appropriate body condition score of a 5/9, and she weighed 865 pounds. She had a mildly elevated heart rate at 54 beats per minute, elevated respiratory rate at 36 breaths per minute, and her temperature was 100.5 degrees Fahrenheit, which was within normal limits. Her mucus membranes were pink and moist, and she had a capillary refill time of less than 2 seconds. Her gastrointestinal tract auscultated normally, with appropriate motility heard in all four quadrants. Her digital pulses in her forelimbs and left hindlimb were within normal limits; however, she had slightly increased digital pulses in her right hindlimb. It was apparent that Sister had experienced gunshot trauma, as she had multi-focal areas of too numerous to count, 2mm x 2mm, circular, actively hemorrhaging, cavity-like entrance wounds, that appeared to be

distributed in a pattern similar to that of a shotgun. The most remarkable lesions were on the proximal-lateral aspect of her left forelimb, left ventral abdomen, and the proximal-medial aspect of her right hindlimb. Additionally, focal areas of lesions could be seen on her left shoulder, left dorsal abdomen, and the most dorsal-axial aspect of her hindquarters. Also, a small, 20mm abrasion could be seen over the left eye, an approximately 80mm long abrasion was noted on the right lateral abdomen, and a 90mm x 70mm soft, pocket of fluid was noted on the caudal region of the left elbow.

Diagnostics

Immediately following a thorough physical exam, a minimum database, including a CBC and serum chemistry, were performed. The CBC was clinically unremarkable; however, the Serum chemistry revealed a moderately elevated alkaline phosphatase (213 U/L), mildly elevated aspartate aminotransferase (434 U/L), mildly decreased total protein (5.7 g/dl), and a mildly elevated creatinine kinase (4,222 U/L). These findings were suggestive that Sister recently sustained muscle damage and hemorrhage, which fits the clinical picture of Sister's recent trauma.

An abdominal ultrasound was then performed. The ultrasound revealed a moderately increased amount of heteroechoic fluid, with a swirling effect consistent with active hemorrhage, within the peritoneal cavity, most notably along the ventral midline. The moderate amount of gas and metal artifact created from the embedded pellets made the remainder of the exam inconclusive. Next, a series of radiographs were taken of the abdomen, thorax, left elbow, right stifle, right tibia and fibula, and left stifle. Radiographs confirmed evidence of gunshot trauma from a shotgun rifle and ruled out projectile involvement of any synovial structures. There were several focal areas of extracapsular soft tissue swelling, along with numerous, smoothly-marginated, circular, metal-opaque, intact pellets, that were approximately 2-3mm in size, cranial

to the distal humeral condyles, circumferentially around the right stifle and the proximal aspect of the tibia, and superimposed over the mainstem bronchi and ventral abdomen.

To further assess the free fluid in Sister's abdomen and to determine the status of the gastrointestinal tract, an abdominocentesis was performed. After finding a large pocket of fluid on ultrasound, Sister's ventral abdomen was prepped about a hands-breath behind the xiphoid process, just to the right of midline, to avoid contacting the spleen. Once the abdominocentesis was completed, the fluid obtained was immediately placed in a purple top tube, containing EDTA-anticoagulant, and a red top tube, which is a non-anticoagulant. It is normal for there to be a mild amount of free fluid in the abdomen, as it allows for lubrication of the surrounding structures and diffusion of substances, such as electrolytes.[13] Normal abdominal fluid should be a clear straw color, with a protein of less than 1.5 g/dl and a nucleated cell count of less than 3,000/ul, with focus being on the color, as this is the main diagnostic indicator.[7,13] The fluid in Sister's abdomen was a uniform red, opaque color, with a protein of 3.5 g/dl, a nucleated cell count of 53,600/ul, and a red blood cell count of 4,830,000/ul.

The abdominal fluid was also submitted for aerobic and anaerobic culture and sensitivity (C/S), as well as a fluid analysis. The fluid analysis revealed evident suppurative inflammation. It was initially speculated on cytology that the sample obtained was contaminated with peripheral blood, considering the marked neutrophilia and increased red blood cell count without true evidence of hemorrhage, which includes hemosiderophages, erythrophages, and hematoidin crystals. But when comparing the nucleated cell count on the abdominocentesis (53,600/ul) to the count from the peripheral blood on the CBC (9,080/ul), which were performed on the same day, the counts were discordant. This suggested that a peripheral blood contamination was not the cause of the leukocytosis nor the elevated red blood cell count in the sample. Furthermore, when the abdominal fluid was placed in the purple top tube, there was no evidence of swirling,

and when the fluid was placed in the red top tube, the fluid did not clot, also suggesting that this was not peripheral blood contamination. Therefore, it was determined that these were true results, indicating early stages of acute peritonitis and confirming intra-abdominal hemorrhage.

The aerobic and anaerobic C/S of the abdominal fluid had no growth at 24 or 48 hours, but it did grow the pathogen, Actinobacillus, in enrichment broth. Actinobacillus is a gram-negative, rod-shaped, bacteria that is part of the normal flora of the equine gastrointestinal tract.[2] The most commonly isolated species is *Actinobacillus equuli;* however, primary peritonitis and systemic infections in adult horses, due to *A. equuli*, are considered rare.[2] In the few reported cases of *A. equuli* associated peritonitis, most of the patients were without clinical signs of concurrent endotoxemia and only showed mild signs of colic, as *A. equuli* typically does not progress to endotoxic shock or death.[2,16] The mechanism by which *A. equuli* accesses the peritoneal cavity remains unknown, with gastrointestinal penetration or perforation, foreign body migration, and larval migration being highly considered.[2] In Sister's case, the origin of the Actinobacillus found in her abdominal fluid remains undetermined, but it was speculated to be either gastrointestinal in origin, through possible perforation of the left ventral colon (this theory was further supported by the appearance of melena in her feces during the first 24-48 hours of her hospitalization), or through abdominal penetration of the projectiles, resulting in inoculation of foreign material and contaminants into the peritoneal cavity. Prognosis for *A. equuli* is considered good to excellent, due to the usual rapid response to antibiotic therapy within the first 48 hours of treatment and without the need for peritoneal lavage.[2]

Lastly, to complete Sister's initial diagnostic work-up, a synovial fluid analysis of the fluid pocket found at the caudal aspect of the left elbow was obtained. The fluid was a slightly orange, opaque color, with a protein of 3.8 g/dl, and nucleated cell count of 1,490/ul. The findings were indicative of an active, mild suppurative inflammatory process that was likely due

to either the recent gunshot trauma or from a previous injury, such as a shoe boil. At this time, Sister was diagnosed with gunshot trauma, with secondary hemoabdomen and acute septic peritonitis. Sister was then admitted to the hospital and treatment was initiated. Approximately four days after initial presentation, Sister's CBC, serum chemistry, and abdominal ultrasound were repeated. The CBC revealed a moderately elevated fibrinogen (600 mg/dl) but, overall, was relatively unchanged. Compared to previous results, serum chemistry revealed a mild increase in alkaline phosphatase (260 U/L), moderate increase in aspartate aminotransferase (628 U/L), and a moderate decrease in the previously elevated creatinine kinase (2,719 U/L). Since the gas artifact in her abdomen had resolved, the abdominal ultrasound revealed more easily discernable images. The most significant findings were of two pellets, one seen adjacent to the surface of the left ventral colon and one seen adjacent to the spleen. Additionally, a portion of the spleen had a sonographic appearance consistent with a large blood clot, distorted splenic tissue, or a small abscess, which was suggestive of recent trauma. There was also significantly less evidence of free abdominal fluid, therefore it was assumed that the blood from the hemoabdomen had been resorbed and redistributed.

Pathophysiology

Two important consequences of gunshot trauma are the direct damage that occurs to bodily tissues and the secondary infection that follows.[11] Before one can accurately assess the damage created by a projectile, it is imperative to first classify the projectile and estimate the projectile's energy. The wounding potential of a projectile is described in relation to three factors: projectile design, kinetic energy of the projectile on impact, and characteristics of the tissues involved.[8,15] Regarding the projectile's design, its shape, center of mass, and caliber all contribute to the overall wounding potential. Caliber, which is defined as the diameter of the projectile, is most significant to wounding potential, but is inversely related to the kinetic energy

and velocity at which it travels.[8] Shotguns pellets are the exception to this rule. Depending on the distance the pellets have to travel and the amount of choke, or constriction, in the barrel of the gun, the total mass of the pellets, regardless of the diameter, actually increases the kinetic energy and, therefore, increases the wounding potential.[8,14]

The kinetic energy that is ultimately transferred from the projectile to the tissue is strongly influenced by the projectile's mass and muzzle velocity; however, increased velocity is a greater contributor to overall tissue damage than increased mass.[8,14] Muzzle velocity is defined as the speed of the projectile, specifically the sum of forward and rotational energies that propel the projectile as it leaves the barrel of the gun.[8] In terms of velocity, guns are classified into 3 general categories: low velocity (<350 m/s), medium velocity (350-600 m/s), and high velocity (>600 m/s).[8,14] Standard handguns generally fall in the low velocity category, whereas shotguns are classified in the medium to high velocity category. Their longer barrels impart a higher velocity to the projectile by increasing the projectile's overall acceleration via expansion of gases.[8] One important influencer on the impact of muzzle velocity is distance the projectile travels. Muzzle velocity can be significantly reduced at distances greater than 90 meters. Shotguns are particularly susceptible to the effects of distance due to poor aerodynamics of individual pellets released from the cartridge. At distances greater than 5 meters, the scatter and loss of kinetic energy significantly reduces the tissue penetration, whereas in distances less than 5 meters (close range), the projectiles act in unison with minimal scatter, moving at speeds similar to those produced by other high-velocity firearms.[6,8,14]

When the projectile strikes the body, it causes two types of trauma.[8,11,14] The first is a crushing, or permanent, primary cavity formation of the tissue in the immediate pathway of the projectile. This crushed tissue does not survive, resulting in direct tissue necrosis. The second is lateral expansion, or temporary, secondary cavity formation of the tissue surrounding the

projectile.[3,8,11,14] Medium and high velocity projectiles create an increased pressure wave that causes soft tissue to balloon out of the way, resulting in a secondary cavitation injury and further traumatization to the regional tissue and its circulation.[3,11] It is because of this secondary cavitation that the extent of the tissue trauma is not often visible on the surface of the skin.[8,11,14] Additionally, as the projectile penetrates the skin, it creates a vacuum-effect, therefore, drawing contaminants and surface debris in with it, which then become widely dispersed through the fascial planes. Since the projectile itself is not sterile and the tissues are inoculated with foreign material when it strikes the body, there is an enhanced potential for infection, making it imperative that gunshot wounds be allowed adequate drainage to prevent contaminants from becoming trapped in the soft tissues, further exacerbating the infection.[6,8,11,14]

The tissues projectiles strike greatly influences the resulting damage. Elastic and thinner tissues, such as skin, muscle, and lung, have a better ability to deform while maintaining structure, while more rigid and denser tissues, such as bone, spleen, and liver, have less give and experience a greater amount of energy transmission and subsequent damage.[8,11,14] Furthermore, the anatomic location where the projectile navigates and is retained significantly influences the treatment plan and prognosis of the patient. Projectiles retained in skeletal muscle often become encased in a fibrous, avascular scar, shielding it from the host, rendering it inert and, depending on the type of projectile, making dissolution and lead toxicity very low.[3] In contrast, projectiles retained in synovial structures, such as joints, may lead to arthropathies, including synovitis and articular cartilage damage, which can be life threatening due to potential loss of function.[3,6,8]

In terms of lead toxicity from gunshot wounds, termed plumbism, it is exceedingly rare and not well documented, likely due to vague, delayed clinical signs, low index of suspicion, and unknown quantitative relationship between projectiles and blood concentrations.[10] In 1991, lead shot was banned in waterfowl hunting, although it is still widely used in deer hunting.[1] Metallic

lead is an insoluble, cumulative toxin, with a slow rate of elimination, meaning the effects and severity of toxicity increase with the length and amount of exposure. Thus, most patients with retained lead projectiles are under no threat of systemic absorption of the lead.[4,5] The fact that lead projectiles may remain imbedded in tissues for decades before toxicity develops, led to the theory that toxicity may only develop when certain conditions arise in gunshot victims that result in mobilization of the lead.[4,10] In humans, the literature suggests that individuals are more likely to become symptomatic during periods of increased metabolic change to the bone or nervous system, such as in hyperparathyroidism or viral meningitis, respectively.[10] Underlying conditions, such as thyrotoxicosis or arthritis may also be precipitating factors.[5] Clinical signs can include unexplained anemia, colic, nephropathy, or encephalopathies, including seizures.[1,10] If clinical, since lead competes and binds to calcium in the body, treatment includes a form of chelation therapy, such as Calcium EDTA, along with supportive care. Until the true incidence of lead toxicity is known, it is not currently recommended that patients with gunshot wounds are subjected to surgery to remove the projectiles unless they are involving a synovial structure.[3,8,10]

Treatment

As in any traumatic injury, establishing airway, breathing, and circulation are of highest priority. Once the patient is considered stable, the focus of treatment for gunshot wounds is to reduce contamination of the wound and control hemorrhage, but ultimately, the extent of treatment depends on the severity of the individual patient's wounds.[3,14] For gunshot trauma that is mostly confined to the skin and skeletal muscle, such as Sister's case, the mainstay of therapy is to adhere to the simple rules of wound management including cleaning the surface of the wound, allowing for adequate drainage, and removing any devitalized tissue.[8] It is important to allow the wound time to declare itself, as the area experiences a vasoconstrictive phase which affects tissue color, contractility, and consistency. This change in tissues could influence local

debridement and future surgical decision making, so it is recommended to remain conservative in your treatment especially for the first few hours after initial projectile penetration.[3,6,8] Also, it is highly important that gunshot wounds be managed as open wounds to heal by second intention, or if necessary, repaired surgically via delayed primary closure due to the contaminated nature of the wound.[6,8,11]

In a case study of 22 horses who suffered gunshot trauma, 8 horses had injury confined to the skin and skeletal muscle.[17] Seven were treated conservatively with medical management and later returned to normal work. The 8th horse was euthanized due to premature wound closure and subsequent, overwhelming purulent infection that became entrapped in the muscle. None of the horses in this study had the projectiles removed from their tissues.[17] Supporting literature suggests that performing standard wound management practices and administering antibiotic therapy is more beneficial to the patient than surgically removing projectiles due to the increased incidence of post-operative complications such as infection, herniation, ileus, and adhesions.[3,6,8,11] Only when the projectile has the possibility to jeopardize the horse's athletic potential or quality of life, such as a projectile located within a synovial structure or when there is uncontrollable hemodynamic instability or severe peritonitis, should surgical intervention be taken into consideration.[8,12,14]

In Sister's case, as soon as diagnostic testing was completed, medical therapy was initiated. Sister's wounds were clipped and thoroughly cleaned with a sterile chlorhexidine scrub. She was then confined to strict stall rest and an indwelling intravenous jugular catheter was placed. She was maintained on systemic anti-inflammatories, analgesics, and free-radical scavengers to reduce inflammation and provide pain relief, including Banamine and a constant rate infusion of DMSO diluted in 5 liters of Lactated Ringers Solution. In order to treat any present infections caused by the gunshot trauma and limit the worsening of her peritonitis, Sister

was started on systemic, broad spectrum antimicrobial therapy. She was administered Potassium-Penicillin G, Gentamicin, and Metronidazole. Once the culture and sensitivity of the abdominal fluid returned with Actinobacillus, Minocycline was also added to Sister's treatments due to the sensitivity of Actinobacillus to a tetracycline.

Sister was also provided with round-the-clock nursing care. This entailed keeping her hindlimbs covered with standing wraps to preemptively decrease the amount of swelling in her distal limbs, particularly in her right hindlimb, as the swelling from the initial trauma began to dissipate downwards due to gravity. Due to the increased digital pulses in all four limbs, ice bracelets were applied hourly to lessen the likelihood of Sister developing secondary laminitis, and they were maintained until the pulses steadily remained within normal limits. Her entry wounds were cold hosed, ice-packed, and cleaned with a sterile chlorhexidine scrub daily. Sister was also administered an anti-anxiety medication, Fluoxetine, to help keep her calm and comfortable during stressful events, such as during wound management or administration of medications. Towards the end of her stay in hospital, due to the prolonged amount of stall rest and administration of antibiotics, as well as the risk of developing colic, Platinum Balance probiotic therapy was started to keep her digestive system healthy.

Case Outcome

In general, superficial musculoskeletal injuries, similar to what Sister sustained, are the most common result of gunshot trauma in horses.[8,9] They generally carry a good to excellent prognosis for survival, with one study suggesting an 87% return to normal function.[8] On December 29th, 2019, Sister was discharged from MSU-CVM, 15 days after her initial presentation. At the time of discharge, Sister's entry wounds were determined to be healing appropriately, and her hemoabdomen had resolved. She was sent home on an additional thirty-day treatment of Minocycline to ensure that her peritonitis continued to resolve without

complication. Sister's owner was advised to keep her activity to a minimum for 2 more weeks to allow for additional healing time and close monitoring of her entry wounds. Specifically, her owner was told to watch for any signs of heat, swelling, discharge, or a malodor, as the entry wounds had the potential to abscess. The owner was also advised to contact their primary veterinarian if any changes in overall demeanor or comfort level, or signs of colic were noted, to ensure that Sister was not developing any further complications.

Since discharging from MSU-CVM, Sister has made a full recovery. Her owner noted that a few of the superficial pellets along her ventral abdomen had made their way out of her skin, but the majority remain embedded in her tissues. Sister was recently started under saddle, and she has not shown any signs of irritation or discomfort from the tack or rider. She is sound at all gaits and her overall performance appears unaffected by her previous trauma.

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