A Major Mishap

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Introduction

Ballistic trauma accounts for an estimated 2.1% of the total traumatic incidents, and for approximately 10% of the reported cruelty cases of companion animals within the United States.[3,7] Amongst the animals affected, there was an overrepresentation of sexually intact males less than 4 years of age and who had the ability to roam freely outdoors.[3,6,7] These dogs were often classified as aggressive breeds such as German Shepherds, Rottweilers, Pit Bull Terriers, Doberman Pinschers, and Mastiffs, or as working dogs such as the Labrador retriever, German Shorthaired Pointer, and Vizsla. The predilections may be explained by the use of aggressive breeds as guard dogs, or by the roaming and territorial natures of intact males under the influence of sex hormones.[3,4,6,7]

The prognosis of ballistic trauma is animal specific and greatly depends on the location, and severity of their injuries. In one study, dogs with thoracic involvement had a 14.4 times increased risk of fatality when compared to animals who did not have thoracic involvement and is suggestive of intent to kill.[4] However in a different study, there was an increased risk of death in dogs with abdominal or spinal involvement.[6] Regardless of the body region affected, the average survival rate until hospital discharge ranged from approximately 80% to 90%.[4,6,7] Ballistic trauma was incidentally found in nearly half of the dogs used in one study.[4] Additionally, a different study believed that many animals with less severe injuries were brought into their primary veterinarian for treatment and therefore, were not included in the retrospective studies of referral level cases.[7] Both indicating that many injuries as a result of ballistic trauma do not ultimately lead to death.[4,7] In order to better estimate prognosis, another source looked at the Animal Trauma Triage (ATT) scoring system.[7] ATT evaluates cardiac, perfusion, respiratory, neurologic, eye-muscle-integument, and skeletal system involvement and grades the severity of each category with a scoring system ranging from 0 to 3, with 3 being the most severe.[7] With a maximum ATT score of 18, the animals who survived until discharge had a median score of 5, compared to the much higher median score of 11 in the animals who did not survive. By creating an odds ratio (OR) comparing the probability of survival until discharge to the probability of not surviving until discharge, the OR was found to be significant at 1.6. Meaning that each increase in the ATT score by 1 point, increased the odds of the animal dying before discharge by the factor 1.6.[7] Eventually, the use of ATT may be used to monitor treatment response, and to estimate treatment cost and prognosis.[7]

History and Presentation

Major, an approximately 3-year-old intact male German Shepherd presented to MSU-CVM on Monday November 5, 2018 for penetrating trauma to the thorax and suspected pneumothorax. Prior to that, on the morning of November 5th Major went missing for several hours, returning home at approximately 8:30 p.m. in what the owner described as respiratory distress. Major was not up to date on vaccinations, but wore a Seresto collar, and received Heartgard monthly. He was primarily an indoor dog but was allowed to roam freely outdoors. He lived with one other dog, a 2-year-old Rottweiler. His diet consisted of Rachel Ray kibble. He had a history of an unknown tick borne disease but had been healthy otherwise.

On presentation, Major was quiet, alert, and responsive. He weighed 46.1 kg, and had a body condition score of 6/9. His vitals were as follows: temperature of 102.2° F (normothermic), pulse of 190 beats/minute (tachycardic), respiratory rate of 64 breaths/minute (tachypneic). He was normotensive with blood pressures of 133/105 (115), 128/81 (97), and 142/90 (107), and he was estimated to be 8% dehydrated. Upon examination, Major had a circular wound on the right lateral thorax at the level of the 7th rib, and another circular wound on his left ventral abdomen a few inches cranial of the inguinal region, which was found to have communication with the abdominal cavity. Upon cardiothoracic auscultation the lungs were quiet bilaterally, being more pronounced on the right. No heart murmurs were appreciated however, an irregular tachyarrhythmia was noted, and electrocardiogram (ECG) revealed multiple runs of ventricular premature contractions (VPCs). Ten minutes after presentation Major began to go into respiratory distress, therefore the remainder of the physical exam was not performed.

Pathophysiology

Ballistics is the study of projectiles and the behavior in which they travel through the firearm, air, and ultimately the target.[2,3,8] Truly understanding ballistics starts with a basic understanding of gun mechanics.[2,3] Each round contains a primer, powder, bullet, and casing. The powder charge is the main determinant of the projectile's velocity. Once the trigger is pulled, a pin strikes the primer thus igniting a flame. This flame then enters the casing to ignite the powder, resulting in a large release of heat and gas which is used to drive the projectile down the barrel. Following the bullet's exit, - gas, soot, unburnt powder, casing, and a flame burst will come out.[2,3] The inside of the firearm barrels are often rifled meaning that spiral grooves were carved into the metal in order to create axial rotation of the bullet upon firing. This offers stability to the bullet while in flight by decreasing its likelihood of tumbling, which improves overall accuracy of the bullet.[2,3,8]

The degree of tissue destruction can be estimated by taking bullet shape, firearm type, and kinetic energy into consideration.[2,3,8]

$$\text{Kinetic Energy (KE)} = \tfrac{1}{2} * \text{Mass} * \text{Velocity}^2$$

As the equation shows, doubling velocity results in a quadrupled kinetic energy and doubling mass only results in a doubled kinetic energy. [2,3,8] This explains how higher velocity firearms are able to create more tissue destruction than those with lower velocities.[2] Bullets are designed to accommodate specific uses and traveling velocities.[2] Those that are designed to minimize losses in velocity are often needle-shaped, while others designed to increase tissue destruction at lower velocities often have a hollow-pointed tip.[2,3] Low-velocity projectiles are classified as traveling less than 1000 feet/second, medium-velocity projectiles are classified as traveling 1000-2000 feet/second, and high-velocities are classified as traveling greater than 2000 feet/second.[2,8] Handguns are typically classified as low to medium velocity, and rifles are typically classified as medium to high velocity.[2,8] It is generally thought that high-velocity bullets involving only soft tissues are more likely to enter and exit the animal without leaving metallic fragments behind. When the high-velocity bullet encounters bone, the bone often shatters, and the bullet may fragment, but the bullet may be able to continue on to another body region.[8] In contrast, low-velocity bullets may impact the soft tissues and become retained, and when they encounter bone, the bone may fracture but the bullet is unlikely to leave that body region.[8]

There are four different processes by which bullets can inflict tissue damage.[2,3] The first is by crushing or laceration. This occurs as a direct result of the bullet's path through the tissue and is the primary form of damage done by low-velocity projectiles.[2,3] The second is by shock wave, which occurs as the bullet causes compression of the tissues in front of it by pressures of up to 100 lb/in^2. This causes the tissues to move away and this movement creates the spherical shock waves that only last 15 to 25 microseconds.[2] The third is by cavitation, which occurs when the bullet causes the tissues to move forward and outward at such high velocities that the tissue continues to travel in this manner even after the bullet has passed. This temporary cavity can have a diameter of up to 30 times the size of the projectile depending on the tissues' nature, and it can last 5 to 30 microseconds before collapsing.[2,8] Tissues with lower densities and more elasticity, like the lungs, will be more resilient to cavitation and shock wave damage when compared to tissues that are rigid with higher densities such as bone, liver, and brain.[2,3,8] Wound contamination primarily occurs through direct inoculation with dirt, hair, and skin debris as the bullet enters the body. Contamination secondarily occurs as a result of the temporary cavitation's subatmospheric pressure that draws in the debris.[1,2,3,8] With this in mind, all gunshot wounds are considered contaminated and should thus be managed appropriately.[2] Both shock waves and cavitation are able to cause disruption to circulation, organs, muscles, and even bones that are distant from the bullets direct path and occur with high-velocity projectiles.[2,8] The fourth method is secondary missile formation, these missiles typically consist of bone or bullet fragments and create additional damage as they move through the tissues.[2]

Diagnostic Approach

Diagnosis can be difficult when the owner is not present at the time of gunshot, which occurs in up to approximately 62% of the cases.[6,7] When the bullet or bullet fragments are visible on radiographs, a definitive diagnosis is easier to make. However, this does not always occur when the bullet passes completely through the animal.[8] These wounds can then potentially be misdiagnosed as bite wounds or vehicular trauma.[4] There are three specific findings which include entrance wounds, intermediary wounds, and exit wounds point to the diagnosis of ballistic trauma. However, these findings are unable to identify the caliber of the bullet and the weapon used.[3] Advancements in bullet cavity measurements are being made with the use of computed tomography (CT) so that these dimensions may become accurate enough to determine the caliber of the projectile and the weapon used for legal cases in the future.[3] Overall, knowing the type of firearm used and location of injuries can aid in treatment recommendations based on the estimated tissue damage.[2,7,8]

Diagnostic protocols are variable depending on the wound location and severity.[8] However, general diagnostic considerations include a thorough physical examination with assessment of airway, breathing, and circulation, baseline bloodwork of a complete blood count (CBC) and chemistry to aid in overall patient status and possible organ damage, pulse oximetry, electrocardiogram (ECG), ultrasonography, blood gases, radiographs, and CT.[8]

Treatment and Management

Treatment largely depends on the patient's status and wound severity therefore, supportive therapy specific to their presentation should be administered.[8] In cases with abdominal involvement, exploratory laparotomy is recommended. Peritonitis is a serious risk in gunshot patients and the best treatment available is often immediate surgical correction.[8] In cases with thoracic involvement, hemothorax and pneumothorax are common. These can be treated with a thoracostomy tube or thoracentesis. However, more severe cases often warrant an exploratory thoracotomy.[8] Due to the bacterial contamination mentioned in the pathophysiology section, broad-spectrum antibiotic therapy should be initiated as soon as culture samples are collected, and then tailored to the culture and sensitivity (C&S) results.[5,8] *Staphylococcus* spp. is thought to be one of the most common wound contaminates.[2]

Case Management

Upon presentation on November 5th Major's injuries were assessed, an 18 gauge left cephalic catheter was placed, and an ECG was started. ECG revealed multiple runs of VPC's, which were likely a result of indirect myocardial damage as a result of the shock waves produced by the projectile and were treated with a bolus of lidocaine (2 mg/kg, IV). There was only temporary resolution, so another bolus at the same dose was given. A packed cell volume (PCV), total protein (TP) and lactate were taken revealing a mild anemia, a mild hypoproteinemia, and a normal lactate. An arterial blood gas was performed revealing mild hypoxemia. The anemia and hypoproteinemia were likely a result of hemorrhage, and the hypoxemia was likely a result of lung pathology, or cardiac compromise. He was also given methadone (1 ml, IV) for pain control. Major began to go into respiratory distress approximately ten minutes after presentation therefore, flow by oxygen was initiated and a right sided thoracentesis was performed which removed 600 ml of air.

On November 6th multiple runs of VPC's were observed therefore, a lidocaine constant rate infusion (CRI) was started. With only a decrease in frequency, the CRI was increased twice and then maintained with no resolution. A CBC revealed a stress leukogram characterized a neutrophilia and lymphopenia, and a chemistry revealed a moderate hyponatremia likely due to hemorrhage, moderate increased blood urea nitrogen (BUN) likely due to dehydration, a moderate elevation in alanine transaminase (ALT) likely due to liver damage, and a moderate creatine kinase (CK) elevation likely due to muscle damage. Thoracic radiographs revealed a pneumothorax, a moderate amount of pleural effusion, and subcutaneous emphysema of the right lateral thoracic body wall. The abdominal radiographs revealed peritoneal effusion, pneumoperitoneum, and pneumoretroperitoneum. Subcutaneous emphysema was also appreciated within the right lateral abdominal soft tissues. These radiographic findings were consistent with penetrating trauma. Surgery was elected due to communication through the abdominal wall and presence of free gas and fluid within the abdomen. Prior to surgery a dose of Unasyn (ampicillin/sulbactam, 30 mg/kg, IV) was given, and a fentanyl CRI (4 mcg/kg) was initiated. During abdominal exploratory surgery, there was a moderate amount of hemorrhage within the abdomen. A splenectomy, partial right caudal lung lobectomy, papillary process of the caudate liver lobectomy, stomach closure, and a small resection of the superficial omental leaf were performed. The lungs were leak checked with warm saline and then the entire thorax and abdomen were lavaged with warm saline in order to decrease the bacterial contamination load within the body cavities. After saline removal, a Jackson-Pratt (JP) drain was placed in the abdomen, and a thoracostomy tube was placed. The diaphragm was repaired, and the abdominal incision was closed. The external thoracic and abdominal wounds were then debrided, lavaged, and closed. Following surgery, a nasal oxygen cannula was placed, and oxygen was set at a flow rate of 2 L/min. His treatment plan included Unasyn (30 mg/kg, IV, q8h), Cerenia (1 mg/kg, IV, q24h), pantoprazole (1 mg/kg, IV q24h), sucralfate (1 g tablet, PO, q6h), fentanyl CRI (3 to 5 mcg/kg/hr), lidocaine CRI (50 mcg/kg/min), and LRS (173 ml/hr). A few hours later, Major began to become increasingly tachycardic with a heart rate that reached up to 200 bpm at one point. He was given a fentanyl bolus to treat for pain induced tachycardia. His heart rate only temporarily decreased therefore, an LRS bolus was given and his fluid rate was increased in order to treat for hypovolemia induced tachycardia. Thirty minutes later, his heart rate went back up to 185 bpm therefore, VetStarch was started in order to provide a longer acting intravascular fluid resuscitation, and another fentanyl bolus was administered. An ECG was continuously monitored, VPC's and normal sinus rhythm were recorded every hour.

On November 7th the histopathology results from the tissue samples collected while in surgery were finalized. The right caudal lung lobe, papillary process of the caudate liver lobe, spleen, and pylorus of the stomach all had hemorrhage filled lacerations and marked disruption of tissue architecture. The multifocal, acute organ lacerations were all of similar chronicity and were consistent with the diagnosis of ballistic trauma. A CBC was performed revealing a slightly worsening anemia. The chemistry revealed a significantly increased CK, reflective of the muscle damage from surgery. Cholesterol was mildly decreased, ALT was still elevated but slightly decreased, and both alkaline phosphatase (ALP) and total bilirubin (TBili) became mildly elevated. He had a mild hypoproteinemia and a moderately low albumin. He also had electrolyte abnormalities with mild hypokalemia, mild hypophosphatemia, mild hypocalcemia, and a slightly worsened hyponatremia. The cholesterol, total protein, albumin, ALT, ALP, and TBili were all consistent with hepatic damage or inflammation. The electrolyte abnormalities were likely as a result of anorexia, and hypocalcemia as a result of low albumin. Major was very sedate and still continued to have VPC's despite treatment, so it was decided to discontinue the lidocaine CRI, taper him off of the fentanyl CRI, and start Tylenol 4 (2 mg/kg, PO, q8h). His LRS rate was decreased and potassium chloride (20 meq/L) was added to the bag in order to correct his hypokalemia. Later that evening, a 10 F nasoesophageal (NE) feeding tube was placed because he was still anorexic, and his nutritional needs were not being met. Tube check radiographs were performed, revealing successful placement of the tube and improvement of the pneumoperitoneum, and pleural effusion. Major remained on VetStarch, sucralfate, Unasyn, pantoprazole, and Cerenia.

On November 8th a chemistry was performed revealing some improvements. However, ALP and TBili worsened, and there was a new mild hypomagnesemia likely as a result of low albumin or decreased dietary intake. The ECG started to show improvements with a decrease in the number of VPC's and a corresponding increase in duration of normal sinus rhythm. Major's chest tube was removed and his KCl containing LRS fluids were discontinued. The intravenous Cerenia was discontinued, along with sucralfate, and pantoprazole. However, Cerenia (2 mg/kg, PO, q24h) and ondansetron (0.3 mg/kg, PO, q12h) were started. He remained on Tylenol 4, Unasyn, and VetStarch. He began to eat on his own, allowing the tube feedings to be skipped.

On November 9th the definitive culture and sensitivity (C&S) results from the abdominal swab taken during surgery revealed a faint to light growth of *Streptococcus spp.* (Alpha), with no anaerobes isolated. Sensitivity was shown to amoxicillin/clavulanic acid and ampicillin so Clavamox (16.3 mg/kg, PO, q12h) was started. Major's NE tube and intravenous catheter were removed. VetStarch and Unasyn were discontinued. He remained on Tylenol 4, ondansetron, and Cerenia. Continuous EGC monitoring was discontinued and spot checked by the student. All treatments stayed the same until discharge except for the Cerenia and ondansetron discontinuation on November 10th. On the morning of November 12th, Major's JP drain was removed. He continued to do well throughout the day, so he was discharged later that afternoon.

Case Outcome

Major was discharged on November 12th. He was sent home on Tylenol 4, Clavamox, and trazodone with instructions on incision care and exercise restrictions. A two week recheck was recommended for evaluation of wound healing, and to reassess the need for further antibiotic therapy. On November 14th a follow-up call was placed to the owner who said Major was doing well at home, that he had a good appetite, and that he would sit by the door to look outside. On November 27th Major's primary veterinarian called to give an update on him. At Major's recheck appointment, he weighed 98 lbs (44.5 kg). The veterinarian said that he had vomited up bile and had soft stools for two days but believed that Major was sensitive to beta-lactam antibiotics, so they were discontinued. His bloodwork revealed a normal CBC, with elevated eosinophils, and an improving PCV at 33%. His chemistry was all within normal limits. In conclusion, Major survived his "Major Mishap."

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