

Blast, Burn and Crush Injuries

With the increased use of improvised explosive devices, blast injury is not uncommon in MWDs. However, there is little definitive clinical information available for managing blast injury in dogs, so recommendations are similar to management for human patients. Burn and crush injuries are less common, but may be encountered.

Blast Injury

Be prepared to provide care for MWDs exposed to bomb blasts and other explosions. Recognize that blast injuries may be subtle or occult for days, with MWDs appearing stable on initial evaluation. Figure 43 (next page) provides the recommended general approach to assessing MWDs exposed to blast.

Blast Injury Mechanisms¹⁻³

Blasts produce injury through primary effects of the blast overpressure wave, secondary injury due to penetrating objects displaced by the explosion impacting victims, tertiary injury due to victims physically being displaced into objects, and quaternary injury due to complications resulting from any combination of injury from primary, secondary, or tertiary injuries or unrelated to these mechanisms.

Initial Management of Blast Injuries

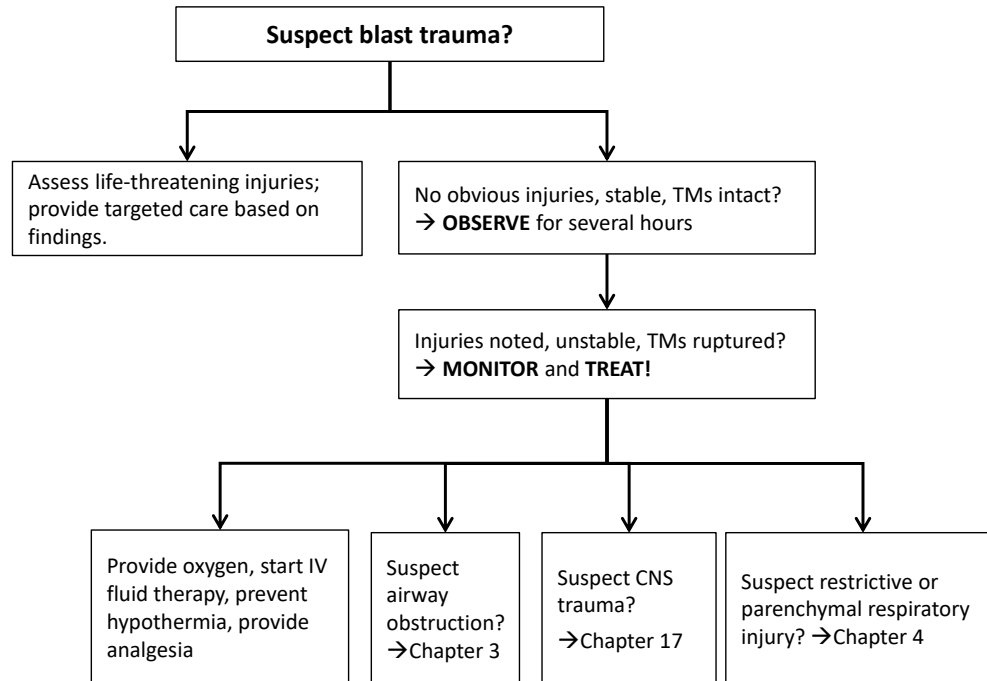
Generally, the approach to blast-injured MWDs is the same as for any other type of trauma – FOCUS on life-threatening problems first, followed by targeted support based on findings, with emphasis on a detailed secondary evaluation and care as needed once the patient is stabilized.

During initial care, focus on those types of life-threatening injuries commonly seen with blasts, especially respiratory distress due to airway obstruction or trauma, pneumothorax, pulmonary contusions, and hemothorax; traumatic amputations or serious bleeding; hemoperitoneum; CNS trauma; air embolism; and shock.

While tympanic membrane (TM) rupture in and of itself is a minor injury, experience suggests that it is a marker of more severe systemic injury, and patients with TM rupture should be observed carefully for signs suggesting the development of other injuries.²⁻³ The absence of TM rupture, however, does not exclude potentially life-threatening internal injuries, based on recent data from humans exposed to blasts.³

Recognize delayed onset of clinical signs. Many injuries from blasts may not manifest for many hours, to include pulmonary contusions, “blast lung,” concussions and mild TBI, and bowel hemorrhage with perforation and peritonitis. Serial monitoring is critical to detect early signs of impending decompensation due to these delayed problems. Any MWD exposed to blast should be evacuated to a veterinary facility as soon as possible for detailed evaluation and observation. If evacuation is not possible or is delayed, hospitalize in the MTF for 12-24 hours for close observation.

Figure 43. General Approach to Military Working Dogs Exposed to Blasts.



Burn Injury

Burn injuries in MWDs are typically caused by fires, motor vehicle mufflers, stoves, caustic chemicals, or explosions. While uncommon, these injuries can cause not only severe pain and complicated local wounds, but also result in serious metabolic abnormalities and systemic infection that can lead to life-threatening compromise.

Burn Classification in MWDs⁴⁻⁶

Burns affecting dogs are physically similar to those in humans. Hair may need to be carefully clipped over burned areas for adequate assessment. Superficial burns are red and painful, similar to sunburn, involving the outer layer of the epidermis. Superficial partial-thickness burns are red or mottled, with epidermal sloughing, fluid leakage, swelling, and extreme hypersensitivity (pain), involving the epidermis and variable amounts of dermis. Hair should not easily pull out. Deep partial-thickness burns are black or yellow-white and hair follicles are destroyed, and the skin surface is dry. These burns are generally less painful, as nerve endings are destroyed. If any hair remains, it will pull out easily. Full-thickness burns are black, dry, and leathery. These burns have destroyed the epidermis and dermis and expose underlying connective tissue, muscle, and bone. Any eschar that forms is painless.

Inhalation Injury

Burn patients may have significant inhalation injury. Clinical signs of inhalation and pulmonary injuries may not manifest for several hours. Clinical signs of inhalation injury include stertor or stridor, harsh cough or upper airway sounds, coughing, production of dark sputum, tachypnea, and respiratory distress. MWDs with inhalation injury should be observed closely for need for orotracheal intubation or (uncommonly) tracheostomy to manage the airway. Intubate or perform tracheostomy for any MWD with observed respiratory distress or if in doubt about the patency of the airway (See [Chapter 3](#)).

Estimation of Total Body Surface Area (TBSA)

Burn Extent in Dogs

Determine the severity of the burn once the MWD has been resuscitated and stabilized. General characteristics of the wound that are important to examine include color, texture, presence or absence of pain, moistness, and extent of swelling, if present.

Estimate the percent of the total body surface area (TBSA) that is burned by using a modification of the “Rule of 9s” used for humans:⁴

ADD the estimated percent of burn from EACH of the following body areas:

- Head and neck (H/N) – 9%
- Chest (C) – 18%
- Abdomen (A) – 18%
- Each forelimb (L FL, R FL) – 9%
- Each hindlimb (L HL, R HL) – 18%

TBSA = H/N + C + A + L FL + R FL + L HL + R HL. For example, the estimated TBSA burn for a dog with burns to the chest and abdomen and left forelimb would be 18% (chest) + 18% (abdomen) + 9% (L FL) = 45%.

The percent TBSA is important in assessing severity, anticipating problems, and determining prognosis. Patients with TBSA >20% often have severe metabolic problems (e.g., hypovolemic shock, albumin and electrolyte losses, acidoses, renal failure); patients with TBSA >50% have a poor prognosis.⁴ Any discussion of prognosis must take into consideration not only the TBSA but also the severity of burn. Note that initial evaluation of severity of burn wound may be inaccurate, as wounds often progress over a period of 3-7 days before completely manifesting ultimate severity.⁴⁻⁵

General Patient Management Recommendations⁴⁻⁶

- Monitor and treat for complications related to burn injury, to include shock, fluid losses, respiratory problems, and electrolyte abnormalities, see appropriate chapters. Stabilize the patient first. Manage pain using appropriate analgesics (See [Chapter 16](#) and [Table 16](#)).
- Cool the burned skin using cool water (45-65° F) by immersion, application of compresses, or gentle spray for at least 30 minutes. Do not apply ice to any burned skin, as the vasoconstriction it causes may impede wound healing and may worsen the extent of tissue damage. Measure the patient’s rectal or esophageal temperature frequently to monitor for and prevent hypothermia.

- Minimize potential contamination of burned skin. Wash hands thoroughly before handling patients; wear clean exam gloves (superficial burns, superficial partial-thickness burns) or sterile surgical gloves (deep partial-thickness burns, full-thickness burns); do not contact wounds with things such as personal clothing, stethoscopes, or other instruments or monitors; wear barrier protection when handling deep partial-thickness burns and full-thickness burns; change gloves and wash hands before handling other burn wounds and invasive devices on the same patient.
- Follow strict aseptic technique when placing invasive devices and use clean examination gloves whenever handling catheters, adapters, fluid lines, etc. Unless absolutely necessary, do not place invasive devices through burned skin. Provide antibiotic coverage using the guidelines in [Chapter 14](#) only for MWDs presumed to be immunocompromised, with pneumonia or acute lung injury, or with sepsis or suspected sepsis.
- Provide excellent nursing care. Turn or rotate the MWD every 4 hours if recumbent, and perform Passive Range of Motion (PROM) exercises of all limbs except burned limbs every 4 hours. Provide soft, padded bedding. Prevent urine scalding and fecal soiling. Allow MWDs to eat and drink if able.

Specific Burn Wound Management Recommendations⁴⁻⁶

- Depending on severity and extent of burn, the patient may require daily heavy sedation or general anesthesia to allow debridement and management. Extreme care must be taken to monitor burn patients adequately during sedation or anesthesia (See Table 16).
- Superficial or superficial partial-thickness burns are generally managed with daily cool water lavage, followed by topical silver sulfadiazine cream application until healed or the wound worsens.
- Deep partial-thickness and full-thickness burns need varying degrees of daily wound debridement. This may be accomplished by use of conservative debridement, chemical debridement, or surgical debridement.
 - Conservative debridement of deep partial-thickness and full-thickness burns involves hydrotherapy using sterile saline lavage under light pressure or application of a wet-to-dry saline dressing under a light bandage for several hours, followed by removal of obvious necrotic or dead tissue using aseptic technique. Surgical debridement may be necessary in very deep or widespread wounds to more aggressively remove necrotic tissue; however, HCPs should not routinely perform surgical debridement – MWDs should be evacuated to veterinary facilities for this level of care.
 - Following debridement, apply silver sulfadiazine (SSD) cream, petrolatum, or hydrogel dressings in a thin layer directly on the wound and cover the burn with a non-adherent dressing (if the wound area is bandaged) or leave the burn uncovered (if bandaging is not permissible due to wound size or location).
- Bandage burn wounds if the burn area is amenable to application (i.e., the bandage can be placed without increasing patient discomfort, the burn area is relatively small, and the bandage will not increase the potential for wound injury). If there is any doubt about whether to bandage a burn wound or not, it is better to leave the wound unbandaged. In most cases, a wet-to-wet bandage is recommended to keep wounds moist and improve comfort. Change bandages at least daily or more often if wound exudate is excessive or the bandage becomes soiled.

TABLE 16. MANAGEMENT OF BURN WOUNDS IN MILITARY WORKING DOGS

Provide heavy sedation or general anesthesia to allow debridement and management, as necessary.

Superficial or superficial partial-thickness burns:

- Perform daily cool water lavage.
- Apply topical silver sulfadiazine cream after cool lavage.

Deep partial-thickness and full-thickness burns:

- Perform daily wound debridement as necessary:
- Perform hydrotherapy using sterile saline lavage under light pressure, or,
- Apply a wet-to-dry saline dressing under a light bandage for several hours, followed by removal of obvious necrotic or dead tissue using aseptic technique.

Protect burn wounds:

- Apply silver sulfadiazine cream in a thin layer directly on the wound.
- Apply a light protective bandage, if the burn area is amenable to application.

Crush Injury and Crush Syndrome

- Crush injury is defined as injury due to compression of extremities or other parts of the body that causes muscle swelling or trauma, with or without neurological or orthopedic problems in the body parts. Body areas most commonly involved are the limbs and torso.
- Crush syndrome develops when crush injury is extensive and prolonged, causing systemic manifestations. These systemic effects are due to traumatic rhabdomyolysis (muscle breakdown) and reperfusion syndrome (release of potentially toxic muscle cell components and electrolytes into the circulatory system) after sudden release of pressure over the crushed limb or torso. Acute hypovolemia and metabolic abnormalities are common and can be severe (even fatal), and myoglobinuria from trauma to muscles frequently may cause or exacerbate renal failure if untreated.
- Crush injuries and crush syndrome in MWDs are expected after building collapses, most frequently after natural disasters or explosions. In humans, the incidence of crush syndrome is 2-15% with approximately 50% of those with crush syndrome developing acute renal failure. Of those with renal failure, 50% need dialysis. Crush syndrome is rarely reported in animals.^{7,8}

Pathophysiology

- Crush injury develops after muscle injury and muscle cell death. Three mechanisms are responsible for the death of muscle cells, to include direct cell lysis by the force of the crush; direct pressure on muscle cells causing muscle ischemia, development of anaerobic metabolism and lactic acidosis, and cell membrane disruption and leakage; and vascular compression or disruption, with loss of blood supply to muscle tissue.
- These mechanisms cause the injured muscle tissue to generate and release a number of substances that may be toxic in the general circulation. The crushing force actually serves as a protective mechanism, preventing these toxins from reaching the central circulation. Once the patient is extricated and the force is

released, reperfusion injury is prevalent due to release of toxic compounds and reactive oxygen species. Reperfusion injury may continue for as long as 60 hours after release of the crush injury.

- Other consequences of reperfusion include massive third spacing of fluids in crushed tissues, leading to hypovolemia and shock and exacerbating renal injury, and leading to compartment syndrome.

Clinical Presentation

Clinical signs of crush injury/crush syndrome include some or all of the following:

- Skin injury of the affected body part (may be subtle and less impressive than other signs)
- Limb swelling (may be delayed)
- Paresis or paralysis (may be mistaken as spinal cord injury)
- Loss of sensation (may mask the severity of underlying injury)
- Pain (typically becomes severe with reperfusion)
- Absent or weak extremity pulses
- Discolored urine due to myoglobinuria or hematuria or both
- Hypotension due to hypovolemia (dehydration, hemorrhage, third spacing of fluids) is commonly present and may be severe
- Massive third spacing (often causes or exacerbates compartment syndrome and renal failure)
- Metabolic abnormalities (hypocalcemia, hyperkalemia, and lactic acidosis)
- Clinical signs of compartment syndrome (severe pain in the involved extremity, pain on passive stretching of the involved muscles, decreased sensation to the affected limb)
- Renal failure (due to rhabdomyolysis and secondary myoglobinuric acute tubular necrosis).

Patient Management

- Treat MWDs, if possible, before and during extrication.
- Maintain a high index of suspicion, as MWDs with crush injury may present initially with few signs or symptoms. Delayed treatment leads to poor outcome.
- Most crush syndrome patients have an extensive area of involvement such as a lower extremity and/or the pelvis. It requires more involvement than just one paw. Also, the crushing force must be present for some time before crush injury syndrome can occur.
- The syndrome may develop in <1 hour in a severe crush situation, but usually it takes 4 to 6 hours of compression for the processes that cause crush injury syndrome to take place.
- The hallmark initial treatment for crush syndrome is IV fluid therapy before release of pressure and contin-

ued during extrication and evacuation. Place multiple IV lines, because the MWD will require large fluid volumes and there is a risk of catheter dislodgement during extrication. Normal saline is the initial fluid of choice. Avoid fluids with potassium.

- Once compression is removed, maintain aggressive fluid therapy. Specific guidelines for fluid volumes to administer are difficult to provide. As a starting point, use a rate of 3-5 mL/kg/hr to improve pulse quality, blood pressure (if possible to measure), CRT, and mentation. Try to estimate urine output – the goal is to maintain urine output >1-2 mL/kg/h.
- Alkalinization of the blood with bicarbonate (as is done for humans) is likely not going to be feasible. Thus, HCPs should focus on aggressive IV fluid therapy to correct dehydration and promote diuresis pending extrication and evacuation.
- Anticipate secondary complications. MWDs with crush injury should be treated initially as any other multiple trauma victim.
- Compartment syndrome is rare in dogs; this seems to be a much more common and more severe problem in humans, so extreme measures to control intracompartmental pressures like fasciotomy are unwarranted.
- Wounds should be cleaned and covered with sterile dressings in the usual fashion. Splint fractures if possible.
- Provide analgesia to any MWD with crush injury or crush syndrome (See [Chapter 16](#)).

Blast, Burn and Crush Injury References

1. Centers for Disease Control and Prevention. Explosions and blast injuries: A primer for clinicians. Accessed online 12 April 2017: <https://www.cdc.gov/masstrauma/preparedness/primer.pdf>.
2. Plurad DS. Blast injury. *Military Medicine* 2011;176:276-282.
3. DePalma RG, Burris DG, Champion HR, Hodgson MJ. Blast injuries. *New England Journal of Medicine* 2005;352:1335-1342.
4. Garzotto CK. Thermal burn injury. In: Silverstein DC, Hopper K, eds. *Small Animal Critical Care Medicine*. St. Louis: Saunders/Elsevier, 2015;743-748.
5. Lagutchik MS, Ford A. Care of the environmentally injured animal. In: Burkitt Creedon JM, Davis, H, eds. *Advanced Monitoring and Procedures for Small Animal Emergency and Critical Care*. Ames, IA: Wiley-Blackwell, 2012; 799-813.
6. Mathews K. Burn injury and smoke inhalation. In: Mathews K, ed. *Veterinary Emergency and Critical Care Manual*. Guelph, Ontario, Canada: Lifelearn, Inc., 2006;682-689.
7. Centers for Disease Control and Prevention. After an earthquake: management of crush injury and crush syndrome. Accessed online 12 April 2017: <http://www.bt.cdc.gov/disasters/earthquakes/crush.asp>.
8. Gonzalez D. Crush syndrome. *Crit Care Med* 2005;33(Suppl 1):S34-S41.