GUIDELINES FOR THE HUMANE EUTHANASIA OF CATTLE

OVERVIEW

Livestock caretakers have an obligation to ensure the welfare of animals under their care. Euthanasia of an animal suffering from irreversible disease or injury is a primary responsibility of the caretakers. Euthanasia is defined in the "AVMA Guidelines for the Euthanasia of Animals (2020)" as: "ending the life of an individual animal in a way that minimizes or eliminates pain and distress." When properly conducted, euthanasia results in a rapid loss of consciousness followed by cardiac and respiratory arrest and death. The contents of this pamphlet are intended to aid animal caretakers and owners, livestock market operators, animal transporters, and veterinarians in choosing effective euthanasia methods.

The "AVMA Guidelines for the Euthanasia of Animals (2020)" recognizes and accepts three primary methods of euthanasia for cattle:

- **Intravenous** (IV) administration of a lethal dose of a barbiturate or barbituric acid derivative to induce a transition from consciousness to unconsciousness and death.
- **Gunshot** using an appropriate firearm, ammunition and anatomic site to cause physical disruption of brain activity by direct destruction of brain tissue.
- **Penetrating captive bolt** to induce unconsciousness in combination with an adjunctive step such as exsanguination, intravenous administration of a solution of either potassium chloride or magnesium sulfate, or pithing (increasing destruction of brain and spinal cord tissue) to ensure death. Non-penetrating captive bolt can be used for the euthanasia of neonates and calves less than two to three months of age when followed by use of an adjunctive method to assure death.

When properly applied, the above euthanasia methods cause the animal's rapid loss of consciousness and death without undue distress to the animal.

INDICATIONS FOR EUTHANASIA

The following lists contain examples of conditions or situations of compromised cattle for which prompt euthanasia is generally indicated (Shearer 2008, Shearer 2018, Griffin 2015):

Indications for prompt euthanasia

- Fracture, trauma or disease of the bony or soft tissue structures resulting in immobility or inability to stand
- Disease conditions for which no effective treatment is known (i.e., Johne's disease, lymphoma)

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- Diseases that involve a significant threat to human health (i.e., rabies)
- Disease conditions for which treatment will not be pursued due to cost
- Diseases for which the level of care to properly manage pain and distress and treat the disease is beyond the willingness or ability of the farm or facility
- Emaciation and/or debilitation from disease, age or injury resulting in an animal being too compromised to be slaughtered on site, transported, or marketed
- Advanced neoplastic conditions (e.g. cancer eye, lymphoma)
- Congenital or acquired conditions that produce a level of pain and distress that cannot be managed adequately by medical or management methods
- Nonambulatory cattle with signs of uncontrolled pain or distress. (Stull 2007)

Euthanasia should be a consideration in the following scenarios

- Loss of production and/or failure to perform and/or failure to thrive (i.e., declining quality of life such as with advanced age, severe mastitis, chronic pneumonia etc.)
- Potential or known exposure to toxins (such as polyfluoroalkyl substances (PFAS) or lead toxicity) that would likely result in a food safety issue if sent to slaughter for human consumption
- Extended drug withdrawal time for clearance of tissue residue
- Behavior or temperament issues which render an otherwise fit animal to be unsafe
- Poor prognosis or prolonged expected recovery
- Diseases that could threaten herd health (i.e., BVD or others)
- Nonambulatory cattle that are not eating or which have not responded to treatment in 24 hours.

DECISION MAKING

Actions involving compromised cattle include treatment, slaughter or euthanasia. The following criteria should be considered when making a decision:

- If the animal is in severe pain, distress, or debilitation. Can appropriate relief be provided.
- Likelihood of recovery
- Ability to provide the compromised animal with sufficient feed and water
- Ability to provide an adequate environment and nursing through the full recovery
- Drug withdrawal if considering slaughter
- Economic considerations of treatment, slaughter or euthanasia
- Potential for pre- or post-mortem condemnation potential if sent to slaughter
- Diagnostic information that can provide additional insights to patient or herd
- Ability of animal to survive and have acceptable welfare during transport to slaughter facility
- Whether the animal poses a danger to people or other animals due to contagious disease or temperament.

Part of meeting our responsibility to reduce pain and suffering must be to see that euthanasia is provided promptly once the decision has been made. No more than four hours (preferably much less) should elapse between making the decision to euthanize and performing the procedure.

CONSIDERATIONS FOR SELECTION OF METHOD OF EUTHANASIA

When euthanasia is the most reasonable option

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for a compromised animal, the following elements should be considered to aid in the selection of the appropriate method:

- **Human Safety** The first consideration in the choice of euthanasia method is human safety. For example, the use of a firearm carries greater safety risks when compared to other methods.
- **Animal Welfare** All methods of euthanasia should produce a rapid death with no detectable pain and distress. Select a euthanasia technique that considers human safety as well as animal welfare and is appropriate for the specific situation.
- **Restraint** When performing euthanasia procedures, appropriate methods of restraint should be used. Some methods, such as captive bolt, require excellent restraint of the animal. Quality and availability of cattle chutes, halters, gates or other forms of restraint make certain forms of euthanasia more practical than others.
- **Practicality** An appropriate euthanasia technique must also be practical to use. For example, not all individuals responsible for carrying out euthanasia procedures have access to pharmaceuticals or firearms.
- **Skill** Certain techniques require skill and training to accomplish correctly. Individuals responsible for conducting euthanasia should be trained in proper euthanasia protocol and have access to appropriate, well-maintained equipment and/or medications.
- **Cost** Euthanasia options vary in cost. Specific techniques, such as firearms or captive bolts, require a greater initial investment, which may be defrayed over time.
- **Aesthetics** Certain euthanasia techniques, such as the use of a barbiturate overdose, may appear more humane to the general public when compared to other techniques. Some methods, such as a penetrating captive bolt, may cause significant involuntary movements by the animal that may be misinterpreted as a painful voluntary response to people inexperienced in bovine euthanasia. When selecting a euthanasia method, potential negative reactions by the animal or observer should be considered
- **Diagnostics** The selected euthanasia method should not compromise diagnostic sample collection (as in rabies testing). Some methods of euthanasia have not been studied for their impacts on diagnostic testing (i.e., intrathecal lidocaine [Aleman et al. 2015]). Veterinarians should use their best judgement when considering any possible post-mortem diagnostics that would be sought.
- **Carcass disposal** Carcass disposal is a critical consideration when selecting a euthanasia technique (Shearer et al. 2018). Carcasses must be handled and disposed of following state and federal regulations. Options may include rendering, burial, composting, incineration and potentially landfills. Cattle euthanized using a barbiturate overdose cannot be accepted at rendering facilities since the FDA has a tolerance and test for the drug in the rendered product. In some regions, regulations require animals euthanized with barbiturates to be incinerated or buried. Appropriate disposal of the carcass prevents scavenging and potential toxicity issues among wildlife. Any scavenging animals will be affected by carcasses with barbiturates, and this must be taken into consideration (Aleman et al. 2016). In addi-

tion, leachate from carcasses of barbiturate overdosed animals have the potential to contaminate other carcasses or the environment. Additionally, it is important to remember that even in death, animals in our care deserve respect, and dead animals should be handled with this in mind.

MECHANISMS OF EUTHANASIA

The agents of primary or adjunct euthanasia cause death by one of the three following mechanisms:

- Direct and swift depression of the central nervous system or organs necessary for life function (overdose with barbiturate or barbituric acid derivatives; intrathecal lidocaine hydrochloride administration). Hypoxia produced by inhaled agents is not recommended for ruminants.
- Hypoxia associated with agents or procedures that displace or block uptake of oxygen (such as that caused by exsanguination when used as an adjunctive method).
- Physical disruption of brain activity (such as that caused by gunshot, penetrating captive bolt, or pithing).
- Cardiac arrest triggered by intravenous administration of saturated potassium chloride (only acceptable as an adjunctive method following confirmation of unconsciousness)
- Neuromuscular blocking of breathing by intravenous administration of saturated magnesium sulfate (only acceptable as an adjunctive method following confirmation of unconsciousness)

Table 1: Recommended methods for practical euthanasia

Method	Risk to Human Safety	Skill Required	Potential Public Perception Issues	Adjunctive Method Required
Gunshot	high	moderate*	moderate: some blood and motion	no
Penetrating captive bolt	moderate	moderate*	moderate: some blood and motion	yes
Barbiturate or barbiturate derivative overdose	low	moderate*	perceived well	no
Two-step method (Anesthesia followed by intrathecal lidocaine or intravenous injection)	low	moderate*	perceived well	yes

*Operator Training Required

RECOMMENDED PRIMARY EUTHANASIA METHODS

1. Gunshot When properly executed, gunshot induces instantaneous unconsciousness and death, is inexpensive and does not require close contact with the animal. It should be emphasized that this method should only be attempted by individuals trained in the use of firearms and who understand the potential associated dangers (Longair 1991, Shearer 2008, Thomson et al. 2013, Griffin 2015, Shearer et al. 2018). Firearm options include rifles, handguns (pistols), or shotguns.

Rifles and Handguns Current recommendations suggest that the .22 caliber handgun or rifle loaded with a long rifle (LR) solid point bullet is sufficient for calves less than four months of age. In cattle over four months of age, it is necessary to use .22 Magnum or higher calibers for consistently

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Landmarks and placing the shot

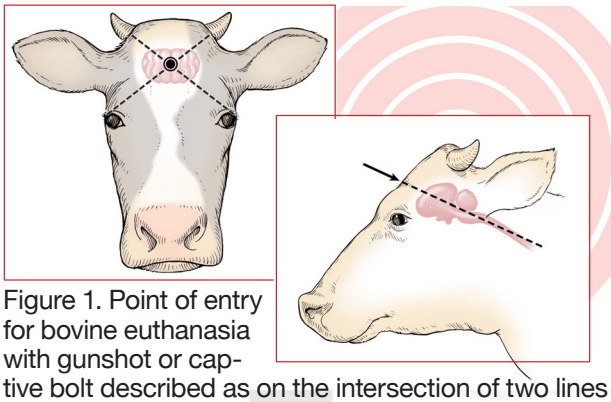


Figure 1. Point of entry for bovine euthanasia with gunshot or captive bolt described as on the intersection of two lines each drawn from the lateral canthus (outer corner) of the eye to the center of the base of the opposite horn (or where horn would be). *Courtesy Gilliam, Shearer, et al. 2012.*

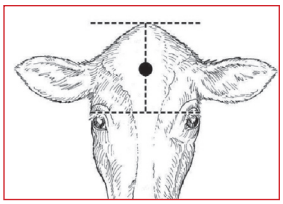
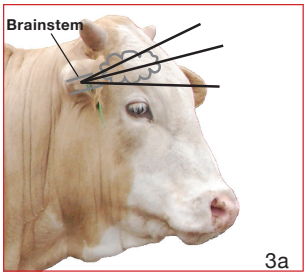


Figure 2. Alternate method: Selecting the proper anatomic site is to place the shot midway between a line connecting the lateral canthus of the eye and the poll on midline. *Gilliam, JN et al. 2016;*



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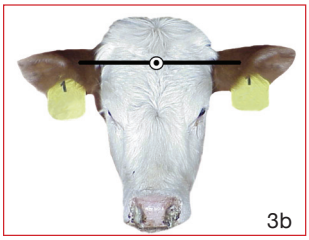

3b

Figures 3a and 3b. Alternate method of selecting the proper anatomic site is to aim the trajectory on midline between the base of the ears at the level of the external meatus and directed perpendicular or slightly downward (no more than 45 degrees). The angle may be modified as shown in Figure 3a to accommodate orientation of animal and caretaker, particularly when using a firearm. Penetrating captive bolts are typically discharged after holding the device flush and perpendicular with the frontal bone.
Courtesy R Dewell et. al. 2016.

effective euthanasia. The "AVMA Guidelines for the Euthanasia of Animals (2020)" recommends use of solid-point bullets. Muzzle energy available from a .22 Long Rifle is in the range of 100- to 150-foot pounds , whereas larger calibers such as the .38 Special, .357 Magnum or 9 mm will push muzzle energies well above the 300 foot pounds range. Rifles are capable of higher muzzle energies compared with handguns and are often a better choice in situations where a fractious animal must be shot from a distance.

Shotguns Shotguns are very lethal at close range (less than three feet from the point of intended entry), whether loaded with shotshells or slugs. The 12-, 16-, and 20-gauge shotguns are a good choice for euthanasia of adult cattle. The 28 or .410 gauge shotgun is an excellent choice for use in calf euthanasia. If using a shotgun loaded with shot shells, the operator should be very conscious of the distance from the gun barrel to the animal as projectiles will spread out into a larger pattern. Ideally, to obtain maximum consistency and efficacy of euthanasia, it is desired that the BBs from the shot shell make contact with the skull as a compact mass.

Placement of firearm When using a handgun, the firearm should be held within one to two feet of the intended target. The projectile(s) should be directed perpendicular to the front of the skull to minimize the likelihood of ricochet. In cattle, the point of entry of the projectile should be at the intersection of two imaginary lines, each drawn from the outside corner of the eye to the base of the opposite horn as shown in Figure 1. For operator and bystander safety, the muzzle of any firearm

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should never be held directly against the animal's head. Discharge of the firearm results in development of enormous pressure within the barrel that can result in explosion of the barrel if the muzzle end is obstructed or blocked.

Figure 4a. Penetrating captive bolt gun.

2. Penetrating captive bolt Captive bolt devices ("guns" or "stunners") are either penetrating or non-penetrating (Gregory & Shaw 2000, Grandin 2002, Humane Slaughter Association 2013, Kline et al. 2019, Casagrande et al. 2020). Only penetrating captive bolt devices are approved for euthanasia of mature bovines and, according to "AVMA Guidelines for Euthanasia of Animals (2020)", must not be used as the sole method of euthanasia. The bolt gun must be placed firmly against the skull at the same entry point previously described for a gunshot. Since use of the captive bolt gun requires close proximity to the animal, adequate restraint and prior sedation or tranquilization may be required. It is critical to maintain and clean the bolt gun as described by the manufacturer (Gilliam et al. 2012). Additionally, selection of cartridge strength may vary among manufacturers and the appropriate type and strength for the size of the animal must be used (Kamenik et al. 2019). Store cartridges in a cool dry area, away from humid environments. Exposing cartridges to moisture can affect burning of the propellant and thus lower the bolt speed and penetrating force. The optimal point of entry for the penetrating captive bolt is depicted in Figure 4b. When using a penetrating captive bolt, a secondary method of euthanasia must also be employed (as described below; Dersheid et al. 2016).

Figure 4b. Placement of captive bolt for optimal point of entry. Captive bolt should be held flush against skull and perpendicular with the frontal bone.

3. Barbiturate and barbituric acid derivatives When properly administered by the intravenous route, barbiturate overdose results in rapid loss of consciousness and death. When using sodium pentobarbital for this purpose, consult the label for the appropriate dose. When choosing a barbiturate for euthanasia, the barbiturate selected should be potent, long-acting, and stable in solution. The carcass of barbiturate treated animals is considered unfit for human or animal consumption. Ingestion of pentobarbital contaminated tissues by wildlife or rendered material consumed by domestic pets can induce toxicities, and all species are considered susceptible (FDA-CVM 2003 http://www.fda.gov/AnimalVeterinary/news Events/CVM updates/ucm119205.htm). Finally, as mentioned previously, the use of barbiturates limits carcass disposal options as renderers will not accept animals euthanized by this method. Due to scavenger risk, environmental contamination, and limited carcass disposal options, it is recommended that barbiturate overdose be a euthanasia tool of last resort.

COMMENT ON THE USE OF ALPHA-2 AGONISTS

It should be noted that the injection of xylazine or any other alpha-2 agonist has not been shown to induce anesthesia and is not acceptable to use for euthanasia either as the sole means or as the

primary method before applying an adjunctive method such as exsanguination, intrathecal lidocaine, potassium chloride, magnesium chloride or magnesium sulfate administration (Ef 2014, Dewell 2013). Animals must be rendered unconscious via general anesthesia, gunshot or captive bolt prior to administering one of the above secondary methods.

Alpha-2 agonists, such as xylazine, are sedatives that may provide safer handling of animals, and reduce the risk of further injury and distress, prior to euthanasia (Hanthorn & Sanderson 2019). However, the depth and duration of sedation in fractious, injured or otherwise compromised animals, especially after intramuscular or subcutaneous injection, can be unpredictable. Practitioners should ensure that the initial dose administered is adequate for deep sedation (for xylazine, 0.3 mg/kg bw IM or SC is recommended). Higher doses may be associated with convulsions and seizures that will make handling more dangerous and increase the risk of further injury. Animals sedated with alpha-2 agonists should be approached with caution and only when sufficient time has passed for the sedative to take full effect. Consideration should also be given to the potential environmental risk posed by alpha-2 agonist residues that may remain in the carcass at the time of disposal.

DETERMINATION OF UNCONCIOUSNESS

A state of apparent unconsciousness must be established immediately following the primary euthanasia procedure (Terlouw et al. 2015, Shearer 2018). In the field, the surrogate to unconsciousness is "lack of response" described below, as actual unconsciousness can only be determined by electroencephalography (EEG). The person performing the euthanasia must be prepared to immediately reapply an acceptable euthanasia technique if any sign of consciousness is demonstrated by the animal and detected by the observer. Secondary or adjunctive euthanasia methods must not be used until the animal has been determined to be unconscious.

Signs of unconsciousness

- Absence of corneal reflex
- Absence of vocalization
- Absence of gag reflex (no voluntary tongue movements or swallowing)
- Lack of rhythmic respiration
- No coordinated attempt to rise or right itself

SECONDARY OR ADJUNCT EUTHANASIA METHODS

Exsanguination, pithing and rapid intravenous injection of a solution of Potassium Chloride (KCl), Magnesium Sulfate ($MgSO_4$) or Magnesium Chloride ($MgCl_2$) are acceptable adjunctive methods. A second shot (penetrating captive bolt or gunshot) in the original frontal or poll location is an acceptable secondary choice of an adjunctive method when exsanguination, pithing or intravenous injection are not available.

1. Exanguination This method can be used to ensure death after stunning, anesthesia, or unconsciousness. It must not be used as a method for euthanasia of conscious animals. The most common exsanguination method in the bovine is to lacerate both the jugular veins and carotid arteries (Figure 5). A 6-inch-long sharp knife is fully inserted

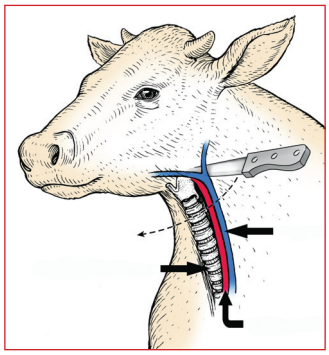

Figure 5. Exsanguination in a bovine *(Shearer 2008)*.

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behind the point of the jaw and directed downwards until blood is freely flowing. Alternatively, severing blood vessels of the brachial plexus may be performed by lifting a forelimb, inserting the knife deeply at the point of the elbow and cutting skin and vasculature until the limb can be laid back against the thorax of the animal. Another method is transecting the aorta via the rectum by a trained individual to pool blood within the abdominal cavity.

2. **Pithing** Pithing is an adjunctive technique designed to cause death by increasing the

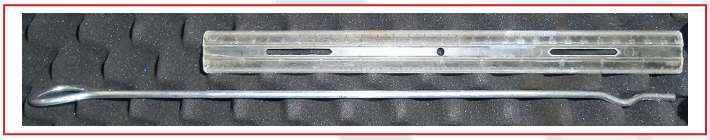

Figure 6. Pithing rod

destruction of brain and spinal cord tissue. It is performed by inserting a pithing rod or similar tool through the entry site produced in the skull by a bullet or penetrating captive bolt device. The operator manipulates the pithing tool to destroy both brain stem and spinal cord tissue, which results in death.

3. **Potassium Chloride (KCL)** Rapid IV administration of a solution of potassium chloride (KCl) induces cardiac arrest. Cattle must be anesthetized or unconscious prior to administration (Griffin 2015). The use of a captive bolt is also acceptable if a state of unconsciousness is achieved. The specific dose of KCl will vary according to the size of the animal, but an injection of 250 ml of a saturated KCl solution is usually sufficient for most mature cows. The KCl solution should always be given to effect (i.e., until death).

Potassium chloride can easily be sourced in the form of water softener salts and can be ordered in bulk off the internet. The typical concentration of KCl for use as a secondary method of euthanasia in ruminants is between 75-100 mg per kg of body weight. First, use a mortar and pestle (or another method) to grind the KCl crystals into a coarse powder. Next, dissolve the appropriate amount of KCl crystals in hot water (about 60 mls of water per 20 g of KCl). For reference, one tablespoon of KCl weighs approximately 20 grams. Maintain the KCl solution at room temperature to avoid precipitate formation. If precipitate forms, rewarm and remix the solution.

4. **Magnesium sulfate or magnesium chloride** Magnesium sulfate (aka $MgSO_4$, commonly referred to as "epsom salt") is a commonly available salt that has been classed as an antidysrhythmic and electrolyte (Medscape). When administered IV as a saturated solution, magnesium sulfate can affect both the central and peripheral nervous systems (Cooney and Titcombe, 2022). Administration of high levels of magnesium sulfate incites cardiac arrest by preventing calcium entry through voltage-dependent channels and reducing acetylcholine release at end-plates-thus inhibiting peripheral neuromuscular transmission and resulting in fatal cardiac arrest (Cooney and Titcombe; Messenger et al).

Similar to the use of saturated potassium chloride solution, magnesium sulfate can halt respiration prior to loss of consciousness, rendering it very inhumane. Thus, the administration of magnesium sulfate must not occur until a deep plane of anesthesia has been ascertained. Compared to rapid IV administration of a saturated potassium chloride solution, death may occur less rapidly when a saturated magnesium sulfate solution is administered (AVMA Guidelines for Euthanasia 2020).

To prepare a saturated $MgSO_4$ solution, a clean 5-liter container can be filled with 2 kg of

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$MgSO_4$. The container can then be "topped off" with clean, hot water. A layer of $MgSO_4$ at the bottom of the container is normal and evidence that the solution is saturated. The use of food dye to color the solution as well as careful labeling is recommended to prevent unintended usage. Used 500ml plastic bottles such as those used for calcium gluconate are often useful to store saturated $MgSO_4$ solution in. Prevent the solution from becoming too cold just prior to use; if the stored solution is exposed to colder temperatures, it may precipitate and clog the tubing and catheter/needle.

The volume required to cause death in an anesthetized animal ranges quite widely. Many practitioners figure approximately 500mls of a saturated $MgSO_4$ solution will kill most animals 450kg or less. It is advised to use a 14 gauge needle or catheter which can be secured with glue. A reusable IV tubing set such as Simplex© can be connected to the catheter/needle and the 500ml bottle of $MgSO_4$ solution and allowed to be administered via gravity flow. Sometimes, muscle fasciculations, stretching, agonal breaths, or clonic spasms are observed during or briefly after administration (Cooney and Titcombe; AVMA).

5. **Second shot** A properly aimed shot with an appropriate firearm or captive bolt, will reliably produce unconsciousness, but especially in the case of the captive bolt, may not lead to death (Casagrande et al. 2020). A second shot in an unconscious animal creates significant additional brain trauma, intracranial hemorrhage and substantial intracranial pressure. The increase in intracranial pressure often impairs regulation of respiratory and cardiac function within the medulla oblongata leading to death. If the first shot does not lead to immediate unconsciousness, a second shot in the original frontal or poll location (Robbins et al. 2021) is required immediately and is not optional.

6. **Intrathecal Lidocaine** A recently introduced method of euthanasia which has been studied in horses is intrathecal lidocaine administration following full anesthesia. Lidocaine is a common local anesthetic which works via sodium channel blocking in addition to other actions and is widely available in 2% sterile solution. Lidocaine has been widely used in both human and animal medicine as a spinal block causing direct anesthesia local nerves. The probable mechanism of death in the case of intrathecal lidocaine is related to the location and high dose of lidocaine resulting in direct anesthesia of vital cerebro-cortical and brainstem structures and secondary loss of respiratory and cardiovascular function (Aleman 2016).

With the patient under anesthesia the animal is positioned laterally and the head and neck is flexed to facilitate access to the atlantooccipital space. A spinal needle is used and advanced perpendicularly until cerebrospinal fluid can be aspirated. Following this the full dose of lidocaine is administered rapidly. In the research in horses and small ruminants the dose of lidocaine has been 4-5mg/kg using 2% lidocaine solution (Aleman 2016, Zolhavarieh 2011).

In a small study done on calf cadavers using dye the researcher demonstrated penetration to the anatomical structures responsible for consciousness (Rousseau 2019). In physiological studies the researchers observed an immediate loss of respirations followed by loss of electrical activity in the brain stem and finally slowing heart rate leading to cardiac arrest. Time to cardia arrest varied between species but took up to 15 minutes. (Aleman 2016,

Zolhavarieh 2011, Rosseau 2019). In one study looking at residues in horses they demonstrated residues from both the anesthetic agents (xylazine, midazolam and ketamine) and the lidocaine in low levels which would be below the dose expected to affect scavengers (Aleman 2016). However, proper carcass disposal is still recommended.

COMMENT ON POLL SHOOTING OR STUNNING

Poll position stunning with a penetrating captive bolt is not recommended as a primary method of euthanasia. However, recent peer reviewed literature has demonstrated there is no significant difference in the time to death (lack of respiration and heartbeat) when the poll shot is properly applied as a secondary shot in captive bolt euthanasia (Robbins et al. 2021). If using a gunshot or PCB behind the poll as a second shot, the shot should be directed toward the base of the tongue with proper positioning essential.

CONFIRMATION OF DEATH

Confirmation of death following a euthanasia procedure is absolutely essential regardless of what method of euthanasia is chosen. Keep personal safety in mind when confirming death because animals can make sudden involuntary movements. The primary indicator for confirmation of death is cardiac arrest. Lack of heartbeat and respiration for three-to-five minutes should be used to confirm death. The presence of a heartbeat can be best evaluated with a stethoscope placed under the left elbow. It should be noted that the heart continues to beat for a period of time with either captive bolt or firearm euthanasia, because heartbeat is controlled by the sino-atrial node and not the brain. Continued cessation of rhythmic breathing is considered a secondary indicator of death, and observation for movement of the chest can be used as an indicator of respiration in addition to lack of a heartbeat. However, respiration rates may be very erratic in unconscious animals; therefore, one must be cautious in the interpretation of respiration for confirmation of death. If respiration is not absent or the animal begins respiring again, a second shot is required. The corneal reflex may be tested by touching the surface of the eye. Normal or conscious animals will blink when the eye's surface is touched. Lack of a corneal reflex alone is not sufficient for confirmation of death, and by itself only proves the animal is unconscious. Continued monitoring of animals for a period of 20 to 30 minutes after euthanasia has been performed is also good advice to livestock owners and managers.

Figure 7. Confirmation of death

UNACCEPTABLE METHODS OF EUTHANASIA

Based on ethical and humane considerations, the following methods are considered unacceptable euthanasia techniques (AVMA 2020):

- Manually applied blunt trauma to the head of calves or mature cattle
- Injection of unapproved chemical agents or substances (e.g., disinfectants, non-anesthetic pharmaceutical agents)
- Sedation with an alpha-2 agonist such as xylazine followed by exsanguination, intrathecal lidocaine, potassium chloride, magnesium sulfate, or any other euthanasia method

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that requires the animal to be unconscious prior to its use
- Air injection into the vein
- Electrocution with a 120-volt electrical cord
- Drowning
- Exsanguination of conscious animals
- Inappropriate caliber of bullet for size of animal
- Puntilla—a method whereby a sharp pointed knife is plunged into the back of the animal's neck to sever the spinal cord by entry into the atlanto-occipital space

CONSIDERATION FOR EUTHANASIA OF CALVES AND BULLS

Calves and bulls require special consideration when selecting the proper method of euthanasia (Dewell et al. 2016). Ethical considerations do not change for the calf because it is small or more easily handled. As noted by USDA Food Safety Inspection Service, "A calf is a young bovine of either sex that has not reached puberty (up to about 9 months of age) and has a maximum live weight of 750 pounds." (USDA) Blunt trauma by physical blow to the head is not an acceptable method of euthanasia of calves because the skull is too hard to consistently achieve immediate and lethal destruction of brain tissue. This method is also difficult to consistently apply because of restraint and complications in positioning the calf for effective use of blunt force trauma methods. In addition to the methods outlined in Table 1 for mature bovines, using a purpose-built non-penetrating captive bolt stunner is an acceptable (with conditions) method of euthanasia for calves, but should be followed with an adjunctive step to assure death.


Figure 8. Consideration for bulls

The euthanasia of bulls presents unique challenges because of their size, temperament, and skull thickness. Operator safety is of primary concern in the euthanasia of bulls, and proper restraint at all times is critical. Bulls may be euthanized with specialized heavy-duty captive bolt guns or firearms capable of muzzle energies of 1000 foot-pounds, or by barbiturate overdose if proper carcass disposal options are met.

CONSIDERATIONS FOR EUTHANASIA OF BISON AND BUFFALO

The recommended method for the euthanasia of a bison is gunshot. A minimum of 1356 joules (J) (1000 ft-lb) of muzzle energy is required for the euthanasia of yearlings, cows and mature bulls. This limits the firearm options to higher caliber centerfire rifles (e.g. 30-30, 270, 30-06 and others). In one study, a 12-gauge shotgun with a 2.75-inch Foster slug was effective as a means of stunning bison heifers prior to on-farm slaughter for meat production (McCorkell et al. 2013). The majority of handguns produce muzzle energies well below 1356 J (1000 ft-lb) and would not be appropriate for euthanasia of mature bison (Galbraith et al. 2016).

The preferred anatomical site for entry of a bullet is on the forehead approximately 2.5 cm (1 inch) above an imaginary line connecting the bottom of the horns, which places the shot in a similar location to recommendations for mature cattle. Ideally, the angle of entry should be perpendicular to the skull. However, if it is necessary to shoot the animal from a distance, targets may be the

head (frontal or lateral side) or the thorax (heart shot; Galbraith et al. 2016). In cases where an animal is alert and holding the head elevated, a heart shot is preferable to avoid the bullet hitting the frontal bone at an angle that does not permit penetration (Rioja-Lang et al. 2019). This form of euthanasia should only be considered if proper restraint is not possible.

There are important anatomical differences that need to be considered when determining the best method of euthanasia for water buffalos compared with cattle. Skull bones are substantially thicker and the frontal and paranasal sinuses noticeably wider in buffaloes compared to cattle. Moreover, measures of the median distance from the frontal skin surface to the thalamus were 14.5 cm (11.7 cm–17.2 cm [4.6 inches to 6.8 inches]) vs 10.2 cm (10.1–12.1 cm [4 – 4.8 inches]) in water buffalos and cattle, respectively (Schwenk et al. 2016). The bolt length of conventional captive bolt devices is 9 to 12 cm (3.5 to 4.7 inches; Casagrande et al. 2020) meaning that the ability of the bolt to make direct contact with the thalamus and brainstem is less likely using frontal sites in water buffalos compared with cattle. For this reason, the use of the PCB at frontal sites in water buffalos is generally less effective (Gregory et al. 2009).

Anatomic Site for conducting euthanasia of bison The preferred anatomic site for entry of a bullet is on the forehead approximately one inch above an imaginary line connecting the bottom of the horns (Galbraith et al. 2016). Alternatively, the site can be identified on the intersection of lines from the lateral canthus to the top of the horn, which is similar to landmarks used in cattle. While it may be difficult to achieve the perfect angle the goal is for the bullet to enter perpendicular to the skull and travel through the brain and brain stem by aiming for the foramen magnum.

Anatomic sites for conducting euthanasia of water buffalo Recommendations for euthanasia of water buffalo with a firearm using frontal sites are to direct the projectile on the intersection of two imaginary lines connecting the lower edge to the upper edge of the contralateral horn (Schwenk et al. 2016). This site is above a line drawn laterally connecting the bottom of the horns. Depending upon the size of the horns this will be at a higher or lower location.

CONSIDERATIONS FOR LIVE FETOTOMIES

A fetotomy is defined as dismemberment of a fetus in utero to aid its delivery via the birth canal. The purpose of a fetotomy is to save the life of the dam. It is typically reserved for cases in which the fetus is dead (or presumed dead) and intractable dystocia. In rare cases, the only way to save a dam is to perform a fetotomy on a live calf, which comes with understandable ethical concerns over whether calves can feel pain and distress. Ruminant fetuses are sentient and have the neural apparatus necessary to feel both positive and negative states, but are under a hormonally induced unconsciousness, which prevents any sensation or noxious stimulus to be perceived (Mellor & Diesch 2006). Evidence from Mellor (2010, 2012) demonstrates that farm animal fetuses remain in an unconscious state throughout late pregnancy and birth and that newborns only become conscious when they have successfully inhaled air into their lungs. In fact, fetal unconsciousness may become deeper during states of transient hypoxemia (as in natural labor or prolonged dystocia). According to Mellor, a calf that has not breathed atmospheric oxygen is not conscious and thus cannot perceive pain. That said, fetotomies on live calves should be restricted to cases where no other dystocia management option exists to preserve the life of the dam.

GUIDELINES FOR THE HUMANE EUTHANASIA OF CATTLE

There are many techniques that can be attempted to determine if a fetus is alive in utero. These include: feel for pulse in the umbilical cord; strongly pinching the tongue, lip, or anus; by applying strong pressure to the supraorbital ridge of the eye socket; or eliciting a leg withdrawal in response to being pulled or pedal reflex stimulation. The movement or withdrawal responses are reflexes to pressure and are not signs indicating fetal conscious awareness. Fetuses that move in response to a noxious stimulus in utero remain hypoxemic and are still considered to be unconscious as judged by EEG evidence (Mellor et al. 2005, Mellor 2010).

Although current studies demonstrate fetal unconsciousness prior to oxygen inhalation, veterinarians may consider euthanasia of the calf prior to dismemberment if feasible. If the umbilical cord can be reached it can be severed manually and fetotomy can continue two to three minutes after cord severance (Mellor 2013). If the head is accessible, the fetus can be euthanized by cutting the throat and exsanguinating before starting the fetotomy. Decapitation using a fetotomy wire will offer the same result if performed expediently.

TRAINING REQUIREMENTS

If euthanasia is to be provided by the owner, employees of the facility, or a non-veterinarian third party, the expectation is that those individuals should have annual training and certification (Turner & Doonan 2010). Each individual must know how to recognize animals in need of euthanasia, proper euthanasia technique, how to properly confirm death, safe use of the methods of euthanizing to be employed, as well as how to maintain the equipment after and between uses. Some documented record of this training should be kept in the facilities training records or herd health plan.

RECORDS AND RECORD KEEPING

Keeping accurate and complete records is an important part of providing euthanasia. Records should include, at a minimum, the ID of all animals euthanized, the date, the person providing euthanasia, the indication of the reason for euthanasia, method of euthanasia and the carcass disposal utilized. Records should be maintained in accordance with the state's requirements for medical records. Records should also be kept for the euthanasia equipment. This should include a gun or captive bolt cleaning and service logs. Properly functioning equipment is critical to rendering the animals immediately insensible.

CONCLUSION

Personnel at sites that routinely handle cattle should be prepared with the knowledge, necessary skills, and well-maintained equipment to conduct euthanasia. Penetrating captive bolt and gunshot are the only two acceptable methods typically available to non-veterinarians for emergency euthanasia of cattle. Animal transporters should also be properly trained in euthanasia techniques and have contact information for appropriate personnel in case of an emergency. An action plan for routine and emergency euthanasia should be developed and followed wherever animals are handled. Dead animals should be disposed of promptly and according to all federal, state, and local regulations. Persons who perform humane euthanasia must be technically proficient, mentally capable, and possess a basic understanding of the anatomical landmarks and equipment used. If there is any degree of question or discomfort with a proposed euth-

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anasia procedure, a veterinarian should be consulted.

Additionally, it is important to remember that even in death, animals in our care deserve respect, and dead animals should not ever be handled in a manner that would be unacceptable for a live non-ambulatory cow. Acceptable methods for moving the carcass would include placing them onto a sled or rolling them into a bucket. If cattle are to be dumped into a container or pit, care should be taken to use the minimum height possible in order to minimize the distance the carcass will fall.

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