

Description and justification of a consistent technique for euthanasia of bovines using firearm and penetrating captive bolt

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Abstract

Firearms and penetrating captive-bolt devices are commonly used to euthanize cattle of all ages, and result in rapid unconsciousness and death due to lethal brain damage when properly conducted. Several reports have described methods to determine the appropriate point of entry when using firearms or penetrating captive bolts for bovine euthanasia. However, some previously described techniques to determine the point of entry may be difficult to remember, necessitate multiple steps to ascertain the point of entry, require adjustment based on breed type, and/or may be challenging in polled cattle if the suggested protocol uses horn anatomy as part of the guidance. A simple, reliable description for an appropriate point of entry and trajectory course for a firearm or captive bolt is to direct the trajectory perpendicular or slightly downward to the frontal sinus plane on midline between the base of the ears at the level of the external acoustic meatus. The orientation of the brainstem and ear is not altered by variables considered in some other protocols. The objective of this report is to describe and justify an uncomplicated, repeatable protocol to consistently determine an appropriate point of entry and line of trajectory for firearm or penetrating captive-bolt euthanasia of domestic bovines across a variety of breeds, ages, skull types, and polled or horned cattle, thus increasing the likelihood that the procedure will be conducted quickly and humanely with minimal stress to the handler and the animal.

Key words: euthanasia, bovine, point of entry, firearm, penetrating captive bolt

Résumé

Les armes à feu et les pistolets à tige perforante sont communément utilisés pour euthanasier les bovins de tous âges, et induisent une perte de conscience et une mort rapide causée par un dommage léthal au cerveau, lorsqu'effectués correctement. Plusieurs rapports ont décrit des méthodes visant à déterminer le point d'entrée approprié lors de l'utilisation d'armes à feu et de pistolets à tige perforante pour l'euthanasie de bovins. Toutefois, certaines techniques décrites précédemment pour déterminer le point d'entrée peuvent être difficiles à mémoriser, nécessiter de nombreuses étapes afin d'assurer le positionnement du point d'entrée, requérir des ajustements selon la race, et/ou représenter un défi avec le bétail sans corne si le protocole suggéré utilise l'anatomie de la corne comme guide. Une description simple et fiable pour un point d'entrée et une trajectoire appropriés pour une arme à feu ou un pistolet à tige perforante est de diriger la trajectoire perpendiculairement ou légèrement vers le bas du plan du sinus frontal sur la ligne médiane entre la base des oreilles au niveau du conduit auditif externe. L'orientation entre le tronc cérébral et l'oreille n'est pas modifiée par des variables considérées dans certains autres protocoles. L'objectif de ce rapport est de décrire et de justifier un protocole simple et reproductible pour déterminer de manière consistante un point d'entrée et une ligne de trajectoire appropriés pour les euthanasies à l'arme à feu ou à pistolet à tige perforante des bovins domestiques de toutes races, âges, types de crânes, avec ou sans corne, et ainsi augmenter la probabilité que la procédure soit effectuée rapidement et humainement avec un minimum de stress pour le manipulateur et l'animal.

Introduction

Euthanasia, defined as a “good death” that occurs with minimal pain and distress, is a key responsibility for veterinarians and other cattle caretakers.¹² Euthanasia decisions may be based on 1 or more factors such as a desire to relieve suffering, the protection of public health, or poor prognosis and economic reasons.¹ Regardless of the rationale for euthanasia, proper application of the selected euthanasia method is critical to achieve rapid death with minimal pain and stress. The American Veterinary Medical Association’s (AVMA) Panel on Euthanasia has recognized 3 primary methods as acceptable for bovine euthanasia: gunshot, penetrating captive bolt, and intravenous administration of a lethal dose of barbiturate or barbiturate acid derivative.¹² The determining factors for a specific method of euthanasia may include consideration of human safety, animal welfare, ability to provide adequate restraint, practicality, required skill to perform euthanasia technique, cost, public perception, carcass disposal options, and preservation of tissues necessary for laboratory diagnostics or other examinations.¹

Firearm and penetrating captive bolt devices are common, practical methods that have been shown to be effective for bovine euthanasia.^{5,7,14} Since many cattlemen and women possess pistols, shotguns or rifles suitable for bovine euthanasia, firearm euthanasia is often a favored method.¹⁷ In contrast to chemical methods of euthanasia such as barbiturate overdose, the use of physical euthanasia techniques like penetrating captive bolts and firearms do not typically result in tissue residues that limit carcass disposal options. In addition to carcass disposal issues associated with intravenous administration of a lethal dose of scheduled drugs, such as barbiturate or barbiturate acid derivatives for bovine euthanasia, accurate records must be diligently maintained, skill in intravenous techniques is required, and veterinary oversight must occur. In contrast, veterinarians as well as non-veterinarians can often access and more effectively implement euthanasia methods using firearms and penetrating captive bolt methods.

Correctly applied, the use of firearms and penetrating captive bolt euthanasia methods provides a humane death by physical disruption and complete destruction of the brainstem, immediately rendering the animal unconscious with death following rapidly. The brainstem is composed of the hypothalamus, midbrain, thalamus, pons, and medulla oblongata. Destruction of the pons and medulla oblongata is important when utilizing a penetrating captive bolt for euthanasia because they have primary control over consciousness, respiratory function, and influence cardiac function.^{3,19} Thus, destruction of the brain stem, specifically the medulla oblongata and pons, results in death due to cardiac anoxia following lack of respiration and is the primary objective of firearm and penetrating captive bolt euthanasia methods.^{3,16} Though some types of penetrating captive bolts may be suitable to use as a single-step euthanasia method, in other cases a secondary

step such as exsanguination, brainstem disruption (pithing), or overdose with potassium chloride or magnesium sulfate is often recommended to ensure death.^{1,5,6,7,10,12,13,14,18}

Numerous published descriptions and protocols provide guidance for the optimal point of entry when using firearms or penetrating captive bolts for bovine euthanasia. One published recommendation simply states: “The “X” is drawn from the top of the eyes to the middle of the horns. This position raises the position of the shot.”⁹ Though the description provides general guidance, it is likely to result in confusion if a user attempts to apply the guidelines to polled or dehorned cattle. Similar guidance to locate the point of entry is provided by the American Humane Association; the operator is instructed to: “Aim at the center of the head, 2/3 of the way up on the forehead. (calves, slightly lower).”¹⁶ This description is likely too obscure for some users because the point of entry may be difficult to discern. Other published descriptions include more detailed guidance using the eye as a landmark, “...the intersection of 2 lines each drawn from the medial canthus of 1 eye to the base of the contralateral ear at an angle directed toward the greater foramen of the occipital bone...”¹⁷ and “In cattle, the point of entry of the projectile should be at the intersection of 2 imaginary lines, each drawn from the inside corner of the eye to the base of the opposite horn (or to a point slightly above the opposite ear in a cow without horns).”¹⁵ The previous guidance recommending the use of the medial canthus has been modified to utilize the lateral canthus instead, “...should be placed on the intersection of 2 lines each drawn from the lateral canthus of the eyes to the site of horn formation on the contralateral (opposite) side.” This modification to include the lateral canthus has also been reflected in the updated AVMA Euthanasia Guidelines.¹² Gilliam et al accounted for polled cattle by directing the operator to use a point “just above the top of the opposite ear” instead of the horn.⁷ More recently, the point of entry has been described as “...midline halfway between the top of the poll and an imaginary line connecting each lateral canthus.”⁷ and also: “Draw an imaginary X from the top of the eye to the center of the opposite horn. The shot is placed in the middle of the X.” The authors then modified the description for polled animals: “Draw an imaginary X horizontal line at the top of the eyes. The correct shot location is midway between the horizontal line and the top of the poll.”²¹ Some authors also suggest factors such as breed type, horn mass, and skull shape could affect the correct point of entry and require adjustment.^{2,20,21}

All of the described protocols target the brainstem when correctly applied. However, some descriptions may be difficult for the user to understand or remember, particularly when bovine euthanasia procedures are only completed occasionally. Protocols may also present confusion if horns are used as an anatomical landmark and the animal is polled. Protocols may also present compliance challenges when there are multiple steps to ascertain the point of entry and when protocols may need to be adjusted based on skull shape, age,

breed type, or horn mass of the animal. A simple, one-step protocol that provides consistent and reliable guidance to target the brainstem regardless of skull shape, age, breed type, or presence/absence of horns could simplify and improve bovine euthanasia procedures when using techniques involving penetrating captive bolts or firearms.

Thus, we propose that an appropriate point of entry when using a firearm or penetrating captive bolt for bovine euthanasia is on midline between the base of the ears at the level of the external acoustic meatus. To maximize the amount of destructive energy directed at the brainstem from the bullet, shell, or bolt, the operator should strive to maintain the trajectory's path to a relatively perpendicular or slightly downward (no more than an estimated 45 degrees) angle with the frontal bone (Figure 1). The rationale for this proposed method is based on the 1) orientation of the external acoustic meatus and the brainstem, 2) the relationship between the external acoustic meatus and brainstem provided by the cranial nerves, and 3) the comparatively minimal brain growth and development in cattle between birth and maturity. Unless there are significant congenital defects, the orientation and association of the brainstem with ear placement is static.

Gross Preparation and Demonstration

To demonstrate the anatomic validity of this proposed method, we obtained 4 heads from beef cattle that had been euthanized using a method from an approved animal use protocol, or died as part of normal production practices. No animals were euthanized specifically for this report, therefore university approval from the Institutional Animal Care and Use Committee (IACUC) was not necessary. Three of the 4 heads were obtained from feedlot calves that did not respond to multiple treatments and were euthanized for humane reasons. The neonatal head originated from a calf that had died without a determined cause of death. Three of the cattle were estimated to be between 18 and 36 months of age, and 1 animal was approximately 3 months of age. Prior to dissection, heads were stored in a walk-in freezer maintained at an estimated -4 °F (-20 °C). All heads were cut while frozen on a band saw using 3 teeth/inch blades. One of the 18 to 36-month-old heads and the 3-month-old head were split by aligning the centerline of the saw over the nose, poll, and the centerline of the foramen magnum to position the band saw blade to cut on a midsagittal plane (Figure 2). A second 18 to 36-month-old head was cut on a transverse plane along temporal lines in order to open the cranium. The cut removed the frontal bone and the soft tissues covering it (Figure 3). A third 18 to 36-month-old head was prepared by dissecting a 4 by 6 inch (10 by 15 cm) section of hide and underlying connective tissue to expose the labyrinth of the frontal sinuses and the internal lamina of the frontal bone overlying the calvarium (Figure 4).

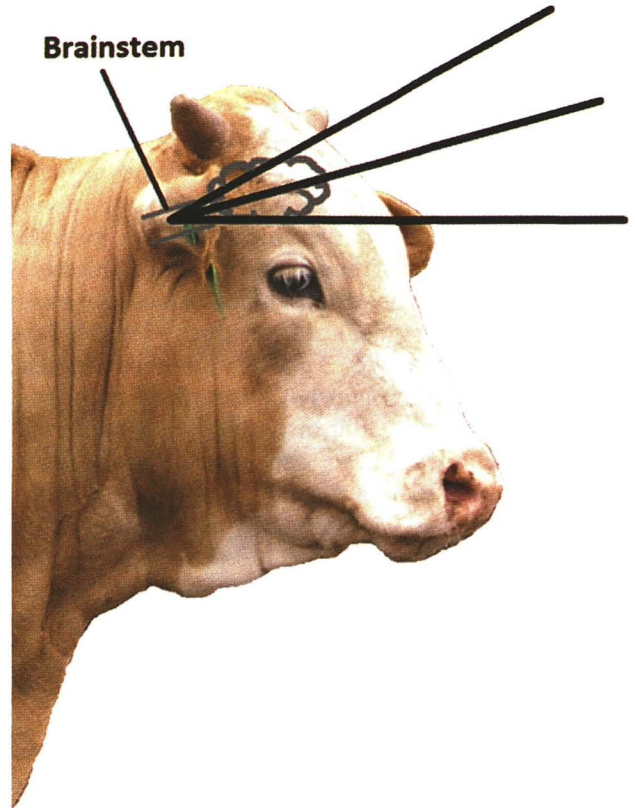


Figure 1a.



Figure 1b.

Figures 1a and 1b. The trajectory should be aimed 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 1a 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.

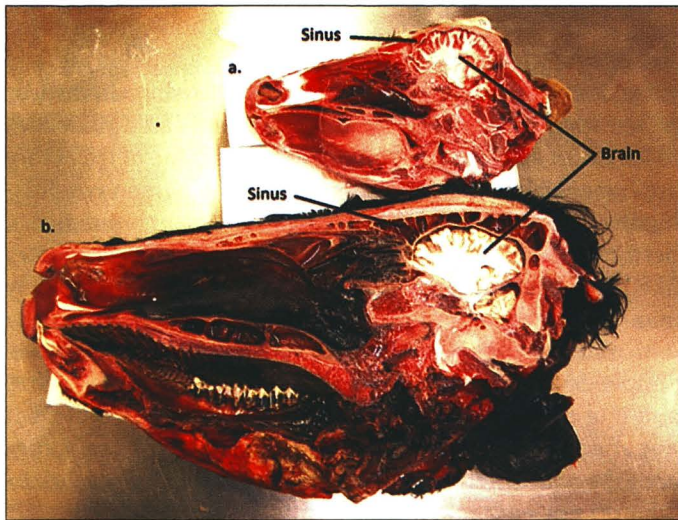


Figure 2. Sagittal view of neonatal (a) and adult (b) bovine heads. Note the relatively minor change in brain size compared to the extensive skull and sinus expansion that occurs as a bovine matures.

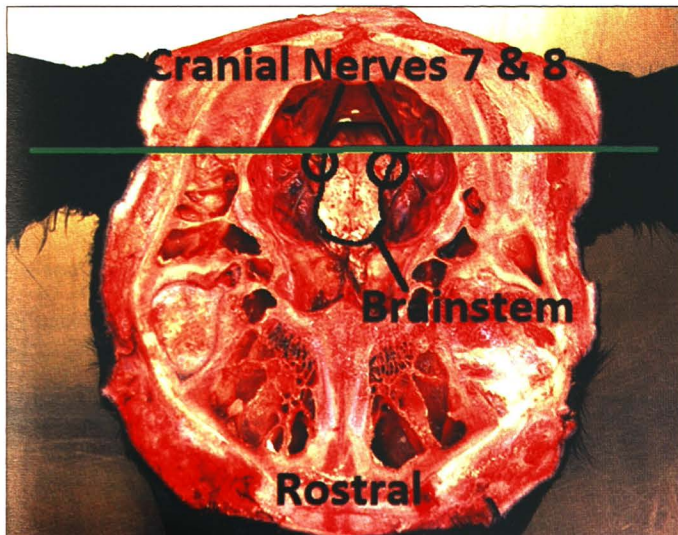


Figure 3. The brainstem is consistently oriented between the ears on the midline (dorso-ventral view, calvarium removed). The line transects both of the external acoustic meatus. The region where cranial nerves 7 and 8 exit the brainstem and travel towards the internal and external acoustic meatus are depicted by the small black circles. Figure 3 demonstrates a sagittal view of the bovine head that shows the orientation of the brainstem to the external meatus.

Cranial Nerve and Skeletal Anatomy

Cranial nerve and skeletal anatomy has been well documented in the bovine. Almost all output from the cerebrum and cerebellum exits the brain by traveling through the brainstem, which becomes the spinal cord caudal to the level of the cranium. Like most domestic mammals, cattle have 12 cranial nerves. The majority of these cranial nerves originate

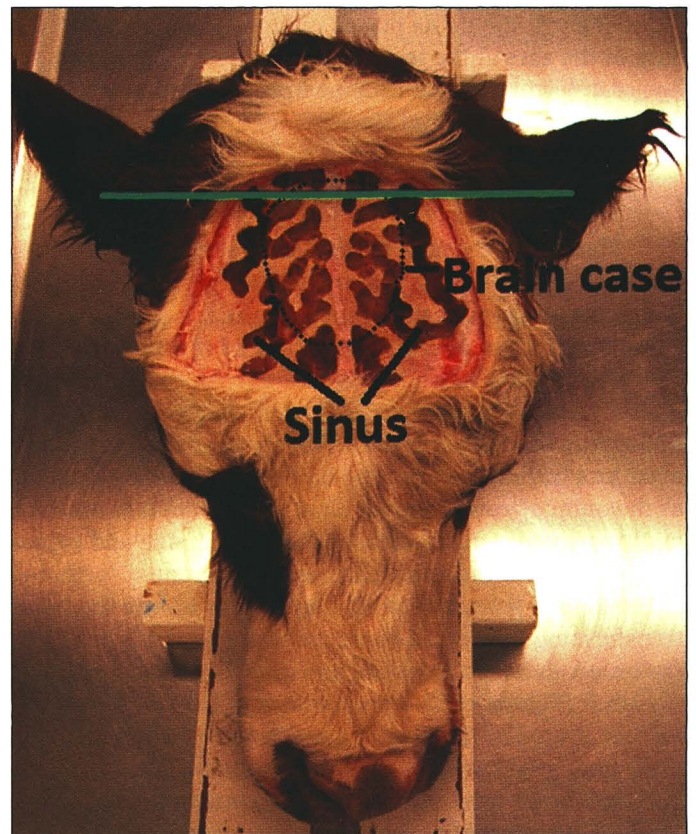


Figure 4. The external lamina of the frontal bone has been removed, showing the extent of post-natal sinus development and the location of the brain case which houses the brain. The brainstem can be targeted by aiming the trajectory on midline between the ears at the level of the external acoustic meatus.

in the brainstem before radiating out to their targets. Two of these nerves, CN VII (facial) and CN VIII (vestibulocochlear), exit the brainstem at the level of the medulla oblongata where it transitions from the pons. In the bovine, the facial and vestibulocochlear nerves exit the brainstem closely associated with each other. The facial nerve emerges laterally from the medulla oblongata and divides into several branches. The vestibulocochlear nerve emerges dorso-laterally from the brainstem and divides into the cochlear and vestibular branches. Both branches of the vestibulocochlear nerve, along with the facial nerve, exit the cranial cavity by traveling the short distance to the internal acoustic meatus of the petrosal temporal bone.⁸ Laterally, the petrosal temporal bone projects the external acoustic meatus in a plane nearly opposite that of the internal meatus. The anatomical orientation of the cranial nerves, brainstem, temporal bone, and the ears provides further confidence that the ears can be reliably used as a simple anatomical landmark for targeting the brainstem when euthanizing cattle with a firearm or penetrating captive bolt. The brainstem is located at the midline, thus the

point of entry should be placed on the midline between the base of the ears at the level of the acoustic meatus, and the line of trajectory should be aimed perpendicular or slightly downward on the frontal sinus plane.

Brain Size and Skull Development

Figure 2 illustrates the midsagittal sections of heads from a young calf and a mature bovine. In cattle, the post-natal development of the brain is limited, especially when compared to the overall expansion of the head (skull). The brain from a newborn calf weighs approximately 227 grams¹¹ while a mature bovine brain weighs about 410 to 480 grams. In contrast to the relatively small change in brain mass as a bovine matures, the bovine skull greatly expands as the animal grows. During skull expansion as the animal matures, the paranasal sinuses increase in size and capacity. The frontal paranasal sinuses are present at birth and as the animal matures the sinuses further invade the bone, transforming the domed contours seen on a calf's head into the broad, flattened forehead and upright nuchal surface of the adult (Figure 4). The proportions of the calf's head are further altered by the greater growth of the facial part of the skull compared to that of the neurocranium.⁴ This disparity between brain growth and skull expansion results in the brain being located in a much smaller region relative to the skull than might be suspected. Due to the minimal increase in brain mass during the post-natal period, the brain location and orientation with the ears remains the same as you would see in a calf, but is now surrounded by a much larger frontal bone and sinus. Thus, the proposed protocol would not be altered by maturity of the bovine animal.

The proposed simple description to target the bovine brainstem when euthanizing with a firearm or penetrating captive bolt is a reliable method because of established anatomical parameters common to the species. It is important that euthanasia be conducted quickly and safely, and cause as little stress as possible to the animal. The use of adequate restraint, appropriate ammunition, and proper facilities and equipment is critical to successfully euthanize cattle.¹⁷ This simple method to accurately locate an appropriate point of entry and line of trajectory for a bullet or captive bolt is expected to simplify bovine euthanasia, result in less stress, increase safety of the person conducting the euthanasia procedure, and importantly to increase the likelihood that the animal will be properly euthanized. The AVMA and American Association of Bovine Practitioners guidelines should be consulted for guidelines on confirming death and for choosing a secondary euthanasia step following the use of a penetrating captive bolt.^{1,12}

Conclusions

Humane euthanasia of cattle is a key responsibility for cattle caretakers. When combined with appropriate equip-

ment and restraint, veterinarians as well as non-veterinarians should find the guidance explained herein a reliable method to facilitate a rapid and humane death when using a firearm or penetrating captive bolt. The use of uncomplicated guidelines to locate an appropriate point of entry and line of trajectory are beneficial to the animal as well as the person conducting the euthanasia, since it may increase user confidence in performing the procedure correctly and result in a greater likelihood that euthanasia decisions will be made in a timely manner. Moreover, the procedure will be completed safely with minimal stress to the animal and the personnel involved. Simple descriptions to locate an appropriate point of entry and line of trajectory that are reliable and predictable, but not affected by breed type, age, skull shape, or horn status, are especially useful for veterinarians and non-veterinarians who do not euthanize cattle routinely and may not easily recall multiple landmarks.

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