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Captive-bolt euthanasia of cattle: determination of optimal-shot placement and evaluation of the Cash Special Euthanizer Kit® for euthanasia of cattle

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Abstract

Humane euthanasia of cattle represents a challenge to the beef and dairy industries. Penetrating captive bolt, while traditionally considered to be only a stunning method, can be an effective single-step euthanasia method if both the cerebral cortex and brainstem are disrupted. This report describes a preliminary study investigating the likelihood of brainstem disruption for two captive-bolt shot locations. Heads were collected from 15 cattle that died or were euthanised for reason unrelated to the study and were then randomly assigned to one of two shot placement groups. Heads in the first group (n = 7) were shot at the intersection of two lines drawn from the medial canthus to the opposite horn or top of the opposite ear. Heads in the second group (n = 8) were shot at the intersection of two lines drawn for the lateral canthus to the opposite horn or top of the opposite ear. The guns were held perpendicular (as assessed visually) to the plane of the forehead. Shot placement was then assessed using computed tomography and disruption of the brainstem was determined. In the first group, the captive bolt failed to disrupt the brainstem in any of the heads. In the second group, the bolt disrupted the brainstem in 6 of 8 heads. The results suggest that selecting a higher shot location leads more readily to disruption of the brainstem which reduces the risk of regaining sensibility and should therefore improve animal welfare when cattle are euthanised with a penetrating captive bolt.

Keywords: *animal welfare, captive bolt, cattle, computed tomography, euthanasia, shot placement*

Introduction

Humane euthanasia of cattle presents special challenges to the beef and dairy industries. Euthanasia is necessary in cases of disease or injury that are impossible or impractical to treat, in cases of prolonged recumbency, when the condition of the animal is not suitable for human consumption and occasionally for diagnostic purposes. Additionally, euthanasia of large numbers of animals may be warranted in cases of an infectious disease outbreak. There are three practical options available to producers and/or veterinarians for euthanising cattle (AVMA 2007). These options include anaesthetic (barbiturate) overdose, captive-bolt shot, or gunshot. While each of these options is effective, each has its own pros and cons.

Expense, lack of access for producers, and the concern of environmental contamination from chemical residues in the carcase make barbiturate overdose impractical in most cases of on-farm euthanasia. Additionally, injectable euthanasia requires excellent animal restraint and close contact with the animal. All of these concerns make injectable euthanasia impractical in a mass depopulation situation.

Gunshot is effective when properly applied, does not require restraint or close contact with the animal, and could be effective for mass depopulation. However, obvious safety concerns exist for the operator, bystanders, and other animals. Additionally, appropriate use of gunshot requires a certain level of operator skill and legal issues concerning firearm use may arise in some areas.

Traditional captive-bolt guns are used routinely to stun animals in commercial slaughter facilities. When used properly, they may be effective tools for euthanising cattle of various ages (Gardner 1999; Shearer 2005). Concern as to whether a penetrating captive bolt produces permanent insensibility has led to the general recommendation that captive-bolt shot be followed by a secondary method to ensure death (Thurmon 1986; AABP 1999; Shearer 2005). Recommended methods include exsanguination, pithing, or potassium chloride injection (Gardner 1999; Shearer 2005). The need to follow a captive-bolt shot with a secondary method to ensure death increases the time, labour, and expense of euthanasia and the need exists for a captive-bolt system that will effectively and humanely euthanise cattle of various ages without the need of a secondary step to ensure death.

The initial goal in euthanasia is to induce unconsciousness so that an animal is insensitive to noxious stimuli or stress (AVMA 2007). Ideally, death occurs rapidly following loss of consciousness. Unconsciousness may be induced instantaneously from concussive forces applied to the brain (Gregory & Shaw 2000). When using a penetrating captive bolt, the concussive forces applied to the skull, rather than physical penetration of the brain, are thought to be the primary cause of immediate loss of consciousness (Daly & Whittington 1989). Level of consciousness is controlled by both the cerebral cortex and brainstem (Gregory & Shaw 2000). While concussive interference with cerebral and brainstem functions results in instantaneous loss of consciousness, the resulting insensibility may not be permanent. Physical disruption of both of the cerebral cortex and brainstem should lead to permanent insensibility and subsequent death.

When using a captive-bolt gun, shot placement is critical. The current recommendation is to place the shot at the intersection of two imaginary lines drawn from the inside corner (medial canthus) of the eye to the opposite horn or just above the opposite ear (AABP 1999). Work performed independently by several researchers (Gilliam *et al* unpublished data) has suggested that this shot placement is not ideal for euthanasia purposes because it does not readily lead to physical disruption of the brainstem which could lead to the regaining of some level of sensibility. This preliminary work has shown that placing the shot higher on the forehead provides maximum opportunity to disrupt both the cerebral cortex and brainstem as long as penetration depth is adequate.

The Cash Special Euthanizer® (Accles and Shelvoke, Sutton Coldfield, West Midlands, UK) system is a pistol-style captive-bolt gun designed specifically for on-farm euthanasia of a variety of livestock species. The system accommodates a variety of both penetrating and non-penetrating bolts, allowing the bolt type to be matched correctly with the type of animal being euthanised. Five power loads of various strengths are also available to allow matching of the appropriate power load to the animal being euthanised. The Cash Special Euthanizer Kit® has been validated as a primary euthanasia tool for mature swine (Woods & Hill unpublished data).

Preliminary research (Gilliam unpublished data) has suggested that the Cash Special Euthanizer® can be used alone to effectively and humanely euthanise adult cattle when the designated power load is used and the shot placement is adjusted to ensure that both the cerebral cortex and brainstem are disrupted.

This study has two primary goals. The first is to determine and document the most appropriate shot placement to optimise disruption of both the cerebral cortex and brainstem in cattle of various ages. The second is to validate the use of the Cash Special Euthanizer Kit® for the euthanasia of cattle in a clinical setting.

The data presented in these proceedings are from preliminary work performed to determine the optimal-shot placement that would provide the best chance of disrupting both the cerebral cortex and brainstem. This study is ongoing with additional data to be generated.

Materials and methods

Equipment

The captive-bolt equipment used in this study consisted of a heavy duty .25 Cash Special with a long bolt. The power loads used consisted of blue (3.25 grain) and orange (3.75 grain) loads. The equipment and power loads were provided by Bunzl Processor Division (Bunzl Processor Division, North Kansas City, MO, USA).

Study animals

Heads (n = 15) were collected from animals that were being euthanised for another reason or from natural mortalities. Animals with suspected brain disease were excluded. Heads were classified as being adult (> 2 years of age) or young (6–12 months of age). The heads were frozen until use, at which time they were allowed to thaw at room temperature for approximately 36 h.

Study protocol

Each head received a single shot from the .25 Cash Special captive bolt. The heads were randomly assigned to one of two shot placement groups, a control group (designated as 'standard' shot location) and a treatment group (designated as 'alternate' shot location). The standard shot location was defined as the intersection of two lines drawn from the medial canthus (inside corner) of the eye and the opposite horn or just above the top of the opposite ear in polled cattle. The alternate shot location was defined as the intersection of two lines drawn from the lateral canthus (outside corner) of the eye and the opposite horn or just above the top of the opposite ear in polled cattle.

The heads were restrained in a commercially available head table (Fore-most Livestock Equipment, Hawarden, IA, USA) to prevent movement of the head during the shooting procedure. Lines, as described above, were projected onto the heads using commercially available laser levels (Black & Decker, New Britain, CT, USA). The captive bolt was placed in contact with the head at the intersection of the two lines and held perpendicular (as assessed visually) to the plane of the forehead. Heads from adult and young cattle were shot using orange and blue power loads, respectively, as per the manufacturer's directions (Accles and Shelvoke).

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Each head then underwent computed tomography (CT) to allow for mapping of the bolt path. Both sagittal and transverse views of the scans were evaluated. Evaluations were performed independently by two veterinary radiologists who were blinded to the shot placement groups. In addition to the views described above, digital 3D reconstructions were created for each skull to allow evaluation of the shot placement relative to bony landmarks.

The primary purpose of the CT evaluation was to determine objectively if both the cerebral cortex and the brainstem were disrupted by a given shot. To accomplish this goal, the radiologists were asked a series of four questions. For the sagittal views, they were asked if the bolt path was caudal to the presphenoid bone and if the bolt path penetrated deep to the level of the third ventricle. For the transverse views, they were asked if the bolt path was within 1.5 cm of midline and if the bolt path penetrated deep to the level of the third ventricles. For this purpose, the bolt path was defined as a clearly visible channel created by the bolt or by bone fragments pushed into the brain by the bolt. In order for a shot to be considered successful, each of the four questions above had to be answered 'yes'. All of the CT scan evaluations were performed using commercially available software (Efilm, Hollywood, CA, USA).

Penetration depth was determined by measuring the distance from the skin surface to the dorsal aspect of the deepest bone fragment. This measurement was only performed for heads in which the bolt directly penetrated the brain. For comparison, the maximum possible penetration was determined by shooting the bolt into ballistic gelatin and measuring the depths of the channels. The ballistic gelatin was made from a recipe found online (http://www.myscienceproject.org/gelatin.html). A total of five shots each with both blue and orange power loads were performed.

Following the CT scan, the brains were removed from the skulls intact and fixed in 10% formalin for at least one week. Once fixed, the brains were assessed for direct physical injury and assigned a traumatic brain injury score (TBI). The scoring system was modified from that published by Millar and Mills (2000). The TBI scores were assigned by a veterinary pathologist who was blinded to both the shot placement and CT findings. The regions of the brain evaluated included the cerebral cortex, thalamus, cerebellum, pons, medulla, and third ventricles. The scores were as follows: 0 = grossly normal; 1 = partial disruption; and 2 = severe disruption/complete destruction characterised by direct penetration of the bolt and/or bone fragments pushed by the bolt.

Statistical analysis

The data from the CT scans consisted of categorical data and was analysed using the Fisher's exact test due to the small sample size. Average penetration depth for the blue and orange power loads were compared using the student's *t*-test. All calculations were performed in Microsoft Excel® 2007. The level of significance was set at $P \leq 0.05$.

Figure 1

Shooting Position

		Alternate	Standard
Brainstem Disruption	Yes	6	0
	No	2	7

$P = 0.007$

Results of Computed Tomography Assessment. Brainstem disruption relative to two different shooting positions.

Results

This preliminary study included heads from fifteen animals. Nine of the animals were adults with age ranging from 2–8 years of age. All of the adult cattle were female. Breeds were as follows: Holstein (5), crossbred beef (2), Angus (1), and Beefmaster (1). The reasons for death were as follows: not recorded (5) and lymphosarcoma (1), calving paralysis (1), pneumonia (1), and coxofemoral luxation (1). Six of the animals were young with age ranging from 6–12 months. All of the young animals were crossbred beef steers that died of pneumonia.

The 'standard' shot placement group included seven animals (four adult, three young) and the 'alternate' shot placement group included eight animals (five adult, three young).

Placing the shot at the higher 'alternate' position resulted in brainstem disruption significantly more frequently than when the shot was placed in the 'standard' position (Figure 1). Six of eight shots in the 'alternate' group disrupted the brainstem while none of the shots in the 'standard' group resulted in brainstem disruption.

Maximum penetration depth determined by shooting into ballistic gelatin averaged 8.36 (± 0.19) and 8.52 (± 0.13) cm for the blue and orange power loads, respectively. Average penetration depth for the eight heads in the 'alternate' group was 8.05 (± 1.06) cm (range 7.1–10.4 cm). Since the 10.4 cm measurement was greater than the maximum obtained from the ballistic gel, this value was excluded. The adjusted average penetration was 7.7 (± 0.51) cm.

The process of assigning TBI scores did not result in valid data. Fourteen of the fifteen brains received the highest possible score for the cerebral cortex. However, the bolt failed to hit two of these brains at all and in the other five 'standard' group heads, the bolt barely fractured the extreme rostral end of the cranial vault.

Discussion

The 15 animals in this study were of various breeds and ages. It is difficult to draw conclusions from such a small data set but this study did make some significant findings. Moving the captive-bolt shot to a higher location increased significantly the chances of disrupting the cerebral cortex and the brainstem compared to when heads were shot in the currently recommended position. While this alternative-shot placement should improve the effectiveness of the captive bolt as a single-step euthanasia method, brainstem disruption was not achieved in two of the heads in that group. In order to be comfortable with this euthanasia method, brainstem disruption needs to be achieved at a much higher rate. This study only assessed the presence or absence of gross physical disruption and did not assess disruption that might occur at the microscopic level in a true euthanasia setting.

The depth of penetration achieved in this study was close to the maximum possible for the equipment based on our ballistics gel findings. The 10.4 cm depth of penetration achieved in one head is difficult to explain and warrants further investigation. One possible explanation is that moving the head onto the CT table may have caused the bone fragment to move beyond where it had been pushed by the bolt. Alternatively, the determination of maximum depth of penetration in the ballistics gel may not have represented the true maximum potential of the equipment.

Adjusting the shot location to an even higher position might result in more consistent physical disruption of the brainstem. However, more research needs to be performed before such a recommendation can be made. Appropriate external landmarks need to be identified, the impact of thicker bone and sinus on bolt speed and penetration need to be investigated and potential concerns about inadequate depth of penetration would also need to be investigated.

The reasons for the failure of the traumatic brain injury scores in this study are not exactly known. While the technique has been validated by other studies, (Millar & Mills 2000; Woods & Hill, unpublished data) the brains assessed in those studies were from live animals that had been shot with a captive bolt or bullet. This would allow assessment of gross and histopathologic changes in the brain tissue while minimising artefacts. The brains in this study had been frozen for variable amounts of time and been thawed at room temperature prior to being shot. Additionally, the time from death of the animal to freezing may have been too long in some cases. Further work needs to be done to assess the validity of TBI scoring on cadaver specimens.

Conclusion

This small study clearly demonstrates the advantages of a higher shot location relative to the ability to cause physical disruption of the brainstem using the Cash Special captive bolt. While the ideal position has yet to be determined, the advantages of a higher shot position are clear. At the time of writing, work on this project is continuing to further define the ideal shot placement for captive-bolt euthanasia and to investigate the influence of factors such as age, head shape, and the presence or absence of horns on the ideal shot placement.

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