

# Comparison of frontal-sinus and poll shot locations as secondary methods for euthanizing dairy cattle with a penetrating captive bolt gun

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## Abstract

Humane euthanasia is a crucial component of dairy farm animal welfare programs. When using either a gunshot or captive bolt, the frontal-sinus area is well established as the primary shot location, but a secondary shot is often used as well. The objective of this study was to evaluate the efficacy of 2 different secondary shot locations. Cattle from a commercial dairy operation (n = 44) were randomly assigned to receive a secondary shot in the frontal-sinus or poll location and clinical signs of consciousness were assessed. A subsample of adult cattle heads (n = 6) were also evaluated to assess the extent of trauma. With the exception of heartbeat, all signs of sensibility were absent immediately following the first frontal-sinus shot and remained absent until confirmation of death, regardless of treatment ( $P > 0.05$ ). Relatively fewer animals shot in the poll location had a heartbeat 5 min after being shot ( $P = 0.03$ ). Pathology results on the subsample of adult cattle showed poll shots rarely penetrated beyond the cerebrum and only 1 of 6 animals had a severed brainstem. We conclude the frontal-sinus and poll locations are similarly effective secondary shot locations, and brainstem damage may not be necessary for irreversible insensibility and death.

**Key words:** euthanasia, anatomical landmarks, animal welfare, captive bolt gun, death, humane

## Introduction

Effective and practical forms of euthanasia are an ethical imperative for the cattle industry, including dairies. Many dairy operations utilize a penetrating captive bolt gun (PCB) for euthanasia. According to the American Veterinary Medical Association (AVMA) Guidelines on Euthanasia, use of PCB is classified as “acceptable”, provided it is followed by a secondary method such as pithing, exsanguination, injection (i.e.

potassium chloride) or the application of a second PCB shot.<sup>11</sup> The requirement for a secondary step appears to be based on data showing 0.2% to 1% of animals shot with a pneumatic PCB in a slaughter facility showed clinical signs indicating a possible return to consciousness after a single shot.<sup>7</sup>

For both practical and aesthetic reasons, many dairy farms elect to utilize an additional PCB shot as their preferred secondary method. Although the location of the primary PCB shot in the frontal-sinus location is well established,<sup>12</sup> practical experience suggests placement of the second shot may vary between the frontal-sinus location (a second time), or the poll location (midline at the external occipital protuberance), in an effort to cause more extensive brain damage and minimize risks associated with using pharmaceuticals for euthanasia.

Recently, however, interpretations of the AVMA Guidelines for the Euthanasia of Animals have called into question the use of the poll location.<sup>11</sup> Furthermore, the American Association of Bovine Practitioners (AABP) Guidelines for the Humane Euthanasia of Cattle warn against using the poll position, stating “research has shown that the depth of penetration and concussion in this region is less than that observed with frontal sites. Furthermore, research indicates that the use of penetrating captive bolt at the poll is prone to operator error and misdirection of the bolt into the spinal cord instead of the brain”.<sup>1</sup>

Unfortunately, the evidentiary basis of these positions, as well as their generalizability to diverse contexts, appears questionable. Data used to support these policy positions are drawn from 2 descriptive studies involving sheep<sup>4</sup> and water buffalo,<sup>8</sup> making their applicability to dairy cattle uncertain. More importantly, the policy statements described above do not differentiate between using the poll shot as a primary vs secondary method, and we are not aware of any studies (in any species) comparing the efficacy of different secondary PCB shot locations.

To help address this gap in the literature, and provide empirical data to support decision making, we conducted a study utilizing a combination of clinical assessment and post-mortem pathology to compare the efficacy of PCB secondary shot locations in a commercial dairy farm setting.

### Materials and Methods

This trial was conducted at a large commercial dairy operation located in the Southwest US during the week of May 1 through 5, 2021. Animals enrolled in this study consisted of female Jersey X Holstein cattle, representing a variety of age groups (calves, heifers, and cows). Animals from multiple age groups were included to mimic actual dairy farm practice where euthanasia procedures are typically the same regardless of life stage. Enrolled animals were selected for euthanasia by trained farm workers according to standard farm protocol emphasizing prompt euthanasia of animals in distress and/or unlikely to recover. Animals selected for euthanasia were randomly assigned to 1 of 2 treatments using the Excel random number generator. Formal power analysis was not conducted because there were no other previous studies comparing the efficacy of different secondary shot locations from which to base effect size calculations.

Per standard farm protocol, the first shot was always applied in the frontal-sinus location for all animals (i.e. a point on the midline of the face that is halfway between the top of the poll and an imaginary line connecting the outside corners of the eyes), regardless of treatment. The PCB muzzle was placed flush, perpendicular to the skull and aimed rostrally toward the intermandibular area. The reason for euthanasia was recorded in Dairy Comp 305<sup>a</sup> by the attending farm worker according to standard farm protocol.

Animals identified for euthanasia were first sedated with xylazine hydrochloride<sup>b</sup> (0.91 mg/lb [2 mg/kg]), IM once.<sup>11</sup> After 5 minutes (min), animals were haltered and the head was tied off to a back leg (Figure 1). The first PCB shot was then administered in the frontal-sinus location and the halter was removed.

Placement of the second shot differed between treatments. In FRONT-FRONT treatment, the second shot was applied to the frontal-sinus location a second time, but slightly higher and displaced to the side.<sup>2</sup> In FRONT-POLL treatment, the second shot was applied in the poll position (midline at the external occipital protuberance) at an angle aiming toward the base of the tongue. All euthanasia procedures were carried out by trained farm personnel using 1 of 2 Jarvis HD Long bolt<sup>c</sup> (PAS 4144132; bolt length = 5.88 inches [14.9 cm]; shaft diameter = 0.45 inches) with orange charges (Jarvis .25 cal./3.5 grain). PCB guns were thoroughly cleaned prior to data collection.

Assessment of clinical signs of consciousness began immediately following the first shot (min 0-1), and then continued nearly continuously after the second shot (min 1-2) until death was confirmed. All clinical observations and



**Figure 1.** Example of how cattle were restrained for PCB euthanasia.

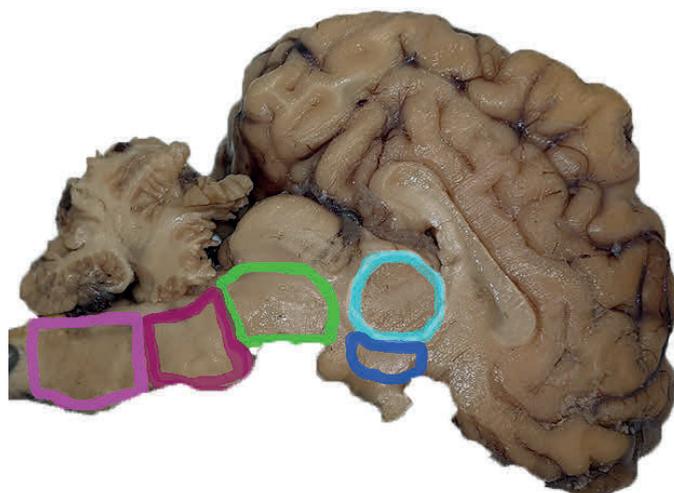
data collection were conducted by 2 observers (RW and JR). Clinical signs and definitions used to assess consciousness were drawn from previously published research provided in Table 1.

Motor movements (i.e., leg kicking, spasms) were not assessed as these are considered less valid indicators of consciousness.<sup>13</sup> Tongue reflex was initially included, but was quickly discontinued as it proved exceedingly difficult to assess in recumbent and haltered animals. Confirmation of death occurred after an animal ceased to show any clinical signs for a period of 5 min. After death was confirmed, shot accuracy was visually assessed and marked on a template of a cow head. After death was confirmed all cattle carcasses were rendered according to standard farm procedure and in accordance with all local, state, and federal regulations.

The cost associated with preserving, shipping, and analyzing heads limited the number available for analysis, so we focused on assessing a small subsample of 6 adult cattle heads (3 from each treatment). Adult cattle were selected because they provided the strongest test of shot placement effects due to their thicker skulls. Heads from adult cattle were randomly selected, disarticulated at the atlanto-occipital joint, and sent out for evaluation by a veterinary pathologist to assess the extent of intracranial trauma. Heads arrived at Iowa State University Veterinary Diagnostic Laboratory frozen, and were allowed to thaw in a cooler for 3 d before being skinned, then split mid-sagittally with a bandsaw. Trauma was evaluated with brain *in situ* and *ex situ* using a modified scoring system based on Derscheid et al.<sup>5</sup> Each of the following anatomical portions of the brain were scored according to the following 0 to 3 scale: 0 = tissue is not disrupted, 1 = mild, limited to less than 25% of the region affected, 2 = moderate, 25 to 75% disruption, 3 = severe, 75% or more destruction. Anatomical portions scored included cerebrum, cerebellum, thalamus, hypothalamus, midbrain, pons, medulla oblongata, and spinal cord and are represented in Figure 2.

**Table 1.** Clinical signs of consciousness and death. All signs assessed as binary outcome 1 = yes/present; 0 = no/absent.

Threat response	Blinks/responds when hand is waved near eyes
Corneal reflex	Blinks when gently touching cornea with finger
Palpebral reflex	Blinks when dorsal eyelid is gently stroked with finger
Spontaneous, natural blinking	Eyes move/blink like a sensate animal
Pain response	Responds to pinch with forceps to nostril
Rhythmic breathing	Thorax/rib movement indicates regular rhythmic breathing OR air felt when hand placed in front of animal's muzzle
Righting reflex	Animal attempts to remain in initial standing or sitting position
Vocalization	Animal bawls, bellows, or makes other intentional sounds
Heartbeat	Consistent, rhythmic heartbeat can be heard using stethoscope



**Figure 2.** Subgross anatomy of the brain, sagittal section. Regions of the brain indicated by outline in the following colors: thalamus, hypothalamus, midbrain, pons, medulla oblongata.

## Results

A total of 44 cattle were euthanized during the week of data collection and were included in this study (FRONT-FRONT, n = 20; FRONT-POLL, n = 24). Average age of animals was 242 d ± 177 (range 14 to 625 d). The primary reason for euthanasia was pneumonia (73% of animals). All shot locations were deemed “ideal” based on visual inspection.

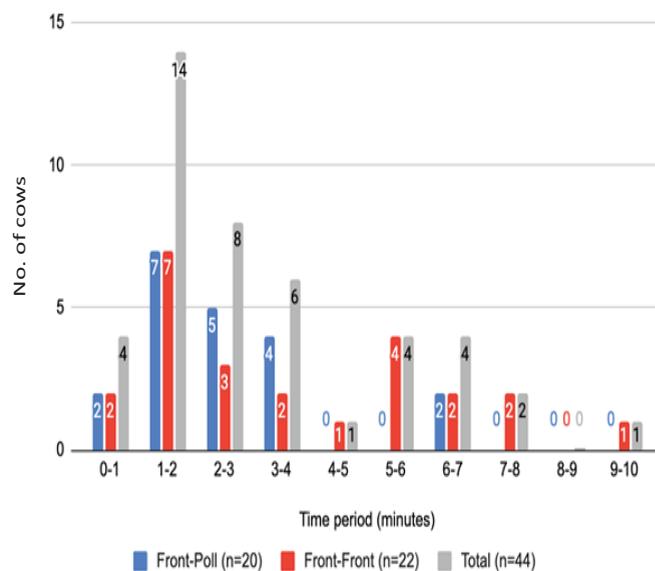
With the exception of heartbeat, all clinical signs of consciousness for all cattle in both treatments (n = 44) were absent immediately following the first frontal-sinus shot and remained absent until confirmation of death. The proportion of all animals with an auscultable heartbeat decreased linearly from the time of the first shot. To test for treatment differences in heartbeat data, each time period was collapsed into a dichotomous variable based on whether each animal's last auscultable heartbeat occurred during min 1 through 5 or > 5 min after the second shot. Cattle lacking a heartbeat in the 0 to 1 min time period were excluded (n = 4) from this analysis as the secondary shot (treatment) occurred immediately after this time period. Chi-square analysis showed heartbeat was associated with secondary shot location, with relatively fewer

animals having a heartbeat after 5 min in the FRONT-POLL treatment ( $\chi^2 = 4.4$ , df = 1;  $P = 0.03$ ; Figure 3). Treatment differences remained after including age as a covariate in a logistic regression model comparing treatments ( $P > 0.05$ ).

Descriptive pathology assessment of the subset of 6 adult heads (3 from each treatment) showed autolysis was minimal. All 6 animals had similar trauma scores for the cerebrum (2), partially due to the volume of this region and direct path from either frontal or poll location. The thalamus was damaged in 4 of 6 animals; the cerebellum was damaged in 3 of 6 animals; and midbrain were damaged in 4 of 6 animals. The brainstem was severed in only 1 animal (431581; FRONT-FRONT). Based on perceived trajectory, poll shots typically only damaged the cerebrum (Figure 4).

## Discussion

This study provides the first data comparing different secondary methods of PCB euthanasia in an on-farm set-



**Figure 3.** Number of cattle (n=44) who lacked an auscultable heartbeat by treatment and time period. Secondary shot occurred between the 0 to 1 min and 1 to 2 min time periods.



**Figure 4.** Cow 425362; FRONT-POLL. Left hemisphere, brain *in situ* to demonstrate poll shot trajectory. Highlighted areas show poll shot and frontal-sinus shot locations.

ting. The consistency observed in the lack of clinical signs of consciousness suggests a frontal-sinus PCB shot followed by either a secondary frontal-sinus or a poll shot are both effective methods for euthanizing dairy cattle of various ages. The high level of shot accuracy in this study also suggests that concerns about operator error and misdirection can be effectively mitigated when animals are sedated and restrained, and when workers are trained and experienced in hitting proper anatomical locations.

The overall persistence of an auscultable heartbeat for 1 to 10 min in this study is within the range reported by other authors studying euthanasia of dairy and beef cattle of various ages.<sup>3,5,6</sup> Treatment did have an effect on the persistence of an auscultable heartbeat, with animals receiving the secondary shot in the poll location being less likely to have a heartbeat 5 min afterwards. This finding is consistent with the view that the secondary poll shot may be preferable to a secondary frontal-sinus shot.

Given the small sample of cadaver heads available for assessment, it is not possible to generalize results to our entire sample, let alone populations beyond this study. Despite the similar effectiveness of both treatments in eliminating clinical signs, postmortem assessment of 6 adult animals suggesting brainstem severing was rare regardless of treatment. This is consistent with Lambooy and Spanjaard who reported calves shot in the poll location immediately lost corneal reflex despite only having damage to their cerebellum.<sup>10</sup> More recently, Kline et al reported young beef steers and heifers shot with a pneumatic PCB in a slaughter facility were successfully rendered unconscious without evidence of brainstem disruption.<sup>9</sup> One possible explanation for these findings is that intracranial pressure and edema, rather than macroscopic brainstem damage, may be sufficient to cause respiratory and cardiac arrest. Such findings highlight the challenges of equating consciousness with specific brain regions.<sup>13</sup>

Caution should be exercised in extrapolating these results. Given all clinical signs of consciousness were absent immediately following the first frontal-sinus shot, our sample may have been too small to detect differences related to secondary shot placement. That said, the heartbeat data indicates the secondary poll shot was at least as effective (if not more effective) as the secondary frontal-sinus shot. Given the relatively small sample size of this study, additional research with larger samples and different breeds is needed to better understand effective and practical methods of euthanizing cattle on commercial dairy operations.

## Conclusions

Results of this study showed clinical signs of consciousness did not differ regardless of whether euthanized animals received a secondary frontal sinus or poll shot. Pathologic evidence on cadaver heads suggests brainstem damage was limited to midbrain or entirely lacking regardless of treatment, and thus may not be necessary for irreversible insensibility and death. However, cessation of heartbeat

**Table 2.** Trauma scores by anatomical location for individual animals (n = 6). Anatomical portions of the brain were scored according to a 0-3 scale, where tissue damage scoring: 0 = tissue is not disrupted, 1 = mild, limited to less than 25% of the region affected, 2 = moderate, 25 to 75% disruption, 3 = severe, 75% or more destruction. Color text for each region corresponds to Figure 2.

Animal ID	FRONT-POLL			FRONT-FRONT		
	218629	437116	425362	418756	431346	431581
Cerebrum	2	2	2	2	2	2
Cerebellum	0	0	1	1	0	1
Thalamus	3	1	1	0	1	2
Hypothalamus	3	0	0	0	1	0
Midbrain	1	3	1	0	0	3
Pons	0	0	0	0	0	2
Medulla oblongata	0	0	0	0	0	0
Spinal cord	0	0	0	0	0	0

tended to occur earlier when animals were euthanized with a secondary poll shot. The use of frontal-sinus or poll shot as secondary method of euthanasia in dairy cattle appears similarly effective in inducing rapid loss of consciousness and death in dairy cattle, regardless of age.

### Endnotes

<sup>a</sup> Valley Agricultural Software, Tulare, CA

<sup>b</sup> AnaSed<sup>®</sup> LA, xylazine hydrochloride 100 mg/ml, VetOne<sup>®</sup> MWI, Boise, ID

<sup>c</sup> Jarvis<sup>®</sup> HD Long bolt, Richlands, Queensland, Australia and Calgary, AB, Canada

### Acknowledgements

The authors wish to thank all the dedicated dairy farm workers for their assistance in carrying out this study.

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