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Effectiveness of a non-penetrating captive bolt for the euthanasia of piglets from birth to 9 kg

T.M. Casey-Trott[1]; R. Brooks[2]; P.V. Turner[1]; S.G. Nykamp[1]; M. Litman[1]; S.M. Millman[2]; T.M. Widowski[1]

[1]University of Guelph, Guelph, Ontario, Canada; [2]Iowa State University, Ames, Iowa

Introduction

On-farm euthanasia is a topic that every producer has to consider. When necessary, timely euthanasia offers both welfare and economic benefits. Low birth weight piglets are often recommended for euthanasia due to low pre-weaning and nursery survival rates (Smith et al., 2007). These higher mortality rates negatively impact the producer in lost feed costs and reduced value of the low quality pigs sent to market. Euthanasia of most piglets in this low birth weight category provides a greater chance of success for the remaining piglets, cuts feed and maintenance costs for the producer, and improves the overall finishing market value of the herd (Fix et al., 2010). Similarly, selecting out compromised piglets at weaning improves the overall welfare scores of the herd (Morrow et al., 2006). When done properly, euthanasia can free the animal from unnecessary suffering and allow for greater well-being within the group.

How do we know when a technique is humane?

The goal of any euthanasia is to minimize pain and distress of the animal (AVMA 2007); therefore, regardless of the technique chosen, the method should induce rapid, sustained unconsciousness until death. For most of the physical euthanasia techniques used on farms, such as blunt force trauma, captive bolt, or gun shot, unconsciousness can be monitored using brainstem and spinal reflexes until death is confirmed by the absence of a heartbeat (Erasmus et al., 2010).

The brainstem is the lower portion of the brain that controls sensory input to the higher centres in the brain, and therefore is necessary for an animal to be 'sensible' or conscious. The brainstem also controls the respiratory and cardiac centres, so that when the brainstem is no longer functioning and the animal has stopped breathing, we can be fairly confident that brain death has occurred and it is likely that cardiac arrest is imminent. Several of the cranial nerves that control reflexes of the eyes originate in the brainstem so they are useful for checking brainstem activity. These include the 'blink reflexes', specifically, the palpebral (related to the eyelid) and corneal reflexes that result in the animal blinking when their eyelid, lashes or cornea is lightly touched. The pupillary or 'light reflex' results in the pupil constricting when a light is shone in the eye. When pupils are 'fixed (not responding to light) and dilated', brain death has likely occurred.

Spinal reflexes are those that are related to sensation of pain, for example, when you quickly withdraw your hand after touching a hot or sharp object. Testing the spinal reflexes is also useful when assessing whether animals that have been administered a euthanasia technique are able to feel pain. The spinal reflexes of pigs can be tested by pinching a foot or lightly pricking their snout or anal area with a needle. If the pig flinches or pulls back, it may still be able to feel pain, and this indicates that the euthanasia method has not been effective.

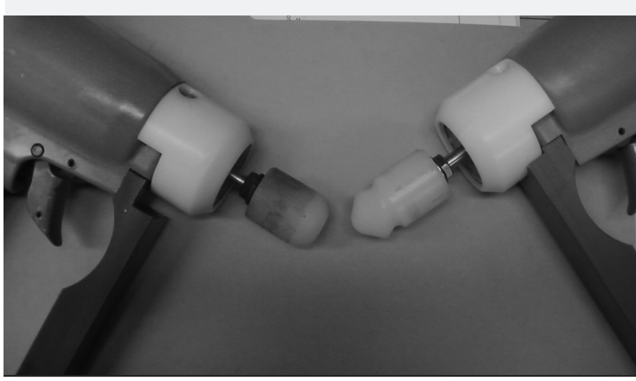
When physical contact with the animal is not possible and brainstem and spinal reflexes cannot be checked, behavioural indicators can be used assess whether the animal is conscious. When observing behavioural responses, it is important to differentiate between voluntary and involuntary movement. With all physical methods of euthanasia, involuntary neuromuscular spasms, or convulsions can be expected. There are two types of convulsions seen in pigs. Clonic spasms appear as flopping or semi-coordinated paddling movements of the legs; whereas tonic spasms consist of a period of rigid extension of the limbs. For piglets, the clonic phase occurs first followed by the tonic phase; however, the sequence can vary depending on the age of the animal. Gasping may also be seen in some animals, but it is not considered a sign of consciousness. Rhythmic breathing differs from gasping in that the motion involves a rhythmic inhale and exhale versus a spastic inhale from a gaping mouth. The righting reflex is a controlled attempt to balance itself or stand upright, possibly followed by deliberate escape attempts. Conscious animals may show rhythmic breathing, righting reflex, escape attempts, and vocalizations. If any of the above actions are present, the animal is considered conscious and the euthanasia technique needs to be reapplied.

While these general principles provide a good guide for assessing euthanasia, it is important to understand that there can be some exceptions. For example, if an animal is paralyzed before a euthanasia procedure – it might be able to still feel pain but not be able to move or withdraw its limb when checked with a painful stimulus. If checking the reflexes indicates that an animal is unconsciousness but their heart continues to beat, then a secondary euthanasia step is necessary. This is usually accomplished by exsanguination or 'bleeding out'. What is important here is that the animal remains unconscious – how long it takes for cardiac arrest to occur is less important because the animal is no longer able to experience pain or distress.

Our research

The overall objective of the project reported here was to test the effectiveness of a non-penetrating captive bolt (NPCB) for the euthanasia of piglets up to 9 kg. This followed up a previous study using a NPCB (the Zephyr) that gave variable results (Widowski et al., 2008). The shape and length of the nylon (bolt) head was modified to increase its effectiveness (Figure 1). The current study using the modified design was completed in two trials. Trial 1 tested the effectiveness of the NPCB on 100 low viability piglets < 72 hrs of age by monitoring signs of sensibility immediately following NPCB application until full cardiac arrest. Trial 2 applied the NPCB to twenty anaesthetized piglets, five in each of four weight classes (3, 5, 7, and 9 kg). Since this was a novel technique for larger piglets, they were anaesthetized prior to NPCB application to eliminate pain and distress if the technique was not effective. Due to the use of anaesthesia, the piglets were already unconscious and therefore signs of sensibility could not be observed; instead, duration of neuromuscular leg spasms (convulsions) and heartbeat were used to assess the effectiveness of the technique for causing death.

Figure 1: Comparison of the nylon bolt head attachments from the non-penetrating captive bolt. The flat-head attachment (left) was used in the initial Zephyr trials and produced variable results (Widowski et al., 2008). The conical attachment (right) increased the depth of depression to 9 mm and caused consistent insensibility without return to consciousness in neonates (Casey-Trott et al., 2010).



Post mortem analyses were completed in both trials using Computed Tomography (CT) scans, visual assessment and scoring of skull fractures and external brain hemorrhage, and histological analysis to assess and compare the degree of internal brain injury.

Methods

Ten stock people from four farms were selected for participation based on piglet and stock person availability. Each stock person euthanized ten piglets. Prior to euthanasia, each stock person was trained on how to use the NPCB. All piglets were non-viable, moribund or injured. Trial 1 piglets were < 72h of age and averaged 1.04 kg ± 0.03 (SE). In Trial 2 piglets weighed 3.0 ± 0.18, 4.84 ± 0.05, 7.15 ± 0.09, and 8.76 ± 0.12 kg. Trial 2 piglets were anesthetized with a mixture of ketamine (71.4 mg/ml), xylazine (14.3 mg/ml) and butorphanol (1.4 mg/ml) administered at a dosage of 0.2 ml/kg IM. The piglets were restrained and the NPCB was applied to the frontal bone between the eyes and fired twice in rapid succession, followed by one shot to the back of the skull behind one ear. Immediately following application, the newborns were assessed for signs of consciousness using brainstem and spinal reflexes. Clonic and tonic neuromuscular leg spasms were monitored along with the presence of breathing and heartbeat. Reflexes were repeatedly checked until the end of leg movements and the body was limp. A secondary step of exsanguination was used for piglets with sustained presence of leg convulsions or heartbeat for > 10 min. Time to full cardiac arrest was recorded when a discernable heartbeat was no longer present.

At necropsy, skull fracture and severity of hemorrhage was scored for all piglets to provide insight into the gross level of damage to the head and brain surface (macroscopic scores). Skull fracture (SK) was scored on a scale from 1-5 (1 = intact skull; 5 = full fragmented) and subcutaneous (SC), subdural-dorsal (SDD), and subdural-ventral (SDV) hemorrhage were scored on a scale from 1-6 (1 = no hemorrhage; 6 = complete coverage). Post-mortem CT scans and histological scoring were completed on 10 piglets from Trial 1 and 20 piglets from Trial 2. CT scans were scored by a veterinary radiologist. Hemorrhage severity (HS) was scored subjectively on a scale from 0-3: (0 = none, 1 = mild, 2 = moderate, 3 = severe). Fracture displacement (FD) was quantitatively determined by measuring skull fragment displacement (in mm) from the intact position. The brains from the piglets selected for CT scans were removed and fixed in 10% buffered formalin for 7 days for histological analysis. Histological analysis was used to detect damage deep within the brain. Sections were taken from the cerebral cortex, midbrain, and brainstem for each brain. These sections of the brain are responsible for consciousness. Slides were stained with hematoxylin and eosin followed by microscopic scoring completed by a veterinary pathologist. Subdural (SD) and parenchymal (P) hemorrhage scores were recorded on a scale from 0-4 (0 = none present, 1 = minimal < 5%, 2 = mild (up to 10%), 3 = moderate (up to 30%), 4 = severe (> 30%)) based on the amount of hemorrhage coverage.

Results

The NPCB was highly effective for the euthanasia of neonatal piglets based on immediate insensibility without return to consciousness of all 100 piglets. Neuromuscular leg spasms ceased within 229 sec (± 9.2 SE) and 94% of piglets reached full cardiac arrest within 438 sec (± 17.9 SE). The remaining 6 % required a secondary step due to a prolonged heartbeat or neuromuscular leg spasms. Macroscopic scoring results indicated that all 100 piglets exhibited moderate to severe hemorrhage and skull fracture damage. CT scan results showed moderate hemorrhage and skull fracture, with an average fracture displacement of 6.2 mm (± 0.7 SE). Microscopic scoring reported moderate to severe subdural hemorrhage and moderate parenchymal hemorrhage deep within the brain.

There was a tendency for some variation between stock people in time to end of leg spasms and ($P = 0.0704$) time to end of heartbeat ($P = 0.1073$). Subdural bleeding on the ventral surface of the brain (SDV) was the only damage assessment score to show significant variation between farms ($P = 0.0113$). SDD tended to vary across farms ($P = 0.0648$).

Trial 2 showed promising results for use of the technique on piglets up to 9 kg. Leg spasms ceased in 148 sec (± 12.4 SE) with all but one piglet reaching full cardiac arrest in 386 sec (± 23.2 SE). An alternative method (sodium pentobarbital 100 mg/kg) was required for the one piglet (2.5 kg) with a sustained heartbeat. A different piglet (8.7 kg) required an additional shot due to the presence of rhythmic breathing, possibly following a misfire. Breathing was absent in all other piglets and immediately ceased following the extra shot. Macroscopic scoring results reported moderate to severe hemorrhage in > 90% of piglets. CT scan results indicated mild HS but severe FD 9.4 (± 0.84 SE) mm. Microscopic results showed mild to moderate SD and minimal to mild P hemorrhage.

In comparison between the two trials, the end of leg spasms was longer in the neonates of Trial 1 compared to the larger piglets ($P < 0.01$). Although the average end of heartbeat was also longer in the neonates, it did not differ significantly ($P > 0.10$). When comparing the brain lesions between trials, overall hemorrhage was less severe in the anaesthetized piglets than in the neonates (Macroscopic scoring: SDV: $P < 0.001$; CT Scan: HS: $P = 0.001$; Microscopic scoring: SD: $P = 0.007$ and P: $P = 0.041$) despite a greater skull fracture displacement of 9.4 (± 0.84 SE) mm ($P = 0.019$). CT scan results also showed a positive linear relationship between piglet weight and fracture displacement ($P = 0.0017$), whereas the linear relationship between piglet weight and hemorrhage severity was negative ($P = 0.0113$).

Discussion

Although insensibility cannot be determined with 100% certainty, monitoring brainstem and spinal reflexes helps give direct insight into the state of vital brain centres responsible for consciousness. Using reflex monitoring as a tool during any euthanasia process can give the stock person greater confidence that the euthanasia has been carried out humanely.

In this study, the NPCB was highly effective for the euthanasia of neonatal piglets and is showing promising results for weaned piglets up to 9 kg. The modified bolt rendered all 100 neonates immediately insensible without returns to consciousness, a critical improvement from the early stages of this device. Despite minor variation between stock personnel, the technique reliably ensured a humane death within a reasonable amount of time. Leg spasms ceased in less than 4 minutes and even though the heartbeat continued for 7 minutes, often times the beats were faint and irregular. Although cessation of heartbeat is the final confirmation that death has occurred, death as a whole is a process. Achieving brain death is part of that process and is a clear indication that the brain has undergone irreversible damage and is progressing towards full cardiac arrest. The end of convulsions and a fixed and dilated pupil are believed to be visual indicators that brain death has occurred (Hills 2010).

The brain damage assessment provided further confirmation that the NPCB was successful. Moderate to severe macroscopic damage was reported in all neonates, and the degree of damage was reaffirmed by the CT scan and microscopic scoring results from a subsample of piglets. Subdural and parenchymal hemorrhage was reported by both the CT scan and microscopic scoring.

The anaesthetized, weaned piglets completed in Trial 2 showed similar results. The duration of leg spasms and heartbeat actually decreased in Trial 2, with spasms ceasing in 2.5 minutes and cardiac arrest achieved in 6.5 minutes. It is possible that the anaesthesia was responsible for this decrease; however, it is more likely that the thicker skulls of the weaned piglets allowed for a greater concussion and faster brain death. The decreased duration of heartbeat may also explain the decrease in hemorrhage reported in the post mortem damage assessment. Alternatively, the increased skull fracture and decreased hemorrhage seen in the weaned piglets may be a result of the dispersal of the kinetic energy from the bolt, suggesting that the brain damage is in fact less severe (Shaw 2002). Although hemorrhage was less severe in the anaesthetized piglets, the NPCB was capable of inducing full cardiac arrest in both trials; therefore, suggesting that the method is causing sufficient subdural and parenchymal hemorrhage to disrupt critical brain function and cause death. The technique appears to be effective for the euthanasia of piglets up to 9 kg; however, the negative linear relationship between weight and hemorrhage, as weight increased hemorrhage decreased, and the positive linear trend between weight and skull fracture, as weight increased skull fracture increased, suggest that the NPCB may not be acceptable for piglets outside of this weight range.

A third trial is currently underway, testing the effectiveness of the NPCB on conscious piglets up to 9 kg. Signs of sensibility will be monitored as well as the presence of leg spasms, breathing, and heartbeat. Post-mortem damage assessment will be completed as in Trial 1 and Trial 2.

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