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Technical contribution: evaluation of the efficacy of a non-penetrating captive bolt to euthanase dairy goat kids up to 30 days of age

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Abstract

*The objective of this study was to evaluate the effectiveness of a non-penetrating captive bolt (NPCB) to euthanase previously disbudded Saanen dairy goat kids (*Capra hircus*) up to 30 days of age and 9 kg bodyweight. Goats were euthanased by placing the muzzle of the NPCB behind the poll between the ears with the goat's head bent so its chin was touching its chest. The NPCB was either fired once (Experiment 1; n = 30) or twice in quick succession (Experiment 2; n = 103). Immediately after application of the NPCB and every 30 s thereafter, signs of sensibility (presence of brainstem reflexes) were assessed together with the presence of cardiac activity, convulsions and rhythmic respiration, until cardiac activity ceased. In Experiment 1, 27 of the 30 goat kids were rendered immediately insensible and remained insensible until cardiac activity ceased; brainstem reflexes (the blink reflex) and rhythmic respiration remained present in three of the animals after application of the NPCB. In Experiment 2, all goat kids were rendered immediately insensible without return to sensibility prior to cessation of cardiac activity and death. In conclusion, applying the NPCB twice in close succession, behind the poll between the ears with the goat's head bent so its chin was touching its chest, reliably caused immediate and sustained insensibility followed by death in Saanen goat kids up to 30 days of age and 9 kg bodyweight.*

Keywords: *animal welfare, behaviour, euthanasia, goats, insensibility, non-penetrating captive bolt*

Introduction

In livestock production systems, occasions arise where individual animals are killed to reduce suffering (euthanasia) or because they have little or no economic value (culling); for simplicity, the term euthanasia will be used throughout this manuscript. Whether for culling or euthanasia, farmers need to identify and euthanase animals as soon as possible to prevent any potential suffering. Manual blunt force trauma (BFT) is the method most commonly used for euthanasia of neonatal goats (*Capra hircus*) (kids). If performed correctly, BFT causes severe damage to the central nervous system resulting in immediate and sustained insensibility and death. However, limitations of manual BFT are that it can be difficult to apply consistently, its effectiveness is reliant upon the strength of the operator performing the procedure, and it is unpleasant for operators to carry out. In contrast, methods of mechanically controlled BFT, such as a penetrating (PCB) or non-penetrating captive bolt (NPCB), can consistently deliver an appropriate and uniform amount of force resulting in more consistent structural damage to the brain (American Veterinary Medical Association [AVMA] 2013).

The NPCBs are aesthetically advantageous over PCBs because they cause less external damage. Efficacy of purpose-built NPCBs have been demonstrated for euthanasing 4 to 5 week old lambs (Finnie *et al* 2000), pigs less than three days of age (Casey-Trott *et al* 2013), pigs weighing 3–9 kg (Casey-Trott *et al* 2014) and turkeys (Erasmus *et al* 2010a,b). Recently, our research team has shown that the NPCB is an effective method of euthanasia for kids up to 48 h of age (3.9 [± 0.60] kg) (Sutherland *et al* 2016). Effectiveness of NPCB for euthanasia of older kids is unknown. However, bodyweight of 30 day old dairy kids is similar to the 9 kg pigs examined by Casey-Trott *et al* (2014) and corresponds with live weight at slaughter for milk-fed meat goat kids (Arguello *et al* 2005). Therefore, the objective of this study was to evaluate the effectiveness of an NPCB to euthanase dairy kids up to 30 days of age (or approximately 9 kg).

Materials and methods

The study was conducted between July and August (southern hemisphere winter) 2015 at the AgResearch Ruakura research facility in New Zealand. All procedures involving animals were approved by the AgResearch Ruakura Animal Ethics Committee (#13588) under the New Zealand Animal Welfare Act of 1999. The study animals were sourced from two commercial farms and identified for euthanasia.

At approximately 48 h of age, goats were transported from two commercial farms to the AgResearch Ruakura research

Figure 1

Optimum anatomical placement and head position of the non-penetrating captive bolt placement to achieve immediate insensibility and death in goat kids (image created by Chelsea Dela Rue).

farm. Kids were group-housed and reared in pens with floors bedded with untreated wood-shavings. Kids were fed Anlamb milk replacer (Fonterra Ltd, Auckland, New Zealand) twice daily at 0800 and 1600h and feeders remained in the pens after feeding time providing *ad libitum* access to milk replacer. Kids also had *ad libitum* access to hay, pellets and water. Since kids euthanased after 3 weeks of age on commercial dairy goat farms would likely have been previously disbudded as part of the farms routine husbandry practices, all kids were disbudded to control for possible anatomical differences associated with this procedure that could potentially affect the efficacy of the NPCB. Disbudding was performed at approximately 3 weeks of age, using an electric cautery iron ('Quality' electric debudder, 230 V, 190 W, Lister GmbH, Lüdenscheid, Germany).

The device used to euthanase all goats in the study was a cordless, propane-powered NPCB (TED, BOCK Industries Inc, Philipsburg, PA, USA). The mass of the NPCB bolt was 61.4 g and was released at a velocity of 30.1 m s^{-1}. The resulting energy produced by the NPCB bolt was 27.8 joules (R Bock, personal communication 2016).

In Experiment 1, 30 (female; n = 25, male; n = 5) Saanen-cross kids, with a mean (± SD) age of less than a month (28.4 [± 0.72] days), were weighed (females; 8.2 [± 0.99], males; 9.0 [± 1.89] kg), restrained and then euthanased using the NPCB. Kids were restrained in a purpose-built, portable, rigid, plastic restraint device, which had four holes through which the legs were placed and a firm surface to support the head. The restraint device was elevated so the legs of the animals hung down without touching the ground (Figure 1). The muzzle of the NPCB was positioned behind the poll, between the ears, with the kid's head bent so its chin was touching its chest as shown in Figure 1. This anatomical placement was chosen as it was shown to be the most efficacious in causing immediate and sustained insensibility in kids less than 48 h of age when using the same NPCB device (Sutherland *et al* 2016). The NPCB was fired once, and the procedure was performed by the same trained technician for all animals.

Every 30 s after application of the NPCB, goats were assessed for signs of sensibility (presence of brainstem reflexes), and the presence of cardiac activity, convulsions and rhythmic respiration, until cardiac activity ceased. Brainstem reflexes included corneal reflex and response to a nose prick. The corneal reflex involved touching the surface of the eye with a finger and observing if the animal blinked. To assess the response to a painful stimulus, a needle prick was applied to the kid's nose and the presence or absence of a withdrawal response was recorded. Presence of cardiac activity was determined by palpation; a technician placed their fingers on the goat's chest and felt for the presence of a heartbeat. Cessation of cardiac activity was declared when the technician could no longer feel any cardiac movement for 30 s or longer. The presence of rhythmic respiration and convulsions were monitored visually. Convulsions were defined as the appearance of clonic and tonic neuromuscular leg spasms (eg leg paddling and ridged leg extensions). Kids were monitored until death was confirmed which was defined as the absence of all signs of sensibility and cessation of cardiac activity. If any animal showed signs of sensibility at any stage after the initial application of the NPCB, the NPCB was applied a second time using the same anatomical placement to ensure insensibility and death.

In Experiment 2, 103 (female; n = 51, male; n = 52) Saanen-cross kids less than one month of age (28.1 [± 0.74] days) were weighed (females; 7.8 [± 1.18], males; 8.6 [± 1.14] kg), then placed in the restraint device. The NPCB was applied using the same anatomical placement as described in Experiment 1, but the NPCB was applied twice in quick succession. Every 30 s after application of the NPCB, kids were assessed for signs of sensibility using brainstem reflexes (eg corneal reflex and response to a nose prick) and the presence of cardiac activity, convulsions and rhythmic respiration as described in Experiment 1. After application of the NPCB, any animal showing signs of sensibility at any stage was administered an intramuscular overdose of xylazine (2% Xylaxine, Phoenix Pharm Distributors Limited, Auckland, New Zealand).

Data are descriptive only and presented as means (± SD).

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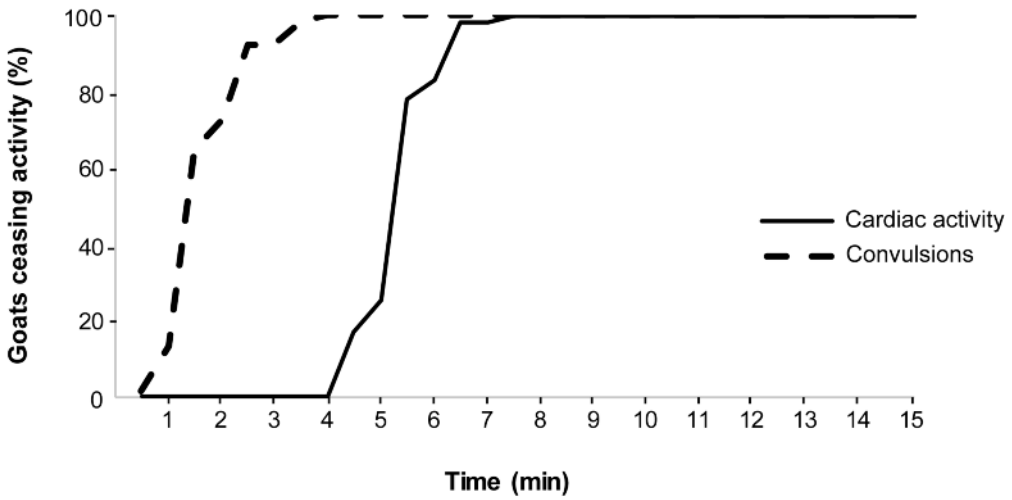
Figure 2



Cumulative percentage of goats (n = 103) ceasing cardiac activity and convulsions over time. Time-point 0 indicates the time immediately following application of the non-penetrating captive bolt.

Results and discussion

In Experiment 1, when the NPCB was applied once, only 27 of the 30 kids were rendered immediately insensible and remained insensible until cardiac activity ceased, resulting in a 90% success rate. The 12th, 26th and 30th animal displayed the presence of the corneal reflex and rhythmic respiration after application of the NPCB. Our previous research demonstrated a single application of the NPCB was associated with a 100% success rate for immediate and sustained insensibility followed by death when applied to kids less than 48 h of age and less than 4 kg bodyweight (Sutherland *et al* 2016). However, a single application did not produce reliable results when applied to 30 day old kids (up to 9 kg) in the current study based on the signs of recognition of a successful mechanical stun as stated by the European Food Safety Authority (EFSA 2004). Of the animals that maintained brainstem reflexes and/or rhythmic respiration after application of the NPCB, the NPCB was applied a second time using the same anatomical placement and head position, which resulted in immediate and sustained insensibility followed by death. This approach is consistent with Casey-Trott *et al* (2014), in which two NPCB applications in quick succession reliably resulted in effective euthanasia of pigs weighing 3 to 9 kg. Failure of the device to cause immediate insensibility was likely due to incorrect placement of the NPCB caused by operator error or the kid moving its head, however it was not possible to confirm this in the present study. The greater size of the 30-day kids compared to kids less than 48 h meant that they were more difficult to restrain which may have led to an increased risk of improper head placement. Therefore, based on the results from Experiment 1, we modified the standard operating procedure to state that the NPCB needed to be applied twice in rapid succession when used on kids between 48 h and up to 30 days of age (9 kg). Since the NPCB does not need to be reloaded prior to firing, successive shots are triggered within a second of each other.

When this modified standard operating procedure was used in Experiment 2, none of the 103 kids displayed rhythmic respiration or the presence of brainstem reflexes (corneal reflex or withdrawal from a painful stimulus) after the second shot was applied and prior to cessation of cardiac activity. The cumulative percentage of kids ceasing cardiac activity was categorised into 1-min intervals and plotted across time (Figure 2). The mean latency to cessation of cardiac activity was 5.2 (± 0.56) min (range: 4.1–7.1 min) and was similar between males (5.2 [± 0.47]) and females (5.3 [± 0.63] min). Conversely, we found latency to cessation of cardiac activity to be almost 3 min longer (approximately 8.2 min) when an NPCB was applied to kids less than 48 h of age (Sutherland *et al* 2016). Similarly, latency to cessation of cardiac activity was 7.0 (Casey-Trott *et al* 2013) and 8.7 min (Casey-Trott *et al* 2014) when NPCB was applied to pigs less than 3 days of age and between 3 to 9 kg, respectively. In the absence of rhythmic respiration, the brain becomes hypoxic, resulting in brain death within 4 to 5 min (Ganong 1993). Therefore, although cardiac activity continued for up to 7 min in some animals, it is likely that brain death had occurred and continuation of cardiac activity was due to stimulation from the autonomic nervous system independent of cerebral regulation (Cooper *et al* 1989).

In Experiment 2, mean latency to cessation of convulsions was 1.4 (± 0.63) min (range: 0.4–3.6 min). The cumulative percentage of kids ceasing convulsions was categorised into 1-min intervals and plotted across time (Figure 2). Time to cessation of convulsions was similar between males (1.5 [± 0.68]) and females (1.3 [± 0.56] min). These results are similar to other NPCB studies, in which the mean latency to cessation of convulsions was 2.7 (± 0.87) min in kids less than 48 h of age (Sutherland *et al* 2016) and mean duration of convulsion ranged from 3.4 to 3.8 min in neonatal pigs (Casey-Trott *et al* 2013, 2014). Although convulsions can be aesthetically unpleasant, they occur

when somatosensory-evoked responses are no longer controlled by the higher centres of the brain and hence are a sign of neurological impairment (Gregory 2005).

The current evidence from the present study suggests that a two-shot method is most efficacious, however it would be worth exploring if a more powerful charge would allow for a one-shot method, but this would require experimental verification. In addition, to further validate this as an appropriate method of euthanasia for kids up to 30 days of age (9 kg), it would be necessary to confirm immediate loss of sensibility and death using other measures of brain function including the measurement of additional brainstem reflexes (eg pupillary light reflex), the extent of traumatic brain injury and ultimately electroencephalogram as an indicator of loss of awareness. It would also be worthwhile to assess the effect of operator on the efficacy of this method.

Animal welfare implications and conclusion

This study demonstrated that an NPCB can be successfully used to euthanase disbudded Saanen dairy kids up to 30 days of age and 9 kg bodyweight. The standard operating procedure for NPCB when applied to kids of this age and weight category includes restraint with the kid's head bent and its chin touching the chest. NPCB must be placed at the back of the goat's head between its ears, and two shots fired in quick succession. To date, this technique has only been evaluated using disbudded kids of dairy breeds; effectiveness when applied to other breeds, larger bodyweights and horned kids is unknown.

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References

American Veterinary Medical Association 2013 *AVMA Guidelines for the Euthanasia of Animals: 2013 Edition*. https://www.avma.org/KB/Policies/Documents/euthanasia.pdf

Arguello A, Castro N, Capote J and Solomon M 2005 Effects of diet and live weight at slaughter on kid meat quality. *Meat Science 70*: 173-179. https://doi.org/10.1016/j.meatsci.2004.12.009

Casey-Trott TM, Millman ST, Turner PV, Nykamp SG and Widowski TM 2013 Effectiveness of a nonpenetrating captive bolt for euthanasia of piglets less than 3 d of age. *Journal of Animal Science 91*: 5477-5484. https://doi.org/10.2527/jas.2013-6320

Casey-Trott TM, Millman ST, Turner PV, Nykamp SG, Lawlis PC and Widowski TM 2014 Effectiveness of a non-penetrating captive bolt for euthanasia of 3-9 kg pigs. *Journal of Animal Science 92*: 5166-5174. https://doi.org/10.2527/jas.2014-7980

Cooper DKC, Novitzky D and Wicomb WN 1989 The pathophysiological effects of brain death on potential donor organs, with particular reference to the heart. *Annals of the Royal College of Surgeons of England 71*: 261-266

Erasmus MA, Lawlis P, Duncan IJH and Widowski TM 2010a Using time to insensibility and estimated time of death to evaluate a nonpenetrating captive bolt, cervical dislocation, and blunt force trauma for on-farm killing of turkeys. *Poultry Science 89*: 1345-1354. https://doi.org/10.3382/ps.2009-00445

Erasmus MA, Turner PV, Nykamp SG and Widowski TM 2010b Brain and skull lesions resulting from use of percussive bolt, cervical dislocation by stretching, cervical dislocation by crushing and blunt force trauma in turkeys. *Veterinary Record 167*: 850-858. https://doi.org/10.1136/vr.c5051

European Food Safety Authority 2004 Welfare aspects of the main systems of stunning and killing the main commercial species of animals. *The EFSA Journal 45*: 1-29

Finnie JW, Blumbergs PC, Manavis J, Summersides GE and Davies RA 2000 Evaluation of brain damage resulting from the penetrating and non-penetrating captive bolt stunning using lambs. *Australian Veterinary Journal 78*: 775-778. https://doi.org/10.1111/j.1751-0813.2000.tb10451.x

Ganong WF 1993 *Review of Medical Physiology, 16th Edition*. Appleton & Lange: Norwalk, Connecticut, USA

Gibson TJ, Johnson CB, Murrell JC, Hulls CM, Mitchinson SL, Stafford KJ, Johnstone AC and Mellor DJ 2009 Electroencephalographic responses of halothane-anaesthetised calves to slaughter by ventral-neck incision without prior stunning. *New Zealand Veterinary Journal* 57: 77-83. https://doi.org/10.1080/00480169.2009.36882

Gregory NG 2005 Recent concerns about stunning and slaughter. *Meat Science 70*: 481-491. https://doi.org/10.1016/j.meatsci.2004.06.026

Sutherland MA, Watson T, Johnson CB and Millman S 2016 Evaluation of the efficacy of a non-penetrating captive bolt to euthanase neonatal goat kids up to 48 hours of age. *Animal Welfare* 25: 471-479. https://doi.org/10.7120/09627286.25.4.471

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