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Topical anesthesia mitigates the pain of castration in beef calves[1]

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ABSTRACT: Castration involves the removal of the testes and is performed to improve product quality and management of male calves. The procedure has been proven to cause significant pain and stress, and despite several attempts to reduce the impact of castration on animal welfare, there has yet to be a practical and affordable option made available for farmer application. To address this issue, we conducted 2 trials (n = 18 and 27) to examine the efficacy of topical anesthetic Tri-Solfen (TA) to alleviate the pain of surgical castration. Angus bull calves (135.8 ± 5.7 kg) aged 3 to 4 mo were randomly allocated to 3 treatment groups, including surgical castration, castration in combination with TA, and uncastrated controls. In Trial 1, pain-related behavior was assessed using a customized numerical rating scale (NRS) over 4 h. In Trial 2, pre- and postoperative skin sensitivity of the wound and periwound areas was assessed using an electronic von Frey anesthesiometer (IITC Life Sciences, Woodland Hills, CA) and von Frey monofilaments (300 g). Sampling was repeated at 1 min and 2, 4, 6, and 24 h after castration. Pain threshold was measured as maximum pressure (g) exerted by the electronic anesthesiometer to invoke animal reflex, and responses to the von Frey monofilaments were scored from 0 to 3 using a NRS on the basis of local and central motor reflexes. Calves treated with TA displayed significantly less pain-related behaviors up to 3.5 h after castration than untreated calves (P < 0.001) and did not differ from uncastrated controls. Topical anesthetic–treated calves also exhibited significantly greater pain threshold of the wound (559.2 ± 14.3 g) and surrounding skin (602.8 ± 16.5 g) than untreated calves (446.0 ± 18.9 and 515.3 ± 20.4 g, respectively; P < 0.001). Control and TA-treated calves had significantly lower mean response scores to von Frey stimulation than untreated calves (0.333, 0.978, and 4.289, respectively; P < 0.001). Results indicate that TA effects rapid and prolonged pain alleviation in calves up to 24 h after castration. Topical anesthesia may present a cost-effective, practical, on-farm approach to pain alleviation and is proposed as a potential tool for reducing the welfare impact on the beef animal in routine husbandry procedures.

Key words: castration, electronic anesthesiometer, numerical rating scale, pain threshold, topical anesthesia, von Frey monofilaments

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INTRODUCTION

Castration of male calves is a routine husbandry procedure commonly performed without anesthesia or analgesia in cattle herds around the world. Castration has been well documented as painful (Molony et al., 1995; Fisher et al., 1996) but is considered necessary for economic, safety, and management reasons. There has been significant research into the use of local anesthesia and various analgesics to address the pain associated with castration (Fisher et al., 1996; Earley and Crowe, 2002; Stilwell et al., 2008; Coetzee, 2011). Although these options are effective, they fail to provide farmers with a practical and affordable option for incorporation into farm management. Huxley and Whay (2007) reported that for the majority of producers, the cost of analgesic agents was a significant issue deterring them from adopting such practices. Growing public concern about farm animal welfare makes it in-

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creasingly important to find more ethical and welfare-appropriate methods of conducting routine husbandry procedures. Incorporation of practical and affordable methods of pain relief into routine surgical procedures on farms is important for improving on-farm welfare.

Tri-Solfen (Bayer Animal Health, Pymble NSW, Australia) is a commercially available topical anesthetic (**TA**), hemostatic, and antiseptic agent for the alleviation of mulesing pain in sheep. It consists of lignocaine (40.6 g/L), bupivacaine (4.5 g/L), adrenalin (24.8 mg/L), and cetrimide (5.0 g/L) in a gel base. It has been reported that Tri-Solfen is effective in alleviating pain of mulesing, castration, and tail docking in sheep and improves wound healing (Lomax et al., 2008, 2010, 2013). Because of the efficacy of this TA for reducing surgical pain in lambs and the similar anatomical nature of the wounds, we hypothesized that a comparable effect would be seen in calves. Thus, this research examines the efficacy of TA for reducing the pain of castration wounds in beef calves.

MATERIALS AND METHODS

All animal procedures were conducted with prior institutional animal ethics approval in accordance with the National Health and Medical Research Council *Code of Practice for the Care and Use of Animals for Scientific Purposes*.

Husbandry of Calves

Two trials were conducted using Angus bull calves selected from a commercial herd in the Central Tablelands of New South Wales, Australia. Calves were 3 to 4 mo of age, born in the winter of 2008, with a mean initial BW of 135.8 ± 5.7 kg. Calves were randomly allocated to 1 of 3 treatment groups to compare calf responses with surgical castration with and without TA treatment to those of uncastrated controls. Control calves were handled in the same manner as castrated calves, where the scrotal sac was physically manipulated without surgery. On the day of each experiment, calves were separated from their mothers into a holding yard and weighed, ear-tagged and ear-notched, vaccinated, and placed in a calf cradle for treatment. The cradle used in these experiments was a swing-away squeeze chute that could be turned on its side to place the animal in lateral recumbency for the performing of procedures.

Method of Surgical Castration and Topical Anesthetic Application

Surgical castration was performed using a sterilized scalpel. An incision through the skin and testicular tunica was made from the base of the scrotum anteriorly (approximately 2.5 cm) to expose the testes. Each testicle was pushed through the opening in the scrotum, and the surrounding tunica was removed. The exposed spermatic cord was then severed with the knife approximately 12 cm proximal to the head of the epididymis. In groups receiving TA treatment, Tri-Solfen was applied to each of the exposed spermatic cords proximal to the site of incision, before the removal of the testis, by inserting the nozzle of the applicator (N.J. Phillips Australia F-grip 2-mL injector, Gosford NSW, Australia) along the length of each cord as far into the scrotum as possible. Three milliliters of TA were applied liberally to coat each spermatic cord and to ensure maximal coverage of the retracting tissue. An additional 2 to 3 mL of TA was applied to the cut edge of the scrotal wounds after the procedure. Because of the blue staining caused by Tri-Solfen, the wounds of castrated calves not treated with Tri-Solfen and the scrotum of control calves were painted with blue food dye to blind observers to treatment in both trials.

Application method is pivotal to maximum efficacy of the topical anesthetic in these trials. Insertion of the applicator into the scrotal sac and spraying into the vicinity of the external inguinal ring ensured that the formulation pooled against the mucosal surfaces for fast and efficient absorption. In addition, once the extracted spermatic cord was severed, the retracting cord and exposed nerve endings were bathed in a pool of anesthetic formulation, enabling almost immediate absorption and anesthesia.

Trial 1: Assessment of Acute Pain-Related Behavior

Behavior was assessed over the first 4 h after castration to examine any acute effects of wound pain or anesthesia on calf recovery, as comparable to previous results in lambs (Lomax et al., 2010). Eighteen calves were weighed and randomly assigned to 1 of the 3 treatment groups as described above. Calves were individually identified by numbers 1 through 18 with colored spray marker on their sides and back to assist behavioral observations. They were then handled and treated accordingly before being released into a large observation yard (50 m^2). The holding yard had complete ground cover, and calves had access to their mothers to allow them to express natural feeding and other behaviors. Pain-related behavior assessments were performed by a trained observer, blind to treatment group strategy at 0.5, 1, 1.5, 2, 2.5, 3, 3.5, and 4 h after castration.

Pain-related behavior was assessed using a previously developed, customized numerical rating scale (**NRS**; Lomax et al., 2008, 2010). Individual calves were allocated a score between 0 and 3 based on behavioral indicators of pain, where 0 = no pain-related behavior, indicated by liberal feeding and suckling and no signs of abnormalities of gait and posture; 1 = mild abnormalities of posture, gait, or behavior, such as mild kyphosis without hyperextension of hind legs, ventral recumbency with hind legs partially extended, or mild stiffening of gait without overt limping or leg dragging; 2 = moderate abnormalities of posture, gait, or behavior, such as "statue standing" with head down and prominent kyphosis, moderate stiffening or slowing of gait, hyperextension and abduction of hind legs, or ventral recumbency with legs fully extended; 3 = display of severe abnormalities of posture, gait, or behavior, such as marked agitation with twisting or writhing, high frequency of postural change from lying to kneeling or standing, distressed vocalization, and lateral or prostrate lying, kneeling, or shaking.

Figure 1. Electronic anesthesiometer applied to castration wound.

Trial 2: Assessment of Skin and Wound Sensitivity

Twenty-seven calves were used in this trial to assess skin and wound sensitivity postcastration. Quantitative sensory testing of the wound and surrounding skin was used to assess sensitivity over the initial expected action period of the TA (4 to 6 h) and at 24 h to assess extended efficacy of the actives beyond the product description. This was measured by means of a pressure transducer (electronic von Frey anesthesiometer with rigid tips; 0 to 1,000 g; IITC-Life Science Instruments, Woodland Hills, CA) and through the use of a von Frey monofilament (300 g, Bailey Instruments Ltd., Manchester, UK). Calves were restrained in the calf cradle, and testing was performed before castration and at 3 min and 2, 6, and 24 h after castration.

Electronic von Frey Anesthesiometer. Animals were placed in the calf cradle, and the tip of the anesthesiometer was applied to the wound and surrounding (periwound) skin (Fig. 1). Pain threshold was automatically recorded as maximum pressure (g) exerted before animal motor response and withdrawal from the device.

von Frey Monofilament. Von Frey monofilaments are calibrated to bend at a predetermined pressure to provide repeatable pain stimulation of predetermined sites on the wound and surrounding (periwound) skin, as previously described in lambs (Lomax et al., 2008, 2010). A 300-g filament was used to perform direct sensory testing at 4 predetermined sites on the cut skin edge of the scrotal wound and 2 sites on the intact skin surrounding the wound.

Evidence of local anesthesia (diminished response to tactile stimulation) and primary and secondary hyperalgesia (heightened response to stimulus directly in the damaged tissue or in surrounding undamaged tissue, respectively) were assessed at each site. Responses were scored by monitoring induced motor reflexes in the rump and head and were graded by severity of expression using a NRS. Response scores were graded as 0 = no response; 1 = minor involuntary motor responses such as minor facial "awareness," such as eye widening or blinking or nasal flaring, local skin twitch, subcutaneous muscle twitch, or anal contraction; 2 = partial head or rump withdrawal reflex, such as slight lifting of the snout or partial head rotation, multiple subcutaneous muscle group contraction, and lifting of the tail; 3 = full startle reflex of the head, resulting in a major movement, such as lifting head off the cradle, full head jerk or full head rotation, or full rump withdrawal reflex with lifting of the rump off the cradle. Total scores were calculated out of 6 for periwound sensitivity and out of 12 for direct wound sensitivity.

Statistical Analysis

Data were analyzed using Genstat software (VSN International, hemel Hempstead, UK). Residual maximum likelihood estimation linear mixed model analyses were used to analyze differences between treatment groups for all behavioral and wound sensitivity testing data, with the factors time, treatment, and interaction between time and treatment as explanatory variables and calf number as the random effect. Where a significant interaction was found, post hoc pairwise comparisons using LSD were performed to analyze between-group differences (Table 1). For all statistical calculations, $P < 0.05$ was considered statistically significant.

RESULTS

Pain-Related Behavior

There was a significant treatment effect on pain-related behavior (Table 2). Calves treated with TA ex-

Table 1. Statistical interactions and df tested in Trials 1 and 2

Trial	Response variate	Factor	Wald statistic	n.df[2]	*P*-value
Trial 1	Behavior	Interaction[1]	23.85	14	0.001
Trial 2					
Electronic anesthesiometer	Wound	Interaction[1]	34.68	8	0.001
	Periwound	Interaction[1]	16.17	8	0.001
Von Frey monofilament					
	Wound	Interaction[1]	93.2	8	0.001
	Periwound	Interaction[1]	54.15	8	0.001

[1]Time × treatment.

[2]Number of degrees of freedom for sample size *n*.

pressed significantly less pain than untreated calves at all time points after castration ($P < 0.001$).

Electronic von Frey Anesthesiometer

Before castration, there was no significant difference in the pain threshold between the 3 treatment groups, with mean pressures of 605.4 ± 17.5 g exerted on the preincision wound site and 628.4 ± 18.3 g on the skin surrounding the wound site.

There was a significant effect of treatment ($P < 0.001$) and time ($P < 0.001$) on pain threshold after castration. Predicted grand means for treatment showed that control calves had the greatest pressure threshold of the wound (613.0 ± 12.2 g) and surrounding skin (637.0 ± 16.7 g), followed by TA-treated castrated calves (559.2 ± 14.3 and 602.8 ± 16.5 g), with untreated castrated calves having the most sensitivity (446.0 ± 18.9 and 515.3 ± 20.4 g). Uncastrated control calves had the greatest wound pain thresholds at all time points after castration (Table 3). The TA-treated calves exhibited significantly greater wound pain thresholds than untreated castrated calves at all time points after castration.

Untreated calves also had significantly lower periwound pain threshold values than both TA-treated and control calves between 2 and 6 h after castration. Periwound pain thresholds did not differ significantly between treated and control calves.

von Frey monofilament

There was minimal response to pain stimulation of the wound site and surrounding skin before castration. Mean NRS response to testing was 0.55 ± 0.2 for the wound site (maximum possible score of 12) and 0.19 ± 0.09 for the surrounding skin (maximum possible score of 6). There were no significant differences between groups (Table 4).

Response scores in the TA-treated calves were significantly below those of the untreated calves between 2 and 24 h after castration ($P < 0.001$; Table 4). Response scores to stimulation of the skin surrounding the castration wound were significantly lower in TA-treated calves than in untreated calves at 2 and 6 h after castration.

Response scores to stimulation of the wound and surrounding skin of TA-treated calves did not differ significantly from uncastrated controls between 1 min and 6 h after castration but were significantly greater by 24 h ($P < 0.001$).

DISCUSSION

There are increasing economical and ethical imperatives to address pain associated with routine husbandry procedures, such as castration of beef calves. Local anesthetics, such as lignocaine, have been found to reduce acute pain associated with castration when injected into the neck of the scrotum and into the spermatic cord (Fisher et al., 1996; Stafford et al., 2002; U.S. National Library of Medicine, 2010a). Regardless, local anesthetic injections are rarely incorporated into routine husbandry procedures of commercial cattle properties.

The development of an affordable and practical means of pain alleviation for such procedures is proposed for incorporation into routine farm management practices. Topical anesthesia, applied during and immediately after the procedure, has previously been found to be practical and effective for reducing postoperative pain associated with surgical husbandry procedures in sheep (Paull et al., 2007; Lomax et al., 2008, 2010; U.S. National Library of Medicine, 2010b). Our studies present evidence that amelioration of pain up to 24 h can be achieved for calves undergoing surgical castration using a farmer-applied, spray-on topical anesthetic. These findings have major welfare implications for all livestock undergoing such procedures.

Local anesthetic agents act directly on nerve tissue to inhibit the conduction of nerve impulses responsible for the sensation of pain. They are absorbed through mucosal surfaces and damaged skin and can effect rapid and profound local anesthesia when applied to open wounds (Brofeldt et al., 1989; Jellish et al., 1999; Kokinsky et al., 1999; Lomax et al., 2008, 2010). Substance P and bradykinin are chemical mediators involved in the inflammatory response which cause vasodilation, edema, and the release of histamine (Ren and Dubner, 1999; U.S. National Library of Medicine, 2010b). They can have a slow and prolonged effect, leading to increased sensitization of neurons to nociceptive signals and exacerbated pain to noxious stimuli. Local anesthetics have been found to suppress bradykinin and substance P-mediated signaling (U.S. National Library of Medicine, 2010b).

Table 2. Mean pain-related behavior numerical rating scale score (±SE) and pairwise comparisons of differences between treatment means at various time points after castration comparing untreated castrated calves with castrated calves treated with topical anesthetic (TA) and uncastrated controls

	Treatment means			Mean differences		
Time,[1] h	Control	Treated[2]	Untreated	Control − Treated	Control − Untreated	Treated − Untreated
0.5	0.00	0.17 ± 0.16	0.50 ± 0.22	−0.17	−0.50[3]	−0.33[3]
1	0.00	0.67 ± 0.33	1.17 ± 0.31	−0.67[3]	−1.17[3]	−0.50[3]
1.5	0.00	0.33 ± 0.21	1.50 ± 0.22	−0.33[3]	−1.50[3]	−1.17[3]
2	0.00	0.00	1.33 ± 0.33	0.00	−1.33[3]	−1.33[3]
2.5	0.33 ± 0.21	0.00	1.17 ± 0.31	0.33[3]	−0.83[3]	−1.17[3]
3	0.00	0.17 ± 0.17	1.33 ± 0.33	−0.17	−1.33[3]	−1.17[3]
3.5	0.17 ± 0	0.00	1.17 ± 0.17	0.17	−1.00[3]	−1.17[3]
4	0.33 ± 0.21	0.33 ± 0.21	0.83 ± 0.17	0.00	−0.50[3]	−0.50[3]

[1]Time after castration.

[2]Treatment with 6mL Tri-Solfen (Bayer Animal Health, Pymble, Australia).

[3]$P < 0.001$, based on LSD of 0.205.

The result is the attenuation of cutaneous microvascular flare responses in damaged tissue and reduced inflammation and therefore decreased hyperalgesia of the wound and surrounding skin.

Local anesthesia via injection of lidocaine and bupivacaine has been shown to significantly reduce the cortisol response to surgical castration (Earley and Crowe, 2002; Stafford et al., 2002; Coetzee, 2011). Our results indicate that topical anesthesia can effect a similar reduction in pain. Trial 1 showed that calves castrated without topical anesthetic treatment displayed more pain-related behaviors, including stiffness of gait, hunched postures, prostration, and less feeding, than treated and uncastrated control calves. These findings are consistent with behavioral observations of calves receiving local anesthetic infiltration of the spermatic cord and scrotum (Boesch et al., 2008). This also supports previous observations of absent or significantly reduced pain-related behaviors in lambs treated with TA applied into the castration and tail docking wounds (Lomax et al., 2010).

In Trial 2, results from mechanical stimulation of the castration wound and surrounding skin with both von Frey monofilaments and the electronic anesthesiometer indicated that significant wound anesthesia was achieved within 1 min of castration. These results concur with previous findings in lambs undergoing surgical husbandry procedures (Lomax et al., 2008, 2010). Calves that received TA were found to tolerate greater pressure exertion on the wound and periwound surfaces after castration. The same calves had significantly lower NRS responses to pain stimulation of the wound and

Table 3. Mean pressure (g) exerted on wound and periwound surfaces (±SE) and pairwise comparisons of differences between treatment means at various time points after castration comparing untreated castrated calves with castrated calves treated with topical anesthetic (TA) and uncastrated controls

	Treatment			Mean differences		
Time[1]	Control	Treated[2]	Untreated	Control − Treated	Control − Untreated	Treated − Untreated
Wound						
Precastration	577.3 ± 19.8	641.7 ± 39.5	597.2 ± 27.9	−64.4	−19.9	44.5
1 min	616.4 ± 44.9	555.8 ± 22.6	449.3 ± 30.8	60.6	167.1[3]	106.5[3]
2 h	585.2 ± 20.6	523.5 ± 8.2	426.3 ± 24.5	61.7	158.9[3]	97.2[3]
6 h	644 ± 15.5	537.2 ± 22.1	330.8 ± 21.5	106.8[3]	313.2[3]	206.4[3]
24 h	641.8 ± 22.7	537.9 ± 42.9	426.5 ± 48.8	103.9[3]	215.3[3]	111.4[3]
Periwound						
Precastration	624.3 ± 30.4	651.9 ± 39.1	609.1 ± 26.5	−27.6	15.2	42.8
1 min	567.6 ± 20.6	538.4 ± 32.1	513.2 ± 27.7	29.2	54.4	25.2
2 h	691.4 ± 47.1	583.7 ± 18.9	462.4 ± 49.7	107.7[4]	229[4]	121.3[4]
6 h	596.5 ± 25.1	630.9 ± 32	431.0 ± 59.1	−34.4	165.5[4]	199.9[4]
24 h	705.1 ± 41.1	609.2 ± 51.1	560.6 ± 36.8	95.9	144.5[4]	48.6

[1]Time after castration.

[2]Treatment with 6mL Tri-Solfen (Bayer Animal Health, Pymble, Australia).

[3]$P < 0.001$, based on LSD of 84.02.

[4]$P = 0.049$, based on LSD of 106.5.

Table 4. Mean numerical rating scale score (±SE) and pairwise comparisons of differences between response to pain stimulation of the castration wound and surrounding skin with a 300-g von Frey filament at various time points after castration comparing untreated castrated calves with castrated calves treated with topical anesthetic (TA) and uncastrated controls

	Treatment			Mean differences		
Time[1]	Control	Treated[2]	Untreated	Control − Treated	Control − Untreated	Treated − Untreated
Wound						
Precastration	0.67 ± 0.44	0.56 ± 0.38	0.44 ± 0.24	0.11	0.22	0.11
1 min	0.44 ± 0.29	0.44 ± 0.24	1.67 ± 0.53	0.00	−1.22	−1.22
2 h	0.22 ± 0.15	0.22 ± 0.15	6.22 ± 0.86	0.00	−6.00[3]	−6.00[3]
6 h	0.11 ± 0.11	1.11 ± 0.42	7.11 ± 0.98	−1.00	−7.00[3]	−6.00[3]
24 h	0.22 ± 0.15	2.56 ± 0.85	6.00 ± 0.78	−2.33[3]	−5.78[3]	−3.44[3]
Periwound						
Precastration	0.11 ± 0.11	0.33 ± 0.24	0.11 ± 0.11	−0.22	0.00	0.22
1 min	0.22 ± 0.22	0.11 ± 0.11	0.67 ± 0.37	0.11	−0.44	−0.56
2 h	0.22 ± 0.22	0.00 ± 0	2.44 ± 0.29	0.22	−2.22[4]	−2.44[4]
6 h	0.00 ± 0	0.11 ± 0.11	1.89 ± 0.39	−0.11	−1.89[4]	−1.78[4]
24 h	0.11 ± 0.11	0.56 ± 0.24	1.11 ± 0.35	−0.44	−1.00[4]	−0.56

[1]Time after castration.

[2]Treatment with 6mL Tri-Solfen (Bayer Animal Health, Pymble, Australia).

[3]$P < 0.001$, based on LSD of 1.41.

[4]$P < 0.001$, based on LSD of 0.64.

thus were concluded to have less wound and periwound pain than untreated calves.

In this study we elected to combine behavioral observations with 2 methods of quantitative sensory testing to clinically assess the pain responses to surgery. We examined pain-related behavior using a numerical rating scale, a method commonly used for grading behavior (Mathews, 2000; Anil et al., 2002, 2005; Hartrick et al., 2003). Subjectivity was minimized through the use of a single trained observer, blinded to treatment protocol.

Quantitative sensory testing is a widely used, validated technique that we have previously used in lambs to record the onset, evolution, and distribution of pain from mulesing and castration wounds and their response to topical local anesthetic (Lomax et al., 2008, 2010). It is an objective, repeatable form of pain assessment enabling the assessor to distinguish between various analgesic interventions (Duarte et al., 2005). Hypersensitivity (hyperalgesia and allodynia) induced by inflammation or nerve injury has been extensively studied as an indicator of perioperative and postoperative pain in humans and animals (Bose, 1979; Wall, 1984; Malatinsky et al., 1986; Kawamata et al., 2002; Brower and Johnson, 2003).

We examined wound hypersensitivity using 2 forms of quantitative sensory testing. Von Frey monofilaments are commonly used in human and animal medicine, and we have used them in previous ovine studies to assess hyperalgesia, allodynia (hypersensitivity to normally nonnoxious stimuli), and hypoesthesia (Lomax et al., 2008, 2010). Responses are recorded using a numerical rating scale, despite concerns of subjectivity and sensitivity. To obtain more objective, discrete data, we also used electronic anesthesiometry. The results from both forms of quantitative sensory testing appeared to align well, showing similar levels of significance in the differences between treatment groups. Correlation tests to validate this observation are proposed, as the 2 methods have different ways of eliciting pain response. The von Frey monofilaments are a sudden, acute stimulation of the wound site to elicit a behavioral response, which is graded on vigor. The electronic anesthesiometer provides slow increasing pressure to elicit animal withdrawal from the noxious stimuli, at which point the maximum pressure exerted may exceed that of the sudden stimulus from the monofilament.

There was evidence of a significant and persistent reduction in primary and secondary hyperalgesia 24 h after castration in calves treated with TA. Extended efficacy of the topical anesthetic is attributed to the inclusion of adrenaline in the formulation. When used topically, adrenaline acts as a vasoconstrictor, slowing the rate of systemic absorption of the 2 anesthetic agents in the formulation and reducing wound hemorrhage. This reduced rate of systemic absorption is likely to prolong the presence of the anesthetic agents concentrated at the wound site and slows the metabolism of the agents, thereby prolonging the intensity and duration of the local anesthesia. In addition, the vasoconstrictive properties of adrenaline slow blood flow to the wound, thereby suppressing the inflammatory cascade. The nerve endings in the damaged tissue are not exposed to inflammatory mediators that would cause them to become sensitized, leading to decreased hyperalgesia.

Results from both techniques of sensory testing indicated no significant difference in secondary hyperalgesia of the periwound surface between treated and untreated calves 1 min after castration. Secondary hyperalgesia is hypersensitivity in tissue adjacent to the wound and is a consequence of central sensitization. This occurs as a result of peripheral sensitization (primary hyperalgesia) enhancing the pain responses of nociceptive neurons in the central nervous system (Ren and Dubner, 1999). Dorsal horn neurons respond to peripheral inputs from the wound site and release chemical mediators that increase central sensitization and lead to the perception of postoperative pain (Ren and Dubner, 1999; U.S. National Library of Medicine, 2010b). This process tends to be slower than peripheral sensitization, which explains why there is very little secondary hyperalgesia seen within 1 min of castration, whereas primary hyperalgesia appears to develop immediately in untreated calves. In addition, the slow progression of the inflammatory cascade means there would be minimal vasodilation within 1 min in surrounding tissues, and thus, hypersensitivity would not yet have developed.

Despite the proven efficacy of various nonsteroidal anti-inflammatory drugs (**NSAID**) and local anesthetics as discussed in the extensive reviews of Coetzee (2011) and Stafford et al. (2005, 2006), there is limited use of these products by farmers and practitioners. Traditionally, pain in farm animals has been overlooked because of attitudes of farmers and veterinary practitioners, practicality, and economic constraints (Heleski et al., 2004; Huxley and Whay, 2006, 2007; Coetzee, 2011). There is a need to further assess these attitudes to pain and the use of analgesics in production animals.

Limitations to the use of injectable anesthetics and NSAID arise from the delayed onset of action, the need for veterinary administration, and the cost of the products. Depending on the country, most drugs can only be obtained with a prescription by a veterinarian, and some must be administered under veterinary supervision or by a veterinarian (Sutherland et al., 1999). Furthermore, many of these anesthetics are invasive, requiring injection to the animal, and, depending on the drug, may take a matter of minutes to exert its effect (Coetzee, 2011). This can require double handling of animals and a time delay between administration and procedure, both of which are impractical in large commercial operations. As with any substance that must be artificially introduced into the body, there are various problematic side effects attributed to their use. Occupational health and safety issues associated with the use of needles and scheduled drugs increase risk to producers and limit access. Finally, there are economic constraints to the use of analgesics in production animals, with product cost in addition to the cost of employment of a veterinarian being significant barriers to general uptake (Stafford et al., 2005; Huxley and Whay, 2006). Options for analgesia are unlikely to be used in routine management procedures if their use is too time-consuming, costly, and generally impractical for the farmer. It is likely that the use of analgesics may become standard farm practice because of the falling cost of most commonly used NSAID as more generic products become registered and available. However, in the interim it is important to consider methods for effective and affordable alleviation of pain.

The topical anesthetic formulation examined in this study has great potential to improve the welfare of livestock undergoing surgical castration. This method of delivery is desirable as it provides an option for safe, efficient, and effective anesthesia of castration wounds. Administering the product topically during and immediately postprocedure allows for rapid onset of anesthesia (within 1 min on the basis of sensory testing results). This removes the need for double handling and has a minimal time impact on regular farm operation. In addition, the product is provided at a relatively low cost (approximately AU$1 per head) through veterinarians.

Conclusions

Through the combination of behavioral observations and quantitative sensory testing we conclude that the topical anesthetic, antiseptic, and hemostatic formulation (Tri-Solfen) effects rapid and prolonged pain alleviation in calves up to 24 h after castration. This was evident through a reduction in pain-related behaviors and reduced sensitivity of the wound and surrounding surfaces in treated calves. Although initially developed for mulesing wounds, this type of product has the capacity to significantly reduce the acute pain associated with routine husbandry procedures in livestock.

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