A new method of administering local anesthesia for calf disbudding: Findings from a comparative on-farm study in New Zealand

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ABSTRACT

Anesthesia of the horn bud for calf disbudding commonly is attained by injection of local anesthetic over branches of the cornual nerve, with anesthesia achieved in 3 to 20 min. With experienced and trained staff, this method is effective in 88 to 100% of calves. Variability in response and time of onset can compromise calf welfare if calves are disbudded before anesthesia is attained. Proposed legislative reliance on effective local anesthetic as the minimal method of pain relief for calves at disbudding means that administration of local anesthetic must achieve a repeatable level and rapid onset of analgesia. We describe an alternative method of local anesthesia administration that uses local site infiltration of anesthetic over the horn bud. However, this method has not yet been scientifically validated. This study assessed differences between disbudding using the cornual nerve block and disbudding with local anesthesia administered by local site infiltration. Efficacy of local anesthesia was assessed at 30-s intervals after administration by absence of reaction to 3 consecutive needle pricks over the horn buds. Behavior indicating pain was assessed during disbudding and scored from 0 to 3. Calf behavior was also recorded for 3 h after disbudding. Accelerometer data loggers were fitted to each calf for 24 h before and after disbudding to assess lying and standing times. Median time to cutaneous desensitization for local infiltration was 60 s compared with 225 s for cornual nerve block, and the variance in time to desensitization was less with local infiltration. Calves disbudded under cornual block had a larger behavioral response (indicated by a graded aversive body reaction) than calves disbudded under local infiltration. A multivariable model predicted that the mean body reaction score would be 0.6 for calves disbudded under local infiltration and 1.2 for calves

disbudded under cornual block. There was no difference in any behaviors between the treatment groups in the 3 h after disbudding. Method of analgesia had no effect on lying time over the 24 h after disbudding. In this study, local infiltration was at least as effective in providing analgesia for disbudding as the cornual nerve block. Our results suggest that a more consistent, effective level of analgesia during disbudding was achieved using local infiltration and that there was no difference in postoperative expressions of pain.

Key words: disbudding, calf, cornual, local, infiltration

INTRODUCTION

The major dairy breeds are naturally horned, and in mature cattle this presents a risk to animals and people (Stock et al., 2013). Disbudding refers to the destruction of free-floating immature horn tissue (horn “buds” growing from the skin), from which the horns of the animal subsequently develop (Mellor and Stafford, 2004). There is evidence that disbudding is less painful than amputation dehorning (Petrie et al., 1996; Stilwell et al., 2007). Within the major dairy-producing countries, disbudding is usually performed using a hot iron when calves are 3 to 6 wk of age and horn buds are 5 to 10 mm long (Bates et al., 2016; Winder et al., 2017). Caustic paste is used in around 20% of disbudded calves in the European Union (Gottardo et al., 2015) and 16% of those in the United States (Adams et al., 2015).

There is abundant evidence in the scientific literature of the benefits of providing local anesthesia and systemic analgesia at the time of disbudding (Stafford and Mellor, 2011; Stock et al., 2013; Bates et al., 2015) and an increasing social understanding of the pain associated with disbudding (Green and Mellor, 2011; Robbins et al., 2015; Ventura et al., 2015). This has led to a legislative and social environment where the provision of analgesia at disbudding is obligatory (Croney and Anthony, 2010; Lundmark et al., 2014; Winder et al., 2017), including within New Zealand (NZ), where the use of local anesthetic at disbudding is mandatory beginning in 2019. The cornual nerve block is currently

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the accepted method of administering local anesthesia for disbudding in calves (Grøndahl-Nielsen et al., 1999; Fierheller et al., 2012), and postoperative analgesia is provided by nonsteroidal anti-inflammatory drugs (Stafford and Mellor, 2011). Ring blocks and cornual blocks with local anesthetic placed medial to the horn bud have also been described (Stock et al., 2013).

Within the United States, Canada, NZ, and much of the European Union, it is common practice for disbudding to be performed on standing calves by non-veterinarians (Gottardo et al., 2015; Bates et al., 2016; Winder et al., 2018). Mandatory use of local anesthetic at disbudding will be effective in improving calf welfare only if an effective nerve block is achieved. Correct application of a cornual nerve block requires technical training on the injection site and technique (Winder et al., 2018). The volume and the amount of time needed between injection and the procedure also needs to be established during training, with Stock et al. (2013) quoting a median of 5 mL per bud (range = 3–5 mL) and a median time of 10 min (range = 5–20 min). Winder et al. (2018) demonstrated that effective training in administering a cornual block in standing calves could be attained using either online or hands-on training techniques. Based on the elimination of behavioral responses to disbudding during the first 5 s of the procedure, an effective corneal nerve block was successfully achieved by 75 and 91% of the hands-on and online trained participants, respectively. In this study, a 10-min delay was used between anesthetic block administration and disbudding. In many seasonal-calving herds, large numbers of calves require disbudding over a short time period, and in NZ there is often a requirement to disbud groups of 200 to 400 calves during a single visit. In this situation, a delay between block administration and procedure leads to double handling of calves or requires multiple restraining crates to avoid downtime. This is often impractical, and the extra handling can cause additional stress to the animal.

The present paper describes an alternative and, to our knowledge, previously undescribed method of administering a local anesthetic block to the horn bud (local infiltration block) that requires a much shorter delay and less technical skill in administration. For horn buds that are not yet attached to the skull, the method consists of injecting local anesthetic (~1 mL) directly over the horn bud, which results in the local anesthetic diffusing in a bubble or bleb around the caudomedial or rostromedial aspect of the horn bud. For larger buds that have attached to the underlying bone, local anesthetic is injected laterally (1 mL) and caudally (1 mL) as close to the horn bud as possible. Similar to the methodology used for the unattached

horn buds, the local anesthetic diffuses in a bubble or bleb around the caudomedial or rostromedial aspect of the horn bud. Unlike the multiple injections required for a ring block (Fierheller et al., 2012), this method involves 1 or at most 2 injection sites per horn bud. Our null hypothesis was that there would be no difference in the behavioral signs of pain and discomfort during disbudding and in the 3 h afterward and no difference in the lying and standing times in the 24 h after disbudding between calves disbudded under a cornual block and calves disbudded under the local infiltration block.

MATERIALS AND METHODS

Animal Use

This trial was conducted between August and September 2017 on 2 commercial seasonal-calving pastoral dairy farms (A and B) in Canterbury, South Island, NZ. Use of animals and all procedures was preapproved by the Ruakura (NZ) Animal Ethics Committee (application no. 14287).

Housing and Management

All calves were born at pasture and brought into the rearing facility within 24 h of birth, and their navels were sprayed with iodine tincture spray containing 2.5% iodine (Ethical Agents, Manukau, NZ). On farm A, calves were housed in groups of approximately 40 calves/pen in purpose-built sheds with solid walls up to 1.5 m high. On farm B, calves were housed in groups of up to 10 in covered, open-front bay sheds with solid walls up to 1.5 m high. All calves were bedded on wood chips that were cleaned daily and topped up weekly. Male and female Jersey-Friesian crossbred calves were used, and all calves remained on the farm of origin for the period of the study.

Nutrition

For the first 24 h after birth, all calves were fed pooled colostrum in 2 feeds of 1.5 to 2.0 L/calf per feed, harvested from cows calving that day. For the next 3 d, calves were fed 2 L of pooled colostrum twice daily from cows between 1 and 4 d calved. Thereafter, calves were fed pooled colostrum and nonsaleable milk and had access to perennial ryegrass (*Lolium perenne*) hay, water, and calf meal (Calf-Pro20%, Winslow Feeds, Tinwald, Ashburton, NZ; and NRM GrowUp 20%, NRM, Canterbury, NZ). This contained 20% CP and 13 MJ of ME/kg of DM. On farm A, calves were fed individually via an automated milk feeding system (rEID Calf Feeder, A&D Reid, Temuka, NZ), which allocated up

Table 1. Description of the treatment groups used in analysis of the efficacy of local anesthetic infiltration and cornual nerve block on the pain arising from calf disbudding

Group	Acronym	Description	Purpose	No.
No local, no disbud	CON	Handled alongside other calves but no further treatment for 48 h	Untreated control	20
Local infiltration, no disbud	INF-NDB	Local anesthetic administered over the horn bud and no further treatment for 48 h	Treated control 1	10
Cornual block, no disbud	CNB-NDB	Local anesthetic administered via a cornual nerve block and no further treatment for 48 h	Treated control 2	10
Local infiltration, disbud	INF-DB	Local anesthetic administered over the horn bud, disbudded with hot iron cautery	Treated group 1	20
Cornual nerve block, disbud	CNB-DB	Local anesthetic administered by a cornual nerve block, disbudded with hot iron cautery	Treated group 2	20

to 4 feeds/d of up to 1.5 L of milk/feed. On farm B, calves were fed 2 equal feeds (0700 and 1500 h) increasing from 2 L/feed over the first 21 d and remaining at 6 to 8 L/d for the duration of the study.

Enrollment

The 2 study farms were chosen on a convenience basis from farms serviced by Vetlife Ltd. (Temuka, New Zealand). Calves with no visible signs of illness were scheduled for routine disbudding from 4 wk of age at biweekly farm visits where 40 calves were disbudded per visit. For each farm a scheduled visit (farm A: Aug. 29, 2017; farm B: Sep. 5, 2017) was chosen using the random number generator in Microsoft Excel (Microsoft Corp., Redmond, WA) to serve as the study group for that farm. The mean age was 31 d (95% CI = 28–34), the mean proportion of Friesian genetics was 0.60 (95% CI = 0.58–0.61), and 16% (95% CI = 10.5–22.0) of study calves were uncastrated males.

Treatment Groups

Twenty-four hours before disbudding, all study calves had Hobo Pendant G accelerometers (64k, Onset Computer Corp., Bourne, MA) attached to the rear right leg and were marked with a unique study number spray-painted using nonirritant stock marker (Tell-Tail; FIL, Mt. Maunganui South, NZ) on the back and left and right flanks. Accelerometers were set at 1-min intervals recording the y- and z-axes, placed in a durable fabric pouch, and strapped onto the lateral side of the hind leg above the metatarsophalangeal joint, as described in Sutherland et al. (2017).

No calves were treated or disbudded at this visit, but calves were allocated using restricted randomization and a random number generator from Microsoft Excel (Microsoft Corp.) to a treatment group for the following day, as detailed in Table 1. Each calf was fitted with a colored neckband to identify treatment group (Shoof NZ Ltd., Cambridge, NZ), but all farm and veterinary

staff were blinded to the color coding of the treatment groups, which was known only to the lead investigator. All calves were managed identically during the study period.

On the morning of disbudding, calves were deprived of milk but had access to meal and roughage. Each pen of calves was divided into a front and back area using mobile gates, and calves were moved into the back area. A mobile calf crate was set up at the front of the rear calf pen, and calves were individually moved into the crate and restrained. All local anesthetic treatments were administered by the same trained veterinarian (the lead author).

The study design was a $2 \times 2 + 1$ factorial with disbudding and method of local anesthesia as the factors and with the following groups. Control (**CON**) calves ($n = 20$) were restrained in the calf crate for 30 to 60 s, and their horn buds were touched with a single digit at 30 s intervals but not disbudded. For the calves in the local infiltration groups (local anesthetic administered over the horn bud and no further treatment for 48 h, **INF-NDB**, $n = 10$; local anesthetic administered over the horn bud and disbudding with hot iron cautery, **INF-DB**, $n = 20$), analgesia was administered to each calf by subcutaneous infiltration of 40 mg of lidocaine hydrochloride (2 mL of Nopaine 2%; Phoenix Pharm Distributors, Auckland, NZ) per horn bud (Figure 1). To standardize the approach in the present study, local anesthetic was injected laterally (1 mL) and caudally (1 mL) as close to each horn bud as possible using an 18-gauge 2.5-cm needle (Rurtec, Hamilton, NZ). Once the local anesthetic was injected, it diffused in a bubble or bleb around the caudomedial or rostromedial aspect of the horn bud in a crescent-shaped pattern.

For the calves in the cornual nerve block group (cornual nerve block with no further treatment for 48 h, **CNB-NDB**, $n = 10$; cornual nerve block and disbudding with hot iron cautery, **CNB-DB**, $n = 20$), analgesia was administered by injecting 5 mL of 2% lidocaine hydrochloride (Nopaine 2%; Phoenix Pharm Distributors) per horn bud subcutaneously using an

18-gauge 2.5-cm needle (Rurtec) around the cornual nerve (located along the occipital groove midway between the horn bud and the eye) as a cornual nerve block. Four milliliters was injected at this location after ensuring that the needle was not in a blood vessel, and the remainder was infiltrated through the tissues on removal and repositioning of the needle subcutaneously over the frontal crest (Skarda, 1996; Fierheller et al., 2012).

Behavioral observations during disbudding were recorded by the same veterinary technician for all calves. Observations of calf behavior during the 3 h after disbudding were recorded by the same team of 4 veterinarians trained in behavioral observation. All observers were blinded to the treatment group of the calves.

Control calves received no further treatment but were restrained in the calf crate for 30 to 60 s and their horn buds were touched with a single digit at 30-s intervals but not disbudded. In all groups that received local anesthetic (INF-NDB, CNB-NDB, INF-DB, CNB-DB), efficacy of the local anesthesia was assessed at 30-s intervals after administration and judged by reaction to a fresh 1.5-inch, 22-gauge sterile needle pricked over the horn buds. The horn bud was approached caudally and dorsally to reduce reaction from the approach of the handler. Initially, the horn buds were digitally massaged and if no reaction was evident (head movement away from the stimulus), a single needle prick was made over the horn bud. If no reaction was evident, second and third needle pricks were made in a similar manner. Reaction at any point triggered another stand-down period of 30 s with a calf having to show no reaction to a total of 3 consecutive needle pricks to be submitted for disbudding.

On attainment of anesthesia, the horn buds of calves in groups INF-NDB and CNB-NDB were massaged manually for 12 s with the thumb and index finger but calves were not disbudded, whereas calves in the groups INF-DB and CNB-DB were disbudded. For INF-DB and CNB-DB calves, on attainment of anesthesia, disbudding was performed using a cordless gas-fueled hot cautery calf dehorner (Portasol Mark 3 debudder; Portasol, Elmira, OR) and the wound was sprayed with a topical aerosol of oxytetracycline (Aerotet-Forte; Birbac NZ, Auckland, NZ). Contact time between the hot iron and the bud was standardized to 12 to 15 s per bud, and the center was scooped out at the end with the disbudding iron. On completion of treatment, the colored neckband was removed and each calf was released from the calf crate into the front half of the pen. At the completion of disbudding, the temporary gates dividing the pen into front and back halves were removed. Thereafter, all calves were treated identically per normal farm management practices.

Outcomes

Time to Skin Desensitization. For CON calves, the time from securing the calf within the crate to absence of reaction to digital contact with the horn bud was recorded. For the remaining groups, the time from administration of local anesthetic to skin desensitization was recorded for each horn bud.

Behavior During Disbudding. Body response was classified on a scale of 0 to 3 using the definitions given in Table 2, modified from Stewart et al. (2008). The frequency of vocalizations and defecations was also recorded for each calf. A second observer was present

Figure 1. Diagram of administration of local anesthetic into the horn bud region by the local infiltration technique used in the present study. (A) Syringes indicate the rostromedial and caudomedial locations around the horn bud where the needle was inserted. (B) Dotted lines indicate how the local anesthetic disperses in a crescent pattern, laterally and caudally, when it is injected.

Table 2. Behaviors recorded during and after disbudding and massaging

Behavior	Description of body response
During disbudding	
Body reaction score	
0	No response, slight movement of body, tail wagging
1	Mild struggling, no foot stamping
2	Struggling with hind and front limbs
3	Massive struggling involving whole body
After disbudding	
Head shaking	Vigorous shaking of the head around a rostral to caudal axis
Head scratching	Scratching the top of the head with a hind foot; includes attempts where hind foot does not make contact with the head
Head rubbing	Rubbing the top of the head against the side of the pen or other calf with an up-down or side-to-side movement
Self-grooming	Calf's tongue is out of its mouth and in contact with its own body
Running (locomotor play)	Includes trotting (2-beat gait), cantering (3-beat gait), and galloping (fast 4-beat gait) with forward or sideways movement

at both farms to determine the level of interobserver agreement.

Behavior After Disbudding. After disbudding, 2 trained observers blinded to the treatment status of the calves recorded calf behavior for all calves using the definitions in Table 2 (Grøndahl-Nielsen et al., 1999; Faulkner and Weary 2000). Observations were recorded against the calves’ spray-painted and ear tag numbers. Each calf was observed for a period of 45 s immediately after exit from the calf crate and then every 20 min until 3 h after disbudding had elapsed. At each observation period, the frequency of the observed behaviors in Table 2 was recorded. These behaviors were chosen because head shaking, scratching, and rubbing have been shown to indicate postdisbudding pain in previous studies (reviewed by Stafford and Mellor, 2005).

Lying and Standing Behavior After Disbudding. Data loggers were removed 24 h after disbudding. Accelerometers were initialized and downloaded using HOBOWare Pro software (version 3.7.2; Onset Computer Corp., Bourne, MA). G-force readings were converted into binary values (e.g., lying = 0, standing = 1), and daily (min/d) summaries of lying time and lying-bout frequency (number of bouts/d) were calculated in SAS 9.3 (SAS Institute Inc., Cary, NC) using a code designed for this purpose (UBC AWP, 2015) and validated by Bonk et al. (2013) for use in calves.

Statistical Analysis

Power Analysis. A prestudy power analysis was conducted using data from Graf and Senn (1999) on the frequency postdisbudding of head shakes and from Heinrich et al. (2010) on ear flicks. A modified version of Lehr’s equation (Lehr, 1992) was used to account for the Poisson distribution of count data (van Belle, 2008). It was estimated that if the difference between control and treatment in counts of outcome was at least

50%, groups of 20 calves would maintain power above 0.84 at a 95% confidence interval for counts ranging from 4 to 10 in the control group, whereas groups of 10 would be sufficient to distinguish counts ranging from 6 to 10 in the control group. All data were recorded on purpose-designed paper records and then entered manually into Microsoft Excel (Microsoft Corp.) and then exported into R version 3.3.2 (R Foundation for Statistical Computing, Vienna, Austria) for statistical analysis.

Independent Variables. Treatment group was forced into all models with calf as the experimental unit. To increase power and aid interpretation, treatment groups were aggregated together where appropriate. For example, to determine the overall success of anesthesia for disbudding, where there was no significant difference between the control groups (CON, INF-NDB, and CNB-NDB), these were aggregated together to form a 3-component categorical variable: calves not disbudded [n = 40; some receiving no local anesthetic (n = 20), some receiving local infiltration of anesthetic (n = 10), and some receiving a cornual block (n = 10)], calves disbudded under local infiltration of anesthetic (n = 20), and calves disbudded under cornual block (n = 20).

Farm was recorded as a categorical variable, calf sex as a categorical variable, age in days as a continuous variable, and breed as the proportion of Friesian genetics (continuous). For each multivariable model, all independent variables were assessed for correlation. Pearson correlation coefficient was calculated for normally distributed continuous variables, Spearman’s coefficient for nonnormally distributed continuous variables, and Goodman and Kruskal’s tau for categorical variables. Where a correlation of >0.2 was found, a variance inflation factor to assess collinearity was calculated using auxiliary regressions of one of the correlated variables on the remaining explanatory variables in the model. If

the variance inflation factor was >10 or if the value of the remaining coefficients changed by more than 10% when rerunning the model without the variable, the collinear variables were assessed for biological plausibility and the least useful were discarded from the final model. Variables that were significant at the univariable level at $P < 0.20$ were entered by hand within each multivariable model and retained if identified as confounders, if a Wald test for the variable gave a P -value < 0.05 , or if a likelihood test for inclusion of the variable category was significant ($P < 0.05$).

Dependent Variables: Time to Skin Desensitization. Time for cutaneous desensitization following administration of local anesthetic was reported for each calf (average for both horn buds) as a discrete variable, reported from 0 to 300 in 30-s intervals. Univariable analysis for the effect of treatment group on time to skin desensitization was conducted using a Kruskal–Wallis rank-sum test followed by a pairwise Wilcoxon rank-sum test with Holm–Bonferroni adjustment for multiple comparisons to allow relative comparison of the effect of individual treatments. Data visualization, Bartlett, Levene, and Fligner–Killeen tests for homogeneity of variance all indicated heterogeneity of variance between treatment groups ($P < 0.001$). As time was measured in discrete intervals of 30 s, the probability of a successful block was estimated for each discrete time interval using a multivariable binomial general linear model. A logit link function was used because it resulted in a lower residual deviance than a complementary log-log link function. Complete separation of the data meant that it was necessary to use penalized maximum likelihood estimation to estimate parameters (Heinze and Schemper, 2002).

Dependent Variables: Behavior During Disbudding. Within each calf, body response to disbudding for each horn bud differed by no more than 1 unit; therefore, calf body response during disbudding was averaged for both horn buds for that calf and reported as an ordinal variable from 0 to 3 in intervals of 0.5. Median average body response score for each calf was compared between groups using a Kruskal–Wallis rank-sum test followed by a pairwise Wilcoxon rank-sum test with Holm–Bonferroni adjustment for multiple comparisons to allow relative comparison of the effect of individual treatments.

All control groups (CON, INF-NDB, CNB-NDB) recorded average body response up to and including 1.0; therefore, calves were also categorized as having a body response of ≤ 1.0 (considered successful anesthesia) or greater than 1.0 (considered unsuccessful anesthesia). Univariable analysis for the effect of treatment on the proportion of calves with successful anesthesia (body response score ≤ 1.0) was conducted using Fisher's

exact test followed by a pairwise Fisher test with Holm–Bonferroni adjustment for multiple comparisons to allow relative comparison of the effect of individual treatments.

Multivariable ordinal logistic models were used to explore the effect of the combined independent variables on the average calf body response score during disbudding. Models with a logistic, probit, and cumulative logistic link function were constructed, and the model with the lowest Akaike fixed and information criteria (AIC) was chosen. The assumption that the coefficient values were appropriate across all levels of the ordinal response (parallel regression assumption) was assessed graphically (Harrell, 2001).

Spearman's rank correlation coefficient was determined for the behavioral score during disbudding recorded by each observer. Values of >0.9 were taken to indicate acceptable agreement between observers.

Dependent Variables: Behavior in the 3 h After Disbudding. Behavior after disbudding was reported as the frequency of observed counts for each behavior over the entire period of observation and at each observation time. For regression analysis, counts were standardized to a denominator of 20 calves to account for the different number of calves in groups INF-NDB and CNB-NDB from the groups CON, INF-DB, and CNB-DB. For all the dependent variables, variance greater than the mean indicated possible overdispersion. Consequently, for each dependent variable, Poisson and negative binomial multivariable models were compared using a likelihood ratio test.

For the analysis of the total count of each behavior, all variables in each model were treated as fixed. For the analysis of the count of observations at each observation time, calf was included as a random intercept within the model to account for repeated observations on the same calf. The proportion of the total variance for repeat measures on the same calf was calculated as the intraclass correlation coefficient. The effect of observation time was nonlinear, and models where observation time was forced into the model as a fixed effect were compared with models where time was treated as a random effect using a likelihood ratio test.

Dependent Variables: Lying and Standing Times. Generally, calves experiencing more discomfort spend more time standing than lying (Theurer et al., 2012). Within each hour, time spent lying and time spent standing summed to 60 min, so only time spent lying was treated as a dependent variable in the analysis. The median lying time per hour by treatment group preceding and following disbudding was compared using a Kruskal–Wallis rank-sum test followed by a pairwise Wilcoxon rank-sum test with Holm–Bonferroni adjustment for multiple comparisons to allow relative

comparison of the effect of individual treatments. The median lying time before and after disbudding by treatment group was also compared using a Kruskal–Wallis rank-sum test.

Multivariable linear mixed regression was used to examine the effect of treatment on lying time per calf per hour of the day after disbudding. Treatment group was forced into all models, and independent variable selection was as described previously. Models were constructed where calf was included as a random intercept and observation hour as a random slope to account for repeated observations on the same calf. These were compared with models where calf and observation time were treated as fixed effects with the model selected with the lowest AIC.

All calves were disbudded within 3 h of 1200 h, so the effect of time of observation could not be differentiated into the effect of time from disbudding compared with the effect of time of day. A quadratic transformation of observation time was used because the association between observation time and lying time was nonlinear, with a peak between 1800 and 0600 h. Within the model, for each calf-hour observation of time spent lying postdisbudding, the corresponding calf-hour of time spent lying in the 24 h preceding disbudding was included as an independent variable. The proportion of the total variance for repeat measures on the same calf and in the same observation hour was calculated as the intraclass correlation coefficient. All regression models were tested using standard diagnostic techniques for homoscedasticity, normality of residuals, linearity of predictor–outcome association, and the effect of outliers.

RESULTS

Distribution of Variables Across Treatment Groups

There was no difference in the distribution of the independent variables across the treatment groups, with

a mean age of 31 d (95% CI = 28–34), mean proportion of Friesian genetics of 0.6 (95% CI = 0.55–0.62), and mean proportion of male calves of 0.2 (95% CI = 0.03–0.36). Results from all 80 calves were available for analysis. All buds were removed with the disbudding iron alone, and no calves required amputation dehorning.

Time to Skin Desensitization

Time to skin desensitization was not normally distributed. For each calf, the median and range in time for skin desensitization averaged over both horn buds are reported in Table 3. For calves that received local infiltration, there was no significant difference for the time to skin desensitization between calves that were disbudded and calves that were not disbudded (INF-DB vs. INF-NDB, *P* = 0.715). Similarly, for calves that received a cornual nerve block, there was no significant difference for the time to skin desensitization between calves that were disbudded and calves that were not disbudded (CNB-DB vs. CNB-NDB, *P* = 0.841). All other pairwise comparisons of treatment groups were significantly different (*P* < 0.001). Supplemental Figure S1 (<https://doi.org/10.3168/jds.2018-15033>) shows a dot plot of the time to skin desensitization for the treatment groups.

For both methods of administering anesthesia, the time to skin desensitization was not influenced by whether the calves were sham disbudded or disbudded. This allowed us to pool the results for time to skin desensitization by method of administration of anesthesia. The median time for skin desensitization for calves receiving local infiltration (60 s; range: 30–105 s) was significantly less than the median time for calves receiving a cornual block (225 s; range: 120–300 s; *P* < 0.001).

The logistic multivariable regression model (Supplemental Table S1, <https://doi.org/10.3168/jds.2018-15033>) for the time to desensitization predicted that

Table 3. Median (range in parentheses) of time to skin desensitization of the horn buds and body reaction score during disbudding over both horn buds in calves that were control handled or injected with local anesthetic using a local infiltration or a cornual nerve block technique before disbudding

Item	Treatment ¹					<i>P</i> -value
	CON	INF-NDB	CNB-NDB	INF-DB	CNB-DB	
Time to skin desensitization (s)	30 ² (30–60)	60 (30–105)	233 (120–270)	60 (30–105)	218 (135–300)	<0.001 ³
Body reaction score (0–3)	0.0 (0.0–0.5)	0.0 (0.0–0.5)	0.3 (0.0–1.0)	0.5 (0.0–2.0)	1.0 (0.0–3.0)	<0.001 ³

¹CON = no local, no disbud (control); INF-NDB = local infiltration, no disbud; CNB-NDB = cornual block, no disbud; INF-DB = local infiltration, disbud; CNB-DB = cornual nerve block, disbud.

²Time recorded from securing within the crate to absence of reaction to digital contact with the horn bud. CON calves received no further treatment and were not disbudded.

³Kruskal–Wallis rank-sum test.

Figure 2. Median and interquartile range of time to skin desensitization predicted by the multivariable logistic regression model from data collected in this study. Columns with different letters (a–c) are significantly different ($P < 0.001$). Error bars = IQR.

the median time for desensitization under cornual block was 210 s (interquartile range: 180–240) compared with 60 s (interquartile range: 30–60) for desensitization under local infiltration ($P < 0.001$). Figure 2 shows the median and interquartile time to skin desensitization as predicted by this model.

The model suggests that for both methods of anesthesia, time for skin desensitization was not influenced by whether the calves were sham disbudded or disbudded. The median time for skin desensitization for calves given local infiltration and disbudded (60 s; interquartile range: 30–60 s) was less than that for calves given a cornual block and disbudded (210 s; interquartile range: 180–240 s; $P < 0.001$).

Behavior During Disbudding

Only 3 calves vocalized and 1 calf defecated during disbudding (all within the group disbudded using the cornual nerve block method), so statistical analysis of these outcomes was not attempted. Median body reaction and range of score for each treatment group are presented in Table 3. Interobserver agreement for the behavior during disbudding was high, with a Spearman rank coefficient of 0.96 for farm A and 0.98 for farm B. For calves that were not disbudded, injecting anesthetic

using the infiltration method led to no greater body reaction than injecting using the cornual block method ($P = 0.537$), but there was a trend for an increase in body reaction for calves injected with a cornual block compared with noninjected calves ($P = 0.054$).

Calves that were disbudded under cornual block had a greater body response than calves that were only injected with a cornual block ($P = 0.010$) and a greater body response than calves disbudded under local infiltration ($P = 0.029$). Calves that were disbudded under local infiltration tended to have a greater body response than calves that were only injected with local infiltration ($P = 0.051$). Supplemental Figure S2 (<https://doi.org/10.3168/jds.2018-15033>) shows a dot plot of the recorded body responses for the treatment groups.

The median body response of calves disbudded under a cornual block (1.0; range: 0.0–3.0) was significantly greater than the body response of calves disbudded under local infiltration (0.0; range: 0.0–2.0; $P = 0.005$). Irrespective of method of administering local anesthetic, disbudding increased the median body response compared with nondisbudded calves (median: 0.0; range: 0.0–1.0; $P < 0.001$).

There was no difference in the proportion of successful anesthesia (body response score of 1.0 or less)

achieved between the control groups, so the control groups of nondisbudded calves were pooled. Successful anesthesia was achieved in all control calves ($n = 40$) and in 18 out of 20 (90%; 95% CI = 76.9–100%) calves disbudded under local infiltration ($P = 0.107$). Successful anesthesia was achieved in 11 out of 20 (55%; 95% CI = 33.2–76.8%) calves disbudded under cornual block. This was significantly less than for control calves ($P < 0.001$) and less than for calves disbudded under local infiltration ($P = 0.047$). Seventeen out of 20 (85%; 95% CI = 69.4–100%) calves disbudded under cornual block and 19 out of 20 (95%; 95% CI = 85.4–100%) calves disbudded under local infiltration ($P = 0.322$) had a body response of <2 .

A multivariable ordinal logistic model for body response score with a probit link had the lowest AIC value (Table 4). Only treatment group was significant in the final model ($P < 0.001$). Because there was no significant difference between the control groups, these were pooled as defined above as nondisbudded calves ($n = 40$).

The coefficients from the model indicate that calves disbudded under local infiltration or under cornual block are significantly more likely to have a higher body response score than calves in the control group ($P < 0.001$). In a separate analysis (not shown), the referent category was changed to calves disbudded under cornual block. The coefficient for calves disbudded under local infiltration was -1.03 (95% CI = -1.72 to -0.35 ; $P < 0.001$) compared with calves disbudded under cornual block. This indicates that the body response was significantly less for calves disbudded under local infiltration than for calves disbudded under cornual block. The predicted probability of each category of body response score is shown in Supplemental Figure S3 (<https://doi.org/10.3168/jds.2018-15033>), and the predicted probability that the body response score will be less than or equal to a given value is plotted in Figure 3.

Figure 3. Predicted probability that the body response score will be less than or equal to a given value for the 3 treatment groups from a multivariable ordinal probit model used in this study. Solid circles represent control calves that were not disbudded, solid triangles represent calves that were disbudded under local infiltration, and solid squares represent calves disbudded under cornual block.

Time between administration of local anesthetic and application of disbudding iron was considered as a potential confounder because it was related to treatment group (CNB calves had a longer average time interval than INF calves) and to the body reaction (unadjusted body reaction odds ratio for a 1-unit increase in the time interval = 1.01; 95% CI = 1.01–1.01).

When time to effect was included as a confounding variable in the model, there was a change in the coefficient values of $<20\%$ and no change in the predicted probability for each body response score ($P > 0.89$). However, the predicted probability of an adverse body reaction score for infiltrated calves increased slightly, whereas the predicted probability for cornual block calves decreased slightly (Supplemental Figure S4,

Table 4. Coefficients from a multivariable ordinal probit model predicting the probability of a body response of 0 to 3

Variable	Coefficient	SE	95% CI	<i>P</i> -value ¹
Treatment group*				
Not disbudded	Referent			
Local infiltration + disbud	1.29	0.33	0.66–1.93	<0.001
Cornual block + disbud	2.32	0.36	1.62–3.03	<0.001
Intercept				
Body response 0–0.5	0.70	0.21	0.28–1.11	<0.001
Body response 0.5–1	1.58	0.26	1.08–2.09	<0.001
Body response 1–1.5	2.53	0.33	1.89–3.17	<0.001
Body response 1.5–2	3.27	0.39	2.51–4.04	<0.001
Body response 2–3	3.66	0.45	2.78–4.54	<0.001

¹Significance of coefficient in the model.

*Overall significance of treatment $P < 0.001$.

<https://doi.org/10.3168/jds.2018-15033>). Thus, in this model, there was no significant difference between the body reaction scores of calves disbudded under infiltration or cornual block.

The multiple intercepts for body response reflect the fact that the probability of a response of 0.0 to 0.5 is less than the probability of a response of 0.0 to 1.0 and less than the probability of a response of 0.0 to 1.5, and so on. The assumption that the coefficient values were appropriate across all levels of the ordinal response (parallel regression assumption) means that the increase in body response score associated with disbudding is equivalent across all levels of body score response.

The probability of a score below 1.0 to 1.5 is significantly greater for calves that are not disbudded or disbudded under local infiltration compared with calves disbudded under cornual block ($P < 0.05$). There was no significant difference between treatment groups in the probability of calves having a body reaction score of 1.5 to 2 or greater.

The probabilities were also used to predict the expected mean score for each treatment group; these are shown in Figure 4, together with the recorded mean treatment scores. Mean predicted body response of calves disbudded under a cornual block (1.2; 95% CI = 0.92–1.48) was significantly greater than the body response of calves disbudded under local infiltration (0.6; 95% CI = 0.40–0.86; $P = 0.005$). For both groups of disbudded calves, the median body response was significantly greater than for calves that were handled identically but otherwise not disbudded (0.15; 95% CI = 0.06–0.24; $P < 0.001$).

Behavior in the 3 h After Disbudding

Total Count of Behaviors. The total number of times that each behavior was recorded in the 3 h after disbudding for each treatment group is presented in Table 5. P -values for a univariable group comparison test within each treatment group are not presented because of repeated observations within calf.

Total Count of Head Shaking. In the analysis of the total number of observed behaviors, only the number of head shakes was significantly related to treatment group ($P = 0.023$), and a negative binomial model fit the data better than a Poisson model ($P < 0.001$; overdispersion parameter = 0.81; SE = 0.51). Calf sex and farm of origin were forced into the model as suspected confounders. The results of the model are presented in Table 6.

The model predicted that the rate of head shaking would be significantly greater in all treatment groups

compared with the control group that was not given local or disbudded. Figure 5 shows the predicted and actual counts of head shakes for each treatment group together with the Tukey adjusted 95% confidence intervals.

Behavior Every 20 Min After Disbudding

Head Shaking. Only head shaking behavior was significantly different between treatment groups ($P = 0.022$) when recorded and analyzed every 20 min. There was no difference in the likelihood of a Poisson model compared with a negative binomial ($P = 1.0$; overdispersion parameter = 0.002; SE = 0.0001), but the Poisson model was selected on the basis of a lower AIC value. Calf sex and farm of origin were forced into the model as suspected confounders. The results of the model are presented in Supplemental Table S2 (<https://doi.org/10.3168/jds.2018-15033>).

The variance within each calf for the number of head shakes recorded at each time was high (0.104) compared with the variance between calves (0.005). Correspondingly, the intraclass correlation coefficient was 0.05 (95% CI = 0.009–0.109), suggesting that clustering was having only a minimal effect on the standard errors of the coefficients. The model with observation time included as a fixed effect fit the data better ($P = 0.002$) than a model with a random slope for observation time.

The model predicted that adjusting for all time observations and when all other covariates are at a value of zero, disbudded calves shake their heads more than calves that are not disbudded. Supplemental Figure S5

Figure 4. Predicted (gray bars) and actual (black bars) mean body response score for the 3 treatment groups from a multivariable ordinal probit model used in this study. Error bars represent Tukey-adjusted 95% CI for the mean. Letters (a–c) indicate difference between treatments.

Table 5. Total counts (no.) and frequency (%; 95% CI in parentheses) of each behavior in the 3 h after disbudding

Item	Treatment ¹				
	CON (n = 20)	INF-NDB (n = 10)	CNB-NDB (n = 10)	INF-DB (n = 20)	CNB-DB (n = 10)
Head shake					
Count	6	8	8	26	24
Frequency	0.3 (0.11–0.65)	0.8 (0.35–1.58)	0.8 (0.35–1.58)	1.3 (0.85–1.90)	1.2 (0.77–1.79)
Head scratch					
Count	6	3	4	5	14
Frequency	0.3 (0.3–0.11)	0.3 (0.06–0.88)	0.4 (0.11–1.02)	0.25 (0.08–0.58)	0.25 (0.38–1.17)
Head rub					
Count	4	3	1	1	0
Frequency	0.2 (0.05–0.51)	0.3 (0.06–0.88)	0.1 (0.00–0.56)	0.05 (0.00–0.28)	
Self-groom					
Count	30	12	9	17	23
Frequency	1.5 (1.01–2.14)	1.2 (0.62–2.10)	0.9 (0.41–1.71)	0.85 (0.50–1.36)	1.2 (0.73–1.73)
Running					
Count	12	5	3	14	10
Frequency	0.6 (0.31–1.05)	0.5 (0.16–1.17)	0.3 (0.06–0.88)	0.7 (0.38–1.17)	0.5 (0.24–0.92)

¹CON = no local, no disbud (control); INF-NDB = local infiltration, no disbud; CNB-NDB = cornual block, no disbud; INF-DB = local infiltration, disbud; CNB-DB = cornual nerve block, disbud.

(<https://doi.org/10.3168/jds.2018-15033>) shows the predicted and actual counts for each treatment group at each time of observation together with the Tukey adjusted 95% confidence intervals.

Allowing for the effects of sex, farm, treatment group, and observation time, calves that are disbudded shake their heads significantly more often at the first observation 20 min after disbudding than calves that are not disbudded ($P < 0.001$). There was no significant interaction between observation time and treatment ($P = 0.229$), in agreement with the coefficients in Supplemental Table S2 (<https://doi.org/10.3168/jds.2018-15033>) and the predicted probabilities in Supplemental Figure S5 (<https://doi.org/10.3168/jds.2018-15033>).

Lying Time Before and After Disbudding

The median time spent lying across all groups after disbudding (45 min; range = 0–60) was more than the median time lying before disbudding (41 min; range = 0–60; $P < 0.001$). However, there was no difference in the median time per hour spent lying by treatment group before ($P = 0.720$) or after ($P = 0.927$) disbudding. The median time per hour spent lying by treatment group before and after disbudding is shown in Supplemental Table S3 (<https://doi.org/10.3168/jds.2018-15033>).

In the multivariable mixed model, only the time of day and the time spent lying before disbudding were significant. Treatment group was not significant ($P =$

Table 6. Negative binomial model predicting the change in the log of the number of counts of head shaking in the 3 h after disbudding (95% CI in parentheses)

Input variable	Estimate	SEM	P-value ¹	Incidence rate ratio	LSM incidence rate ²
Intercept	−1.26	0.48	0.009		
Treatment group ³					
Not disbudded	Referent				0.32 (0.12–0.63)
Local infiltration, not disbudded	1.68	0.59	0.005	5.35 (1.74–18.25)	1.71 (0.76–3.88)
Cornual block, not disbudded	1.65	0.59	0.005	5.22 (1.69–17.90)	1.67 (0.76–3.66)
Local infiltration, disbudded	1.46	0.53	0.006	4.28 (1.57–13.18)	1.37 (0.73–2.57)
Cornual block, disbudded	1.35	0.54	0.013	3.85 (1.37–12.13)	1.23 (0.67–2.25)
Farm					
Farm 1	Referent				1.06 (0.56–1.99)
Farm 2	0.07	0.34	0.85	1.07 (0.54–2.12)	1.13 (0.72–1.77)
Sex					
Female	Referent				1.01 (0.71–1.43)
Male	0.16	0.45	0.72	1.17 (0.47–2.91)	1.18 (0.53–2.61)

¹Significance of coefficient in the model.

²Least squares means prediction from the regression model.

³Overall significance of treatment in the model $P = 0.023$.

0.678), and there were no significant interactions in the model. The results for this model are presented in Supplemental Table S4 (<https://doi.org/10.3168/jds.2018-15033>). Model prediction of the lying time per hour for the 24 h after disbudding is plotted against the observed data in Supplemental Figure S6 (<https://doi.org/10.3168/jds.2018-15033>).

DISCUSSION

The results from our study suggest that the local infiltration block method may be a viable alternative to the cornual nerve block method for the provision of anesthesia for calf disbudding. Compared with a cornual block, we found that onset of anesthesia was faster and less varied, pain response during disbudding was no greater, pain responses in the 3 h following disbudding were equivalent, and lying behavior associated with pain was equivalent for the 24 h after disbudding. Producers' ability to implement a change is a key element to adopting new techniques (Jansen et al., 2009; Sorge et al., 2010). We believe the ease of administration and the faster onset produced by this alternative method

of anesthetic administration will be more attractive to on-farm users and will promote greater use of local anesthetic for disbudding.

We acknowledge, though, that one of the potential limitations of this study was the needle prick test used to confirm effective anesthesia. Calves undergoing CNB had a greater time to effect than INF calves and therefore received more needle pricks and were restrained for longer ($P < 0.001$). Although this was done to ensure that all animals were adequately anesthetized before disbudding, it meant that some animals received more needle pricks than others. If repeated needle pricks acted as a source of anxiety for the calves, this could potentially have confounded the relationship between the method of local anesthetic administration and the outcomes of the study. However, the needle prick test was designed to cause an aversive response rather than a painful one in the present study, and we do not believe this test would have been sufficient to lead to aversive anticipation in the calves. Moreover, there was no difference in the time to effect between CNB calves that were disbudded and CNB calves that were not disbudded ($P = 1.0$), meaning that all CNB calves received an

Figure 5. Predicted (gray bars) and actual (black bars) count of head shakes for each treatment group together with the Tukey adjusted 95% confidence intervals. Different letters (a, b) indicate a difference ($P < 0.05$) for a pairwise comparison between the predicted values for each group.

equal number of needle pricks and were restrained for the same time. Despite this, CNB calves that were disbudded had a greater median body response than CNB calves that were not disbudded ($P = 0.010$), suggesting that the difference in body response was not due to the increase in restraint time or needle pricks. We believe this makes it unlikely that the difference in body response between calves disbudded under CNB and calves disbudded under INF ($P = 0.029$) was attributable to differences in the time to effect. Furthermore, studies evaluating anxiety and central sensitization in animals and humans generally repeat the stimulus at much shorter intervals than 30 s (Herrero et al., 2000; Coste et al., 2008), which may give the animals and the nervous system more time to recover.

Although in the field it is unlikely that calves will receive multiple needle pricks before disbudding, it is still the case that calves disbudded under cornual block will require a longer wait time between administration of local anesthetic and disbudding. Stewart et al. (2008) recommended a wait period of 10 min for the local anesthetic to be effective, which will involve either restraint in the handling facility for this time or double handling of each calf. When we attempted to adjust for time to effect analytically (Jager et al., 2008), inclusion of time to effect changed the model coefficients by $<20\%$. Although the probability of an adverse response for cornual block calves decreased when time was included, there was no statistical difference in the predicted probability of an adverse response ($P = 0.763$).

In this situation, our null hypothesis was that there is no difference in the coefficients regardless of whether time to effect is included. Simulation studies allowing for the odds ratio, sample size, and correlation between time and group indicated that to keep the probability of a type 1 error $<5\%$ and maintain power above 80%, for variables to be treated as confounders they would need to induce a change in coefficient values greater than 30% (Lee, 2014).

Consequently, we treated time to effect as an intermediary variable (Chaiton et al., 2015) lying on the causal pathway between exposure and outcome (Greenland, 2008). In these circumstances, including intermediary variables leads to overadjustment bias and an inappropriate downward adjustment of the effect of treatment (Hernández-Díaz et al., 2008; Schisterman et al., 2009; Ananth and Schisterman, 2017).

The cornual nerve block has been recommended over a ring block (Winder et al., 2017) because of a greater duration of anesthesia after the procedure (Fierheller et al., 2012). In addition, the deposition of local anesthetic proximal to the site of disbudding may lead to a poorer effect because local anesthetic (e.g., lidocaine)

is less likely to dissociate to its active form in an acidic environment resulting from tissue damage (Anderson and Edmondson, 2013). Given that anesthesia from lidocaine persists for approximately 2 h (Sutherland et al., 2002) irrespective of how it is administered, we would recommend the addition of a nonsteroidal anti-inflammatory drug at disbudding to both the local infiltration and cornual block in accordance with Stafford and Mellor (2011) and Stock et al. (2013).

We did not observe any difference in the 3 h or the 24 h after disbudding in calf behavior. Our presample power calculation suggested that we would have had power in excess of 80% for observation of head shakes and scratches as well as self-grooming and running (Table 5). In addition, our number of study animals was comparable with those used in other papers (8 calves per group in McMeekan et al., 1999; 6 calves per group in Theurer et al., 2012; and 10 calves per group in Faulkner and Weary, 2000). We cannot rule out a lack of power in our present study, but we suggest that any difference in the postoperative behavior between calves disbudded with a cornual block versus a local infiltration block is small.

Although we had high interobserver agreement for the measure of calf behavior during disbudding, a lack of available trained staff meant that we were not able to measure interobserver agreement for the 3 h of observation after disbudding. However, as all observers were blind to treatment status, any bias in observation would have been evenly distributed between the treatment groups.

The efficacy of the cornual block in our study was less than the 75 to 91% reported by Winder et al. (2018) and the 87.5% reported by Fierheller et al. (2012). In our study, the person administering the blocks was not blind to the treatment status during the analysis period, and it is possible that lack of operator skill or familiarity with the technique could have been a factor. Qualification status and length of time qualified is no guarantee that a cornual block will be administered correctly. However, the question becomes, if lack of skill was a factor, how well would relatively inexperienced farm staff manage this task?

In their study looking at the effect of different training methods, Winder et al. (2018) demonstrated that 75 to 91% of farm staff with no previous experience could achieve an effective cornual block in a single calf when the evaluation period was the first 5 s of disbudding and the time between injecting the cornual block and disbudding was standardized to 10 min. We observed some calves responding adversely to disbudding as soon as the disbudding iron was applied, whereas others would show a negative response only when the

horn bud was scooped out at the end of the procedure. Potentially, this latter group would not have been recorded as a negative reaction when only the first 5 s of disbudding was scored; therefore, our recording technique may have been more sensitive. We also reported greater range in the body reaction under cornual block compared with local infiltration block. This suggests that successful evaluation should be based on observation of multiple measures of pain in response to disbudding.

We also reported a greater range in the time to skin desensitization under the cornual block compared with the local infiltration block. Time of onset for lidocaine is 2 to 5 min (Coetzee, 2013). Rapid onset of action with a cornual nerve block is dependent on proximity of placement of the lidocaine to the branches of the cornual nerve, with delay or failure associated with deposition in the muscle, deep to the nerve fibers (Skarda, 1996; Anderson and Edmondson, 2013). We suggest that the time delay between administration of the block and disbudding is critical for its efficacy. This needs to be factored into training along with an effective means of assessing block efficacy, such as a blink response during administration of the block and drooping of the eyelid thereafter (Skarda, 1996). In the current study, all calves were assessed for skin sensitivity to needle prick before disbudding, but some disbudded calves still had a body reaction score higher than control calves. As a test for anesthesia for hot iron disbudding, absence of response to needle prick may overestimate the degree of block.

Whether time to effect is treated as a confounding or intermediary variable, these results suggest that the local infiltration block is as effective as the cornual block method for alleviating the immediate pain associated with disbudding. Further work on farmer training in the use of the local infiltration and cornual block is warranted to establish a method of delivering effective pain relief on farm. Additional methods of recording nociceptive perception such as infrared thermography (Stewart et al., 2009), heart rate variability (Stewart et al., 2008), and response to mechanical or electrical stimulation (Heinrich et al., 2010) should be applied to calves disbudded with the local infiltration block to ensure that they are not worse off postoperatively than calves disbudded under a cornual block.

Reliable local anesthesia for calf disbudding is increasingly recognized as an industry requirement. The local infiltration block method appears to represent a viable alternative to the cornual block method and may have some practical advantages for use by nonveterinarians. Further work is required to evaluate the efficacy of nerve blocks when applied by farmers.

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