Effects of a Concentrated Lidocaine Solution on the Acute Phase Stress Response to Dehorning in Dairy Calves

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ABSTRACT

The objective of this study was to more fully define the surgical stress response to dehorning by heat cauterization in dairy calves by measuring behavioral, hormonal, inflammatory, and immunological markers of stress and to determine whether a nerve block of the surgical site with a concentrated solution of lidocaine (5%) reduces the degree of stress. Thirty-two 10- to 12-wk-old female Holstein calves were randomly allotted to 1 of 4 treatments: 5% lidocaine followed by dehorning, 2% lidocaine followed by dehorning, saline followed by dehorning, or 5% lidocaine followed by sham dehorning. Plasma cortisol concentration was measured in blood samples collected via a jugular catheter at -0.5, 0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 6, 9, 12, 24, 48, and 72 h. Various other blood constituents were measured in samples collected at -0.5, 12, 24, 48, and 72 h. Feeding, drinking, scratching, grooming, rubbing, licking, and inactivity behaviors were observed in the standing and recumbent positions using a 10-min scan sampling method analyzed on a time period and daily basis for 72 h following the dehorning procedure. The frequency of vocalization, kicking, and lying in the chute during the dehorning procedure were also assessed. The overall plasma cortisol concentrations were higher in calves subjected to dehorning than in control calves. Compared with the control group, the saline-treated calves had a higher cortisol concentration at 30 and 60 min postdehorning. Plasma cortisol concentrations were higher in all groups at 30 min postdehorning than at other sampling times. The percentage of circulating neutrophils and the neutrophil:lymphocyte ratio were increased in the saline and 2% lidocaine group. Total plasma protein, fibrinogen, and α_1 -acid glycoprotein concentrations were similar among treatments. The behavioral response to dehorning, as manifested by kicking while in

the chute, was greater in the saline and 2% lidocaine group than in the control or 5% lidocaine treatment groups. In the postdehorning period, the percentage of time calves spent performing various maintenance behaviors did not differ among treatments. Thus, injection of 5% lidocaine may not provide any added comfort after the dehorning but may decrease the overall stress response during the procedure.

Key words: calf, dehorning, cortisol, lidocaine

INTRODUCTION

Dehorning of cattle is a commonly performed husbandry procedure designed to reduce the risk of injury to herd mates and stock persons handling the animals in confined areas. The well-being of calves undergoing the dehorning procedure has been of great concern. Recognition and assessment of acute stress and pain following procedures such as dehorning is difficult, although a combination of physiological and behavioral measures has been recommended to more accurately measure an animal's reaction (Grandin, 1997; Ewing et al., 1999). Dehorning, regardless of the method used, has been shown to affect the animal's physiology (e.g., increased heart rate and plasma cortisol concentration) and behavior (e.g., greater frequency of head shaking and rubbing) in a manner typical of an acute stress response (Sylvester et al., 1998; Graf and Senn, 1999; Grøndahl-Nielsen et al., 1999). In addition, changes in several circulating acute phase proteins, including fibrinogen, haptoglobin, and α_1 -acid glycoprotein, have been associated with the animal experiencing trauma, pain, or inflammation (Eckersall and Conner, 1988; Gilpin et al., 1996; Stull et al., 1999).

In many countries, including the United States, dehorning is performed without the use of local anesthesia, whereas in most European countries, the procedure is regulated so that calves older than 7 d of age (depending on the country) must receive a local anesthetic. Research has shown that most local anesthetics are effective in decreasing the initial cortisol response; how-

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ever, once the local anesthetic loses its effectiveness, cortisol concentrations increase and are similar to those in calves dehorned without anesthesia (Sylvester et al., 1998; Graf and Senn, 1999; Grøndahl-Nielsen et al., 1999). The nonsteroidal anti-inflammatory drug ketoprofen, combined with local anesthesia, reduced the short-term cortisol (McMeekan et al., 1998b; Stafford et al., 2003) and behavioral responses (Faulkner and Weary, 2000; Milligan et al., 2004) to dehorning beyond that which was provided by local anesthesia alone.

Although a 2% lidocaine solution is typically used in the clinical setting, recent information indicates that a 5% solution of lidocaine produces a long-lasting, preferential block of C nerve fibers, which are involved in the conduction of dull, poorly localized, throbbing pain (Choi and Liu, 1998). In clinical studies in humans, 5% lidocaine infiltrated around peripheral nerves controlled intractable chronic pain for at least 5 wk (Choi and Liu, 1998).

The aim of the present study was to assess the effectiveness of 5% lidocaine versus 2% lidocaine in providing prolonged analgesia and reducing the stress response in dairy calves during the 72-h period after hot-iron dehorning.

MATERIALS AND METHODS

Calf Housing and Acclimation

Thirty-two healthy, Holstein Friesian heifer calves, 10 to 12 wk of age, were blocked in groups of 4 according to their date of birth. Four days prior to surgery, a group of calves was transported to an environmentally controlled room maintained at 23°C with continuous light and housed individually in 1.2 × 2.4 m pens fitted with a rubber floor mat. During the acclimation period, calves were handled at least 4 times a day for a minimum of 5 min per visit, at which time they were gently restrained and their necks stroked to simulate the activity of blood sampling via a catheter. Calves were offered 2.7 kg of a pelleted grower feed containing 16% CP twice daily at 0830 and 1630 h, and water was provided ad libitum. The University of Tennessee Animal Care and Use Committee approved all animal use in this study.

Experimental Procedures and Design

One day before surgery, calves were sheared at the base of their horns, and a jugular catheter (Angiocath, 16G, 83 mm, Becton Dickinson, Sandy, UT) fitted with an extension set (Microbore Extension Set, Abbott Laboratories, North Chicago, IL) and injection port (Argyle, Sherwood Medical, St. Louis, MO) was placed to allow for frequent collection of blood. A 2% lidocaine (Lido-

caine HCl Injection 2%, Burns Veterinary Supply Inc., Rockerville Centre, NY) solution was used to anesthetize the skin over the vein prior to catheterization. To prevent coagulation, catheters were filled with a heparin-saline solution (10 IU/mL), and the injection port was changed daily. The extension and catheter were secured to the calf's neck using 5.0-cm-wide flexible bandaging tape (3M Vetrap, 3M Animal Care Products, St. Paul, MN).

On the day of surgery, each of the 4 calves was randomly assigned to 1 of 4 treatments: 1) 5% lidocaine injection (Xylocaine-MDF; Astra USA Inc., Westborough, MA) followed by sham surgery (control), 2) 5% lidocaine injection followed by dehorning (5% lidocaine), 3) 2% lidocaine injection (VedCo, St. Joseph, MO) followed by dehorning (2% lidocaine), and 4) saline injection (0.9 Sodium Chloride Injectable, Abbott Laboratories) followed by dehorning (saline). A total of 10 mL of injectate was administered to each calf, with 3 mL being deposited adjacent to the cornual branch of the zygomatico-temporal nerve, 3 mL adjacent to the cornual branch of the infratrochlear nerve, and 4 mL rostral to the horn base to desensitize areas supplied by cervical nerves (Butler, 1967). Treatments occurred approximately 30 min prior to surgery.

Calves were lead to a nearby room and guided into a holding chute. The saline-, 2% lidocaine-, and 5% lidocaine-treated calves were dehorned by an experienced veterinarian using a hot-iron dehorner (Rhinehart X50 with thermostat, Nasco, Fort Atkinson, WI) at 538°C. The control calves had a cold iron placed on the horn-bud for the same amount of time that it took to do the actual dehorning. All calves were sprayed with a fly spray (Calron IV, Boehringer Ingelheim, Permethrin 0.5%) following dehorning to minimize the risk of infection.

Behavior

Animal behavior was recorded using ceiling-mounted video cameras (Panasonic Model WVCP412, Panasonic, Secaucus, NJ). Continuous recordings (Panasonic VCR Model # AG-6730P) were taken over the 72-h period in which blood samples were collected. Scan sampling, where each animal was viewed in one frame of videotape every 10 min, was used in conjunction with a computer event recorder (Observer 3.0, Noldus, Wageningen, the Netherlands) to record the frequency of a variety of maintenance behaviors (Table 1). Each day was partitioned into six 4-h time periods, with the first time period spanning from 0700 to 1100 h. Twenty-four 10-min scan samples per period with 6 time periods provided a total of 144 observations per day. A separate camera, video, and sound recorder were used to docu-

Table 1. Description of behaviors recorded following dehorning

Behavior	Description
Eating	Ingestion of food, including head in the bucket without actually ingesting
Drinking	Ingestion of water, including head in the bucket without actually ingesting
Standing-inactive	Standing in pen without performing any behavior, includes walking
Standing-grooming	Standing in pen and grooming the body using the tongue
Standing-scratching	Standing in the pen and using one of the legs to scratch any part of the body
Standing-licking	Standing and licking parts of the pen
Standing-rubbing	Standing and pressing the head on parts of the pen
Recumbent-inactive	Lying and performing no defined behavior
Recumbent-grooming	Lying and grooming the body using the tongue
Recumbent-scratching	Lying and using one of the legs to scratch any part of the body
Recumbent-licking	Lying and licking parts of the pen
Recumbent-rubbing	Lying and pressing the head on parts of the pen

ment the animals' behavior and vocalization during the dehorning procedure.

Blood Collection and Analyses

At 0630 h, a blood sample (10 mL) was collected from each calf via the jugular catheter 30 min prior to administering the treatment (−1.0 h) and again immediately prior to dehorning (0 h). The remaining blood samples were collected at 30 min intervals for the first 4 h following the procedure. Subsequent blood samples were taken at 6, 9, 12, 24, 48, and 72 h postdehorning. Prior to sample collection, 3 mL of blood was removed via the catheter and discarded. Each blood sample was aliquoted to 2 tubes containing 1.5% EDTA. One tube was analyzed for red blood cell number and subsequently hemolyzed for analysis of white blood cell (total and differential), hemoglobin and fibrinogen by using the Cell-dyne 3500 (Abbott Laboratories). The neutrophil:lymphocyte ratio was calculated for each sample. Plasma was collected from the second tube following centrifugation at $2,000 \times g$ for 20 min at 4°C, aliquoted into three 1.8-mL cryogenic vials, and stored at −20°C until analyzed for total cortisol, total protein, and α_1 -acid glycoprotein.

Total Cortisol. Plasma total cortisol concentration was determined using an RIA procedure (Coat-A-Count, Diagnostic Products, Los Angeles, CA). Samples were analyzed in duplicate and counted for 1 min using a gamma counter (Cobra II Auto-gamma counter, Model D5005, Packard Instrument Co., Meriden, CT). Cortisol concentration was expressed as nanomoles per liter of plasma. Intra- and interassay coefficients of variation were 6.9 and 8.9%, respectively.

Plasma Proteins. Total plasma protein concentration was determined using the TS meter (Leica, Buffalo, NY), and plasma fibrinogen concentration was determined with the heat precipitation method. The α_1 -acid glycoprotein concentration was determined using a single radial immunodiffusion assay kit (Cardiotech Ser-

vices, Lexington, KY). Plasma or standard (5 μ L) was added to wells of gel plates containing antiserum to the acute phase protein being measured. The diameter of the ring was inversely related to the amount of the acute phase protein. Results were evaluated using a logarithmic regression ($Y = -928.2 + 205.18\ln X$, $r^2 = 0.995$) to determine the acute phase protein concentration in each plasma sample. Measurement of the precipitin ring's diameter allows the calculation of the acute phase protein concentration as compared to known standards. Intraassay coefficient of variation of duplicate estimates was 5.1%.

Statistical Analyses

A completely randomized design with 4 treatments and repeated measures across days and time periods was used for statistical analysis of the behavioral and physiological measures. Analysis was performed using the MIXED procedure (SAS Institute, 2004), where a calf was considered the experimental unit. For all behavioral variables measured following the dehorning procedure, the model included effects for type of anesthetic treatment, time period, and treatment $\times$ time period interaction, where time period is hours or days depending on the measure. For all physiological variables, the model included effects for type of anesthetic treatment, sampling time, and treatment $\times$ sampling time interaction. For the behavioral data while the calves were in the chute, the model included treatment only. Error terms were calf (treat) for treatment and the residual for hour or day terms. Least squares means and standard errors were calculated for all variables, and means were compared using protected pairwise contrasts.

RESULTS

Because of technical difficulties, no video was obtained on 6 of the calves while in the chute during

Table 2. Mean ($\pm$ SE) percentage of time dehorned calves were observed exhibiting each behavior during restraint after treatment with or without local anesthesia with lidocaine

Treatment	n	Restraint time (s)	Behavior (%)		
			Lying	Kicking	Vocalizing
Control ¹	7	253 $\pm$ 33	2.9 $\pm$ 5.1	0.5 $\pm$ 5.3 ^a	0 $\pm$ 0.9
5% Lidocaine	6	315 $\pm$ 35	0.3 $\pm$ 5.5	1.0 $\pm$ 5.8 ^a	1.5 $\pm$ 1.0
2% Lidocaine	7	310 $\pm$ 33	10.9 $\pm$ 5.1	15.2 $\pm$ 5.3 ^b	1.1 $\pm$ 0.9
Saline	6	346 $\pm$ 35	10.4 $\pm$ 5.5	15.3 $\pm$ 5.8 ^b	1.9 $\pm$ 1.0

^{a,b}Means within column having different superscript letters differ ($P = 0.009$).

¹Control calves not dehorned but given 5% lidocaine.

dehorning/simulated dehorning (Table 2). For the remaining calves, the length of time spent restrained in the chute during the procedure ranged from 144 to 476 s, with the average time among treatment groups being similar. The percentage of time calves were observed kicking during restraint in contrast to remaining still was greater ($P = 0.009$) for the saline and 2% lidocaine compared with the control and 5% lidocaine treatment groups. Standing versus lying and vocalization versus non-vocalization behaviors while in restraint were not different among treatments.

Frequency of maintenance behaviors after dehorning was summed for the 72-h taping and the results presented on a percentage basis by day (Table 3). Because

of their low incidence of occurrence (fewer than 1.0% over 72 h), the data from 6 of the selected behaviors (standing-scratching, standing-rubbing, standing-licking, recumbent-scratching, recumbent-rubbing, recumbent-licking) were combined and analyzed under the behavioral category of other. The percentage of time spent performing each of the behaviors was not significantly different among calves due to treatment, time period, or treatment $\times$ time period interaction. Overall, calves spent more than 60% of their time displaying recumbent-inactive behavior, especially from 2300 to 0700 h. The percentage of time calves spent eating, drinking, and standing-inactive, regardless of treatment, was greatest ($P < 0.001$) from 0700 to 1100 h and 1500 to 1900 h (9.9 and 6.3 $\pm$ 0.7%, respectively). From 1500 to 2300 h calves displayed more ($P < 0.001$) standing-grooming and standing-licking activity compared with other times of the day. Contrast statements, comparing control versus dehorned calves and saline versus anesthetic-treated calves, were not statistically different for any of the maintenance behaviors examined.

Mean plasma cortisol concentrations in control, 2% lidocaine-, 5% lidocaine-, and saline-treated calves are presented by time of sampling in Figure 1. Regardless of treatment, plasma cortisol concentration was greater ($P < 0.001$) in all calves 30 min postdehorning compared with the other sampling times. The saline-treated ani-

Table 3. Daily percentage of time dehorned calves (n = 8/group) spent performing various maintenance behaviors after treatment with or without local anesthesia with lidocaine

Treatment	Behavior, % of observations						
	Eating	Drinking	Standing-inactive	Standing-grooming	Recumbent-inactive	Recumbent-grooming	Other
Control ¹							
d 1	4.2	2.8	18.2	1.9	64.8	5.3	2.8
d 2	3.5	1.8	13.6	1.9	69.4	7.5	2.3
d 3	3.3	1.7	16.8	1.6	69.5	5.4	1.7
SE	0.7	0.4	1.5	0.5	2.0	1.2	1.3
Overall $\pm$ SE	3.7 $\pm$ 0.5	2.1 $\pm$ 0.3	16.2 $\pm$ 1.1	1.8 $\pm$ 0.4	67.9 $\pm$ 1.5	6.1 $\pm$ 0.9	2.2 $\pm$ 0.7
5% Lidocaine							
d 1	4.3	2.7	20.4	1.1	64.2	5.6	1.7
d 2	5.3	1.6	13.0	2.0	70.3	6.1	1.7
d 3	4.0	1.4	16.7	1.5	71.4	4.7	0.3
SE	0.7	0.4	1.5	0.5	2.0	1.2	1.3
Overall $\pm$ SE	4.5 $\pm$ 0.5	1.9 $\pm$ 0.3	16.7 $\pm$ 1.1	1.5 $\pm$ 0.4	68.6 $\pm$ 1.5	5.4 $\pm$ 0.9	1.4 $\pm$ 0.7
2% Lidocaine							
d 1	4.7	2.9	19.2	1.9	58.3	5.8	7.2
d 2	3.9	2.1	13.4	2.4	70.6	6.4	1.2
d 3	3.5	2.5	15.5	1.8	69.7	6.0	1.0
SE	0.7	0.4	1.5	0.5	2.0	1.2	1.3
Overall $\pm$ SE	4.0 $\pm$ 0.5	2.4 $\pm$ 0.3	16.0 $\pm$ 1.1	2.0 $\pm$ 0.4	66.2 $\pm$ 1.5	6.0 $\pm$ 0.9	3.4 $\pm$ 0.7
Saline							
d 1	4.2	2.6	19.1	1.9	66.2	4.8	1.2
d 2	3.3	1.8	11.8	2.3	74.4	5.5	0.9
d 3	5.5	1.9	13.5	1.8	70.9	6.0	0.4
SE	0.7	0.4	1.5	0.5	2.0	1.2	1.3
Overall $\pm$ SE	4.3 $\pm$ 0.5	2.1 $\pm$ 0.3	14.8 $\pm$ 1.1	2.0 $\pm$ 0.4	70.5 $\pm$ 1.5	5.4 $\pm$ 0.9	0.9 $\pm$ 0.7

¹Control calves not dehorned but given 5% lidocaine.

Figure 1. Mean ($\pm$ SEM) plasma cortisol concentrations in 10- to 12-wk-old Holstein calves ($n = 8$ /group) administered 2% lidocaine and dehorned ($\blacktriangle$), 5% lidocaine and dehorned ($\blacklozenge$), saline and dehorned ($\bullet$), or 5% lidocaine and not dehorned ($\blacksquare$). ^{a,b}Means within the same time differ from the other treatments ($P < 0.05$).

mals exhibited a greater ($P = 0.02$) cortisol response at 30 and 60 min postdehorning compared with animals in the other 3 treatment groups. Calves treated with 5% lidocaine had a greater cortisol concentration than did the control group ($P = 0.02$), saline group ($P = 0.001$), and the 2% lidocaine group ($P = 0.029$) at 4 h postdehorning. Calves subjected to dehorning tended ($P = 0.07$) to display an overall greater plasma cortisol concentration compared with the control group.

The percentage of circulating neutrophils and the neutrophil:lymphocyte ratio was greatest ($P < 0.001$) at 12 h with saline- and 2% lidocaine-treated animals exhibiting the greatest values during this time (Table 4). There were no treatment or sampling time effects for the remaining blood measurements (data not shown).

DISCUSSION

The purpose of this study was to document changes in select physiological and behavioral indices of stress in dairy calves following hot-iron dehorning, and to examine whether the injection of a 2 versus 5% lidocaine

solution would alter the stress response. The calves in the present study were slightly older than the usual age at which calves are dehorned, and it has been recommended that calves be dehorned by 3 mo of age (Agriculture Canada, 1990). In general, calves in commercial production systems are dehorned by 8 wk of age; however, because calves are often dehorned as a group at the end of the calving season some will invariably be older than 12 wk. Some calves in the present study were at the upper limit of these age recommendations; however, they were of a similar age to calves in other dehorning studies (Boandl et al., 1989; McMeekan et al., 1998a; Stafford et al., 2003). The horn buds of the calves in the present study were small enough so that they could be successfully removed with a hot iron.

All calves exhibited a spike in cortisol concentration within 30 min of treatment. The saline- and 2% lidocaine-treated calves, however, displayed the greatest magnitude of cortisol increase. These results are similar to the findings of Boandl et al. (1989) who demonstrated an additive effect of handling, injection of an anesthetic, and dehorning on increasing plasma cortisol

Table 4. Distribution of neutrophils, lymphocytes, and neutrophil:lymphocyte (N:L) ratio within the circulation of dehorned calves (n = 8/group) after treatment with or without local anesthesia with lidocaine

Parameter	Time (h)	Treatment				Overall
		Control ¹	5% Lidocaine	2% Lidocaine	Saline	
Neutrophils, %	–0.5	41.0	44.7	46.1	40.5	43.0 ^a
	12	45.0	45.2	55.8	50.0	49.0 ^b
	24	44.8	45.2	44.2	41.0	43.8 ^a
	48	37.7	38.2	40.4	39.9	39.0 ^a
	72	37.3	41.1	49.0	43.6	42.8 ^a
SE		4.3	4.3	4.3	4.3	2.2
Overall ± SE		41.1 ± 3.2	42.9 ± 3.2	47.1 ± 3.2	43.0 ± 3.2	
Lymphocytes, %	–0.5	48.5	49.5	44.2	50.8	48.2
	12	49.6	49.4	37.8	42.2	44.7
	24	48.8	48.3	42.6	53.3	48.2
	48	55.2	53.0	47.4	49.6	51.3
	72	57.5	52.1	47.7	48.4	51.4
SE		4.1	4.1	4.3	4.1	2.1
Overall ± SE		51.9 ± 2.8	50.5 ± 2.8	43.9 ± 2.8	48.8 ± 2.8	
N:L ratio	–0.5	0.94	0.98	1.11	0.83	0.93 ^a
	12	0.98	1.09	1.62	1.37	1.27 ^b
	24	1.08	1.04	1.22	0.82	1.04 ^a
	48	0.79	0.80	0.93	0.91	0.86 ^a
	72	0.72	0.84	1.14	0.94	0.91 ^b
SE		0.19	0.19	0.20	0.20	0.10
Overall ± SE		0.90 ± 0.13	0.95 ± 0.13	0.97 ± 0.13	1.21 ± 0.13	

^{a,b}Means within variable with different superscript letters differ ($P < 0.001$).

¹Control calves not dehorned but given 5% lidocaine.

concentrations at 30 min postdehorning in similarly aged Holstein calves. Graf and Senn (1999) showed that local administration of 2% lidocaine prior to dehorning almost completely alleviated the cortisol response for the duration of the block; however, a significant increase in cortisol occurred at 3 h postdehorning. Others have reported this delayed increase, although the magnitude of the increase varies among studies, following hot-iron dehorning with 2% lidocaine (Sylvester et al., 1998; Grøndahl-Nielsen et al., 1999) and the longer-acting local anesthetic bupivacaine (McMeekan et al., 1998a). Petrie et al. (1996), using 2% lidocaine, however, found that the integrated cortisol response for the 7.5-h period posttreatment did not differ from that of control calves. Likewise, no delayed increase in cortisol occurred in the 2% lidocaine group in the present study.

The reasons for the difference in the delayed cortisol response among the studies are not immediately obvious. All studies were performed in the early part of the day, and whereas all simulations and dehornings in the present study occurred at approximately 0800 h, which was 2 to 3 h earlier than that performed by Graf and Senn (1999), diurnal differences of this magnitude were unlikely to have had a major effect on cortisol concentrations. Differences also existed in the method of achieving local anesthesia. Most studies block only the cornual nerve, whereas the study of Graf and Senn (1999) and the present study attempted to completely desensitize the surgical field by depositing lidocaine at 3 sites.

There appears then to be conflicting evidence on the degree of stress associated with hot-iron dehorning. Third-degree burns characteristic of those associated with thermal dehorning involve destruction of all the epidermal and dermal layers and extend down to the subcutaneous tissue. Burn injury can cause complete or partial desensitization of nociceptors at the burn site and thus may not cause severe pain. It is also interesting to note that cauterization of the skin and dermis around the horn bud, in the absence of local anesthesia, blunted the delayed cortisol response (Petrie et al., 1996). Third-degree burns can create extensive tissue damage and edema extending beyond the burn site. These changes result in an increase in the receptor field size to include areas of newly sensitized skin outside the original burn site, thus creating nociceptor activity outside of the primary area of thermal injury (Junger et al., 2002). Subtle differences in technique may account for reported differences between studies using thermal dehorning.

In contrast to the 2% lidocaine treatment, no increase in cortisol occurred in the 5% lidocaine-treated group at 30 min postdehorning; however, the cortisol concentration in the 5% lidocaine group was significantly greater than all treatments at 4 h postdehorning. If this were a true effect of the anesthesia wearing off, then cortisol should have remained elevated for a longer period. Reevaluation of individual calf data indicated that one calf had a cortisol value 4 times greater than

the mean of the remaining calves at 4 h postdehorning. When this calf was removed from the analysis, no significant difference existed between treatments.

The control and 5% lidocaine-treated calves responded similarly with regard to changes in cortisol and behavioral parameters recorded during dehorning. Calves in the 5% lidocaine group had a significantly lower incidence of kicking at induction compared with the saline and 2% lidocaine groups. In addition, 5% lidocaine appeared to mitigate any increase in the neutrophil:lymphocyte ratio within the first 12 h following dehorning in contrast with that seen for the saline and 2% lidocaine treatments. Stressful events such as abrupt weaning are also known to change the neutrophil:lymphocyte ratio in calves within 24 h (Hickey et al., 2003). An increase in the neutrophil:lymphocyte ratio has been reported in cattle 48 h following injection of dexamethasone (Anderson et al., 1999). Bovine neutrophils possess a high expression of glucocorticoid receptors and thus are sensitive to glucocorticoids (Burton et al., 1995). The increase in the neutrophil count in the early phase of glucocorticoid or stress-induced neutrophilia results primarily from the demargination of segmented neutrophils from blood vessels as a result of downregulation of surface adhesion molecule expression (Weber et al., 2004). Glucocorticoids have also been shown to influence neutrophil production and release from bovine bone marrow by inducing expression changes in a number of hematopoietic regulatory genes and prolong neutrophil survival by inhibiting apoptosis (Burton et al., 2005). Because these changes are initiated within 12 h, they may have contributed to the rapid, although nonsignificant, increase in neutrophil count seen in this study.

Behavioral differences observed in this study were detected only at the time of dehorning. Calves injected with 5% lidocaine prior to dehorning or simulation of dehorning had lower frequencies of kicking. This is an important observation, suggesting that perhaps calves injected with 5% lidocaine rather than 2% lidocaine or saline maintained a greater level of well-being during the procedure. Administration of a concentrated solution of lidocaine has been shown to cause irreversible conduction block of desheathed frog nerve (Lambert et al., 1994) and have a prolonged analgesic action following peripheral nerve block in human patients (Choi and Liu, 1998). Calves injected with 2% lidocaine behaved similar to calves treated with saline at the time of dehorning, which is in contrast to the results of a previous study (Graf and Senn, 1999). There is no clear explanation for this difference in the response to 2% lidocaine between the 2 studies. To ensure complete blockade of the surgical field, injections in both studies were performed by experienced persons, and both studies

used a similar method for injection. The only obvious difference is the age of the calves. Calves in the study by Graf and Senn (1999) were 4 to 6 wk of age compared with 10- to 12-wk-old calves in the present study, but how this may have affected the response to lidocaine is unclear.

The effects of sedating calves prior to injection of local anesthetic and dehorning have been investigated (Grøndahl-Nielsen et al., 1999; Vickers et al., 2005). In a study comparing the behavioral responses to hot-iron and caustic paste dehorning in calves given local anesthesia with 2% lidocaine and the α_2 sedative xylazine, calves began to show pain-related behaviors (head rubbing, head shaking, and transitioning from lying to standing) by 1 h after hot-iron dehorning (Vickers et al., 2005), indicating that xylazine did not have a long-lasting effect. Perhaps the main advantage of adding xylazine, which has analgesic effects in addition to its sedative action, is that it eliminates the calf's response to the initial handling for injection of the local anesthetic (Grøndahl-Nielsen et al., 1999).

Aside from behavioral differences occurring at the actual time of dehorning, no behavioral differences were noted among treatments in the post-dehorning period. Similarly, Morisse et al. (1995) showed that there was no difference in the ratio of standing to lying behavior (67 versus 33%) between the 24-h periods before and after dehorning when 2% lignocaine was injected prior to dehorning. In our study, calves were fed directly following the procedure, which may have masked any differences in behavior that might have been present in the first 2 h postdehorning.

Fibrinogen and α_1 -acid glycoprotein concentrations remained similar for all calves following dehorning. The reason for the lack of difference in treatments might be that it takes several days for an acute phase protein response (e.g., α_1 -acid glycoprotein) to occur (Downton and Colten, 1988). The acute phase protein haptoglobin, however, increased significantly on d 1 and continued to increase for 7 d following surgical castration of calves (Ting et al., 2003). Perhaps the magnitude of tissue inflammation following dehorning was not sufficient to induce a significant increase in acute-phase proteins.

Overall, the use of lidocaine, 2 or 5%, provided the animals with no additional pain relief following the dehorning procedure. Animals administered 5% lidocaine, however, showed relatively less discomfort during dehorning compared with calves given minimal (2% lidocaine) or no anesthesia based on their reduced incidence of kicking. The use of an adequate level of anesthesia (i.e., 5% lidocaine) may therefore provide an overall decrease in the stress response in calves at the time of dehorning.

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