

CATTLE BEHAVIORAL RESPONSES FOLLOWING CASTRATION AND DEHORNING  
MEASURED BY ACCELEROMETERS

by

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B.S., Pittsburg State University, 2006  
D.V.M., Kansas State University, 2011

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Clinical Science  
College of Veterinary Medicine

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

2011

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2011

## **Abstract**

Castration and dehorning are common husbandry practices in the United States. The objective of this research was to evaluate behavioral responses to these painful procedures. Two studies were conducted using three dimensional accelerometers to measure behavioral differences in cattle following dehorning and castration. The first study evaluated the potential of different analgesics to mitigate pain following castration and dehorning compared to negative controls as judged by behavioral measures. Holstein-Fresian calves given one of three different analgesic protocols (sodium salicylate, a combination of xylazine, ketamine and butorphanol, and both treatments together) or received no analgesia. All cattle were surgically castrated and dehorned. All treatment groups spent more time lying down and less time walking in the post-surgery than pre-surgery, and significant interactions were found between treatment and time relative to surgery ( $P < 0.05$ ). The second study evaluated behavioral changes following castration and dehorning performed independently or concurrently when compared to a negative control (no surgery). Accelerometers recorded behavior in Holstein-Fresian calves in which differing surgical procedures were performed: castration only (CO), dehorning only (DO), castration and dehorning (CD), and no surgical procedure performed (CON). Behavioral data was measured for 6 days following surgery. Significant interactions were found between treatment and time ( $P < 0.05$ ) in both walking and lying behavior. Calves that were dehorned and castrated spent less time walking one day after the procedure compared to controls, but very few other behavioral differences were identified. These studies illustrate that cattle behavior changes following painful procedures such as castration and dehorning.

## Table of Contents

List of Figures .....	vi
List of Tables .....	vii
Acknowledgements.....	viii
Chapter 1 - Thesis Introduction .....	1
Chapter 2 – Review of Literature.....	3
Introduction .....	3
Behavior Analysis .....	3
Dehorning.....	5
Castration .....	6
Conclusion.....	7
Chapter 3 - Evaluation of Analgesic Protocol Effect on Calf Behavior after Concurrent Castration and Dehorning .....	9
Abstract .....	9
Introduction.....	9
Materials and Methods .....	12
Animals and Treatment Allocation.....	12
Experimental Procedures.....	13
Behavioral Monitoring .....	14
Statistics.....	15
Results .....	15
Discussion .....	17
Conclusion.....	19
Chapter 4 - The effects of castration and dehorning on cattle behavior. ....	23
Abstract .....	23
Introduction.....	24
Materials and Methods .....	25
Castration and dehorning procedures .....	26
Behavioral data collection .....	27
Statistical analysis.....	28
Results.....	29

Discussion .....	29
Conclusions .....	31
Chapter 5 – Thesis Conclusion .....	35
Chapter 6 - References .....	37

## List of Figures

Figure 3-1. Model adjusted proportion of time lying by analgesic treatment group and study period.....	21
Figure 3-2. Model adjusted proportion of time walking by analgesic treatment group <sup>2</sup> and study period.....	22
Figure4-1. Model adjusted proportion of time walking by treatment group and study day. .....	33
Figure 4-2. Model adjusted proportion of time lying by treatment group and study day.	34

## List of Tables

Table 3-1. Model adjusted proportion (SE) of time lying and walking by analgesic treatment group through the three study periods. ....	20
Table 4-1. Study procedures by trial day as completed for each replicate. ....	26

## **Acknowledgements**

It is a privilege of mine to thank those who have helped me complete my Master's program. To the persons I am most grateful is my advisory committee consisting of Dr. Brad White, Dr. Hans Coetzee, and Dr. David Anderson through their constant mentorship and diligence I was able to complete a humbling goal. I was fortunate to have such a great committee that helped with every step of my program from setting up study designs to proof-reading papers and somehow they kept the process fun and rewarding.

I would also like to thank my colleagues that I was able to lean on and learn from. This list is not exhaustive but I would especially like to mention Brad Robert, Jason Nickell, Brian Lubbers, Abram Babcock, Sara Barron, Lindsey Kelly, Dr. Greg Hanzlicek and Charley Cull. These people were there to help in research trials and I was able develop friendships with them all and for this I'm greatly honored.



## **Chapter 1 - Thesis Introduction**

A growing consumer concern on animal welfare in the U.S and legislation in other countries raises the importance of understanding cattle responses to painful procedures such as castration and dehorning. These procedures are commonly performed as a part of routine management and evaluating ways to mitigate pain due following surgery is an important research goal. The U.S. currently has no legislation on the use of analgesics or procedural laws regarding castration and dehorning, but new regulations regarding analgesic use could be put in place similar to other countries. Research is needed to evaluate potential differences in cattle response based on analgesic use and the specific procedures performed.

Cattle behavior may be an important indicator of pain following surgical procedures; however, objectively measuring changes in activity in a field environment is challenging. Cattle should be monitored in their natural environment in a noninvasive way to document only changes related to the procedure of interest. Collecting these data are difficult in cattle without artificially altering their behavior by the presence of individuals or collection apparatuses. Accurately and objectively measuring cattle behavior differences due to painful procedures allows for future research to evaluate the utility of pain mitigation techniques. An increased understanding of cattle response to pain may provide insight for designing analgesic or operational protocols that can help decrease pain. Video observation and remote monitoring devices (such as accelerometers) have been used to objectively record animal activity and these tools may be valuable in measuring behavior changes following a painful procedure.

The research described in this thesis provides insight on how accelerometers can be used to analyze cattle behavior after painful procedures compared to negative control animals. A study (Chapter 3) was completed administering different analgesic protocols for calves before and after a sham and actual castration and surgical dehorning for activity analysis. The other study contained in this thesis (Chapter 4) compared the procedures of castration and dehorning independently and combined to determine cattle behavioral differences following these procedures. This research evaluates the behavioral changes following castration and dehorning and the potential impacts of specific analgesic protocols.

## **Chapter 2 – Review of Literature**

### **Introduction**

Common cattle production husbandry practices such as castration and dehorning are considered painful stimuli that may alter cattle behavior. Accurate assessment of changes in cattle behavior following painful procedures facilitates the ability to evaluate the utility of potential pain mitigation strategies including optimum use of analgesic protocols. Multiple methods exist to monitor behavior including video observations and the use of remote animal monitoring devices. Castration and dehorning are common procedures in cattle and previous research has evaluated the physiological and behavioral response to these surgical procedures. The purpose of this literature review is to describe common techniques for behavioral analysis in cattle and outline previous research related to cattle response following dehorning and castration.

### **Behavior Analysis**

Previous research has evaluated the potential correlation between behavioral measurements and pain in cattle. (Molony, Kent et al. 1995; Morisse, Cotte et al. 1995; Doherty, Kattesh et al. 2007) Specific behaviors such as head rubbing, head shaking, ear flicking, and changes in activity have been associated with pain in cattle.(Weary, Niel et al. 2006) Cattle behavior has been evaluated in numerous studies pertaining to dehorning, disbudding (Faulkner and Weary 2000; Stewart, Stookey et al. 2009) and castration. (Schwartzkopf-Genswein, Booth-McLean et al. 2005; Coetzee, KuKanich et al. 2009; Currah, Hendrick et al. 2009) Although several studies evaluate the pain response to castration or dehorning, relatively little research describes the impact when both procedures are performed at the same time, as is commonly done in typical production practices. (Schwartzkopf-Genswein, Booth-McLean et al. 2005)

Assessment of pain in cattle has historically been labor intensive, expensive, and in some instances subjective. In order to provide accurate measures of behavior various video recording techniques have been used and validated in cattle. (Mitlohner, Morrow-Tesch et al. 2001) Video analysis has been validated as a measure of behavior in a study of Holstein dairy cattle housed in pens where feeding and drinking behaviors were recorded.(Huzzey, Veira et al. 2007) Due to the evaluation process, video has to be watched or software programs used to record different activities. This creates a lag period between the cattle activity and analysis unless the video is watched real time. Video analysis is difficult in pen studies due to the number of animals which makes it difficult to monitor the whole population continuously. Recording behavioral data based on video observations may still be subjective due to human error in analyzing the video and classifying the behavior, and estimating the time that the animal was engaged specific behaviors.

An objective system that remotely monitors cattle activity has been used to measure behavioral changes in field settings. Three dimensional accelerometers are wireless, remote sensors that allow for measurements of both static and dynamic movements. The data can be downloaded chute side in a laptop computer. These data can then be put into a classification system into which activity can accurately be described as walking, lying, or standing and statistically analyzed.(Robert, White et al. 2009) Accelerometers are validated to be accurate in determining behavior as defined by time spent lying down, standing, and locomotion (Robert, White et al. 2009) and have been used in previous studies to record animal behavior.(White, Coetzee et al. 2008; Robert, White et al. 2011) The ability to remotely monitor cattle behavior allows an objective classification of animal activity in an efficient manner without the potential introduction of bias related to human interaction during the observation period.

## Dehorning

The use of analgesics during the dehorning to mitigate pain has been evaluated by behavioral evaluations during or after the surgical procedure.(Morisse, Cotte et al. 1995; Stafford and Mellor 2005; Doherty, Kattesh et al. 2007) Doherty et al (2007) used differing concentrations of lidocaine to block the cornual branch of the zygomatico-temporal nerve, infratrochlear nerve, and the cervical nerves 30 minutes prior to surgery. Ceiling-mounted video cameras using a scan sampling technique determined that various behaviors did not differ among treatments and a control group.(Doherty, Kattesh et al. 2007) Stafford et al (2005) evaluated previous research trials using amputation dehorning and cautery disbudding after giving analgesic treatments of a lidocaine cornual nerve block, ketoprofen (intravenously), and xylazine, in combination compared to negative control. The behavioral results showed many behaviors similar to controls with some differences 2-6 hours post procedure. Morisse et al (2005) disbudded calves using chemical treatment and heat cauterization. The two procedures each had two treatments consisting of a local lidocaine block and negative control. The calves were monitored using video with standing and lying activities being monitored 24 h before and after the procedures. No differences were found in the lying behaviors with either procedure or treatment during this time period. Local anesthetics have been evaluated related to dehorning and research has shown mixed results related to behavioral changes.

Previous research has also evaluated the use of systemic analgesics to mitigate pain associated with dehorning. One study compared two different treatments: one consisting of an intravenous injection of meloxicam compared to a control with both groups receiving a local lidocaine block.(Heinrich, Duffield et al. 2010) In this study the calves were electrically cauterized and accelerometers were used to monitor activity. The authors concluded that the

meloxicam treated calves had less activity after dehorning than the controls for the first 5 hours after the procedure but no difference between 5 hours and 24 hours, the completion of the activity study.(Heinrich, Duffield et al. 2010) These studies support the hypothesis that activities may differ based on the analgesic program utilized, but this effect varies over time following the procedure. These studies measured behavior for a relatively short period of time following the procedure, and it may be useful to monitor behavior for longer periods to determine if analgesic protocols have a lasting benefit.

### **Castration**

Research has also been completed that used analgesics before surgical castration and compared cattle behavior between analgesic groups. Currah et al (2009) used pedometers to monitor activity after surgical castration. There were three treatment groups: 1) castration without analgesia (control) 2) lidocaine given as via a caudal epidural 3) lidocaine epidural along with intravenous flunixin meglumine. This trial failed to find a difference in activity during the timeframe analyzed which was 24 hours after the procedure. In a study performed by Faulkner et al (1992) chute activity was visually measured and scored in on a 1 to 5 scale with 1 being the least active. Cross bred bull calves were castrated with intravenous administration of butorphanol and xylazine compared to a controls. Their results showed that castration and administration of butorphanol and xylazine decreased chute activity. Another study measured distress behavior in the chute during castration of beef calves in which low dose administration of xylazine and ketamine significantly reduced distress behaviors.(Coetzee, Gehring et al. 2010) Stafford et al (2007) also stated that a local anesthetic (lidocaine) minimized painful behavior during the castration procedure. These trials illustrate potential transient changes in behavior at or soon after

the time of castration when using analgesic protocols, but little research is present evaluating the potential longer term (>24 hours) impacts of analgesic utilization on cattle behavior.

A study was done by Molony et al (1995) that indicated that calves spent more time standing for 3 hours following castration than calves that were not castrated. In the aforementioned study they visually recorded the data. This study was in agreement with a study by White et al (2008) that used accelerometers to monitor standing behavior 24 hours post castration in beef calves, and found that castrated calves spent significantly more time standing (82.2%) in the 24 hours following the procedure than in the same period of time before castration (37.9%). Schwartzkopf-Genswein et al (2005) measured distress behavior in Holstein calves during the castration procedure and noted an increase in these behaviors compared to a sham procedure ( $P < 0.01$ ). In these trials no analgesia was used but there is indication that calves behavior is changed either during or following castration. These trials focus on changes during the procedure or in the first 24 hours post castration. Previous research illustrates that cattle demonstrate at least transient behavioral changes following castration. Evaluating behavior may be a valid tool to evaluate the impact of potential pain mitigation techniques such as analgesics.

### **Conclusion**

In summary, there have been studies evaluating the effects of castration and dehorning on cattle behavior. As a whole, this work illustrates changes in behavior after these procedures that are likely associated with pain. Most of these studies only evaluated behavior during the surgical procedure or for only a short period of time following the procedures. There are few studies evaluating both castration and dehorning performed simultaneously; yet, these procedures are often performed at the same time as a husbandry practice. Although most studies describe

transient behavioral changes following these surgical procedures, some of the findings are conflicting and more information is needed accurately describing behavioral changes following castration and dehorning. Observing behavior for a longer observational period may be warranted to determine if differences in behavior are still present after castration and/or dehorning with or without the addition of analgesia. Collection of data using remote animal monitoring devices (e.g. accelerometers) may be advantageous as data can be captured in a non-invasive manner and objectively analyzed. Further studies will provide more information in which to create recommendations to minimize pain utilizing evidence-based medicine.



## **Chapter 3 - Evaluation of Analgesic Protocol Effect on Calf Behavior after Concurrent Castration and Dehorning**

### **Abstract**

Castration and dehorning are common procedures in the U.S. cattle industry, but the impact of analgesic programs on post-surgical behavior when both procedures are performed concurrently is not well documented. The research objective was to determine the impact of three different analgesic protocols (sodium salicylate, a combination of xylazine, ketamine and butorphanol, and both treatments together) and the absence of analgesia on cattle behavior after concurrent castration and dehorning. Accelerometers recorded activity on 40 calves for three periods of time: prior to sham surgery, between sham and actual surgery, and four days post-surgery. Significant interactions were found between treatment and time relative to surgery; however few differences in behavior were found between treatment groups within each time period.

### **Introduction**

Surgical removal of the horns and testicles are common husbandry practices in the U.S. cattle industry.(Coetzee, Nutsch et al. 2010) Recent findings in 2007-2008 by the National Animal Health Monitoring System (NAHMS) stated that 77.1% of bulls are castrated prior to sale.(USDA 2008) Castration facilitates easier and safer cattle handling through decreased aggression, prevention of unwanted pregnancies, and improved carcass characteristics relative to

bull calves.(Faulkner, Eurell et al. 1992; Stafford 2007) Dehorning also has management advantages including decreased carcass bruising and decreased wounds inflicted by the horns. Cattle without horns also require less room at the feed bunk and during transport.(Faulkner and Weary 2000) According to the NAHMS 82.6% of cattle going into the slaughter market came from feedlot production systems, and in this close proximity environment the advantages for dehorning are pronounced.(USDA 2008) Although castration and dehorning are known to inflict pain (Faulkner and Weary 2000; Stafford and Mellor 2005) the benefits to the animal and the producer outweigh the adverse effects.(AVMA 2007)

The pain associated with castration and dehorning has led to legislation or recommendations for the use of analgesics during castration and dehorning (depending on age and procedure method) in several countries, including the United Kingdom, Switzerland, and Canada.(AVMA 2007) Currently the U.S. has no legislation for the use of analgesics but public awareness of animal welfare issues associated with these surgical procedures has increased.(Weary, Niel et al. 2006) Mitigation of pain associated with these procedures is important to animal care providers; however, little research exists documenting the effects of analgesic drug protocols on animal behavior. There is also a paucity of studies examining the combined effect of dehorning and castration on cattle behavior.

Pain assessment in cattle is cumbersome and often lacks validity.(Molony, Kent et al. 1995) Perception of animal pain is often subjectively measured using visual parameters to assess changes in behavior associated with pain.(Molony, Kent et al. 1995; Morisse, Cotte et al. 1995; Doherty, Kattesh et al. 2007) Validation of video recording using certain scan video collection techniques has been performed.(Mitlohner, Morrow-Tesch et al. 2001) However, video monitoring is labor intensive, expensive, and can be a somewhat subjective assessment of

changes in behavior. Accelerometers have been shown to accurately predict cattle behaviors (standing, lying, walking), (Robert, White et al. 2009) and have been used in previous research to characterize behavioral differences in cattle following castration.(White, Coetzee et al. 2008) Research has illustrated that cattle display varied lying behavior patterns throughout the day and the average time spent lying differs between calves.(Robert, White et al. 2011) Documenting changes in the lying behaviors of individual calves may prove useful for determining analgesic treatment efficacy following a painful procedure. Castration and dehorning are commonly performed at the same time to reduce veterinary costs, decrease stress on the animals due to chute procedures, and minimize handling times.(Schwartzkopf-Genswein, Booth-McLean et al. 2005) Published work exists that investigates the pain of castration (Faulkner, Eurell et al. 1992; Molony, Kent et al. 1995; Schwartzkopf-Genswein, Booth-McLean et al. 2005; White, Coetzee et al. 2008) and dehorning, (Morisse, Cotte et al. 1995; Schwartzkopf-Genswein, Booth-McLean et al. 2005; Doherty, Kattesh et al. 2007; Stewart, Stookey et al. 2009) separately; however, minimal research evaluates both procedures performed at the same time with the addition of analgesics.

The objective of this trial was to determine the impact of three different analgesic protocols compared to no analgesia on cattle behavior after castration and dehorning. The four pre-operative treatments were: negative controls (CON, no analgesia), sodium salicylate (SS) free-choice in the drinking water, a combination of xylazine, ketamine and butorphanol (XKB), and a combination of the last two treatments (XKBSS). Behavioral changes measured in this experiment may be indicative of differences related to pain or stress responses and the ability of the included treatments to mitigate that response. This work is unique as it provides an objective

measure of behavior (accelerometers) to evaluate potential changes associated with analgesic protocol when applied to calves dehorned and castrated concurrently.

## **Materials and Methods**

### ***Animals and Treatment Allocation***

All animals were handled in accordance with a protocol approved by the Kansas State University Institutional Animal Care and Use Committee (IACUC #2694). Calves were weighed upon arrival and the following measurements also recorded: horn-base diameter, horn length, and scrotal circumference. The calves were then processed with an eight-way clostridial vaccine (Covexin 8, Schering Plough, Summit, NJ), a modified-live viral vaccine (Bovi-Shield Gold 4, Pfizer, New York, NY), a metaphylactic dose of antibiotic (Draxxin, Pfizer, New York, NY), and given a pour-on anti-parasitic (Dectomax Pour-on, Pfizer, New York, NY). Amprolium (Corid, Merial, Duluth, GA) was added to the drinking water to provide 10 mg/kg per os (PO) for 5 days. Calves were blocked by arrival weight, scrotal circumference, horn base diameter, and horn length then randomly assigned to one of four treatment groups: negative controls (CON), sodium salicylate in the drinking water (Sodium Salicylate, Fisher Scientific, Fair Lawn, NY) (SS), a combination of xylazine (AnaSed ,Lloyd Laboratories, Shenandoah, IA), ketamine (Ketaset, Fort Dodge, Fort Dodge, IA) and butorphanol (Torbugesic, Fort Dodge, Fort Dodge, IA) (XKB), and a combination of the last two treatments (XKBSS). Negative controls received no analgesic treatments at any time point during the study but did receive an isotonic saline injection (1 mL) given IM one minute before the procedure. The cattle in the SS group were administered sodium salicylate via the drinking water 24 hrs at 2.5 to 5 mg/mL and continued to

receive this dose ad libitum until 48 hours after the actual procedure. Cattle in the XKB group received 0.05 mg/kg xylazine, 0.1 mg/kg ketamine, 0.025 mg/kg butorphanol via IM injection one minute before both sham and actual castration and dehorning. The final treatment group (XKBSS) received both SS and XKB treatments in the administered in the same manner and at the same dosages as described above.

### ***Experimental Procedures***

The trial was completed in 5 replicates with each consisting of 8 animals (n= 2 per treatment) in each replicate. Each replicate consisted of three basic phases: before the sham (mock) surgery (day 0 to day 3, PRE), between the sham and actual surgery (day 4 to day 5, SHAM), and post-surgery (day 6 to day 9, POST). On day 0, four days prior to sham castration cattle were individually housed in randomly allocated pens (3.5m x 3.5m) within a completely roofed facility with side doors that could be opened to regulate temperature. Throughout the study all calves were fed the same grain diet with free choice prairie hay.

All calves went through the same sham and surgical procedures with the same experienced individual performing all procedures. For the sham procedure, the calves were restrained by a halter in a squeeze chute along with the administration of tail elevation when the scrotum was approached and manipulated. The sham procedure consisted of palpating the scrotum with a rag soaked in dilute chlorhexidine solution (Chlorhexidine Solution, MWI, Meridian, ID). The horn bases were stimulated by removing the hair around the horn bud with electronic clippers (Oster Golden A5 Single Speed Vet Clipper, Jarden Corp., Rye, NY). The sham procedure was performed two days before the actual castration and dehorning allowing for a washout period for the xylazine, ketamine, and butorphanol. Sodium salicylate was

continuously administered 24 hours before the sham to 48 hours after the actual surgical procedures.

For the castration procedure, calves were restrained in the same manner as described for the sham castration. The calves were castrated by removal of the bottom third of the scrotum with a #21 scalpel blade and the removal of testicles by gloved hand using traction in accordance with standard industry practices. The removal of horns was accomplished with a Barnes-type dehorner (Stone Precision Barnes Dehorner, Stone Mfg., Kansas City, MO) and cauterization of the horn base after horn removal was done with an electronic hot iron (Stone Electric Dehorner Model 24210, Stone Mfg., Kansas City, MO). Blood stop powder (Blood Stop Powder, Agri Laboratories Ltd., St. Joseph, MO) was then applied to the horn base to help ensure clotting. The lesions of the horns and scrotum were sprayed with a fly insecticide (Prozap Screw Worm Aerosol, Chem Tech Ltd., Pleasantville, IA). Calves were monitored 4 times daily for potential clinical signs of illness or adverse sequelae from the surgical procedures.

### ***Behavioral Monitoring***

Each calf was outfitted with a tri-axial capacitive accelerometer (Sensr GP1 Programmable Accelerometer, Reference LLC., Elkader, IA) attached to the right rear leg just proximal the fetlock at initiation of each trial phase (day 0). The accelerometers were placed inside a padded waterproof case before attachment to the leg. The sham castration was performed on day 4, followed by castration and dehorning on day 6. Calves were monitored for a total of 10 days for each phase of the trial.

Accelerometers were downloaded chute-side three times for each replicate: at sham surgery, at the actual surgery, and at the end of the trial. During each download, the

accelerometer was removed from the case, connected to a laptop by USB for downloading, disconnected, put back in the case and reattached the calf's leg. Accelerometers were set to record five variables including average acceleration in each of the three axes (X, Y, Z) and the average and maximum vector magnitude. Each variable was aggregated over a 5 second epoch as previously described.(Robert, White et al. 2009) Data were processed through a previously described classification system(Robert, White et al. 2009) to classify the activity of the animal at each time point into standing, lying, or walking.

### *Statistics*

Classified accelerometer data was aggregated to calculate the percent of time each calf spent lying for each hour in the trial. To remove potential bias of human interaction due to other trial procedures such as blood collection, only the hours between 6 pm and 6 am were included in the statistical analysis. This allowed for analysis of behavior with minimal human interaction resultant of two blood draws. The accelerometer data were exported to a statistical software program (SAS 9.1, SAS Institute Inc., Cary, NC) for analysis. Logistic regression was used to determine potential associations between the amount of time spent lying and walking with analgesic treatment (CON, SS, XKB, XKBSS), time relative to surgical procedure (PRE, SHAM, POST), and the interaction between analgesic treatment and time relative to surgery. Calf identification was included as a random effect in the models to account for repeated measures on individuals. Trial replicate and hour of the study were included as random effects in all models to account for the lack of independence between animals within each replicate and each hour relative to treatment application.

### **Results**

Forty Holstein bull calves were enrolled in the trial (mean weight 153.6 kg / SE 11.50 kg) that had scrotal circumference (mean 16.76cm / SE 1.10cm), horn base diameter (mean 34.73mm / SE 2.56mm) and horn length (mean 42.12 mm / SE 4.93mm) measurements recorded. During the trial phase for each replicate no cattle were removed due to illness or adverse health events. After the trial period some calves acquired phlebitis at the catheter site and required antibiotic treatment. All accelerometer data points recorded during the time between 6pm and 6am were analyzed with none being discarded. Analgesic treatment group, time relative to surgery, and the interaction between treatment group and time period were all significantly ( $P < 0.02$ ) associated with the proportion of time calves spent lying down. As the interaction between time and treatment group was significant, only the interactive estimates are discussed. Calves in all treatment groups spent more time lying POST when compared to PRE. Cattle in all analgesic treatments, except XKBSS, the time spent lying was greater POST compared to SHAM (Table 3-1). When comparing within a time period, XKBSS calves spent more time lying PRE compared to all other treatment groups (Figure 3-1). In the POST period, XKBSS calves spent more time lying relative to XKB calves, yet CON or SS did not differ from either group.

Evaluation of the proportion of time walking also identified a significant interaction ( $P < 0.01$ ) between analgesic treatment and time relative to surgery; therefore, only interactive model results are described. Calves in all treatment groups spent less time walking POST compared to PRE readings (Table 3-1). Only the CON calves spent less time walking in the SHAM period compared to the PRE time frame. Comparing within study time frames, CON and SS calves spent more time walking compared to XKB and XKBSS calves in PRE time frame; however, CON calves spent less time walking post-surgery compared to SS and XKB calves in POST (Figure 3-2).



## Discussion

The experimental model of castration and dehorning concurrently performed induced a behavioral change exhibited by the control group that walked less and spent more time lying compared to the previous time frame following both sham and actual surgical procedures. The measurable change in behavior may be indicative of stress associated with processing in the SHAM period and stress with the addition of pain in the POST period. Cattle in each of the analgesic groups also followed the same behavioral trends as control cattle when comparing the PRE to POST time frames. Therefore, administration of the analgesic protocols selected for this research did not mitigate the behavioral changes associated with castration and dehorning at the same time.

Our finding of increased lying behavior post-surgery (in all treatment groups) contradicts previous research indicating cattle spend higher percent of time standing immediately following castration.(Doherty, Kattesh et al. 2007; White, Coetzee et al. 2008) These differences may be due to procedures performed, the timing of observations, and length of behavioral measurements. In the aforementioned studies, calves were only castrated, while in the current study both castration and dehorning were performed concurrently. The increase in standing behavior has been noted at 3 (Molony, Kent et al. 1995) and 24 (White, Coetzee et al. 2008) hours following castration; however, our current study had only limited data available for evaluation during this time period due to exclusion of hours between 6 am and 6 pm related to intensive cattle handling. Our data also covered a longer observational period of time post-surgery as measurements were recorded for four evenings after the surgery. The difference noted in the four day post-operative period may be meaningful and indicate that the recovery period to return to normal behavior is longer than the time period we monitored.

Previous research by Morisse et al. (1995) showed there were no differences in the time spent lying down after young calves were dehorned chemically or by cauterization with and without anesthesia when compared 24 hrs before and after dehorning. Morisse et al. (1995) used a video sampling technique in which a 1 minute video recording was taken every 15 minutes for 24 hours resulting in 96 observations per calf for which results were interpreted. The lack of a behavioral difference post-dehorning was also displayed by Doherty et al. (2007) in calves dehorned by hot iron and followed 72 hours afterward using a video scan sampling technique. During our experiment the calves were larger and dehorned by scoop dehorning so comparisons between our results and Doherty et al. (2007) study must take technique differences into consideration along with the use of different analgesics and a different behavioral monitoring system.

Cattle spent less time walking after the castration and dehorning than in pre-treatment measurement period. The percent of time cattle spent walking in our study was very low, and this is likely due to study constraints that restricted our data to nighttime hours when cattle normally spend most time resting.(Robert, White et al. 2011) The fact that the calves were in smaller pens with water and feed readily available also might have contributed to reduced walking behavior. Other studies document that cattle under similar husbandry conditions spend less time walking than standing or lying.(Mitlohner, Morrow-Tesch et al. 2001; White, Coetzee et al. 2008) Although walking as a percent of the total time period was very low, the finding of decreased walking behavior post-surgery may be an indicator of calf attitude or responsiveness to the environment. One interesting note was that the CON calves decreased walking behavior after the sham procedure; however none of the treated calves (SS, XKB, XKBSS) displayed different walking behavior in the SHAM period. This finding may indicate that the pharmaceutical agents

decreased animal stress during this time period, but walking behavior of these treated cattle decreased POST in a similar fashion as the CON group.

In this study, the experimental model induced a behavioral change in CON cattle; however, the analgesic agents selected did not mitigate these changes in the treated groups. The only behaviors analyzed in this study were time spent lying down and walking. This is because time spent lying down is very close to the inverse of standing due to the low percentage of time walking throughout the time periods and also because similar behaviors have been recorded in previous research allowing comparisons. (Molony, Kent et al. 1995; Morisse, Cotte et al. 1995; White, Coetzee et al. 2008) Control cattle spent less time walking and more time lying following the procedures; however the level of association between these measurements and pain in cattle should be explored with further research.

### **Conclusion**

This research provides behavioral trends following the concurrent procedures of castration and dehorning. Although the analgesic treatments may have contributed to changes in other parameters following castration and dehorning they did not mitigate the post-surgical lying and walking behavior changes when compared to controls. This research illustrates the use of objective measures to evaluate the ability of analgesic agents to minimize behavioral changes after a painful procedure.

**Table 3-1.** Model adjusted<sup>1</sup> proportion (SE) of time lying and walking by analgesic treatment group<sup>2</sup> through the three study periods.<sup>3</sup>

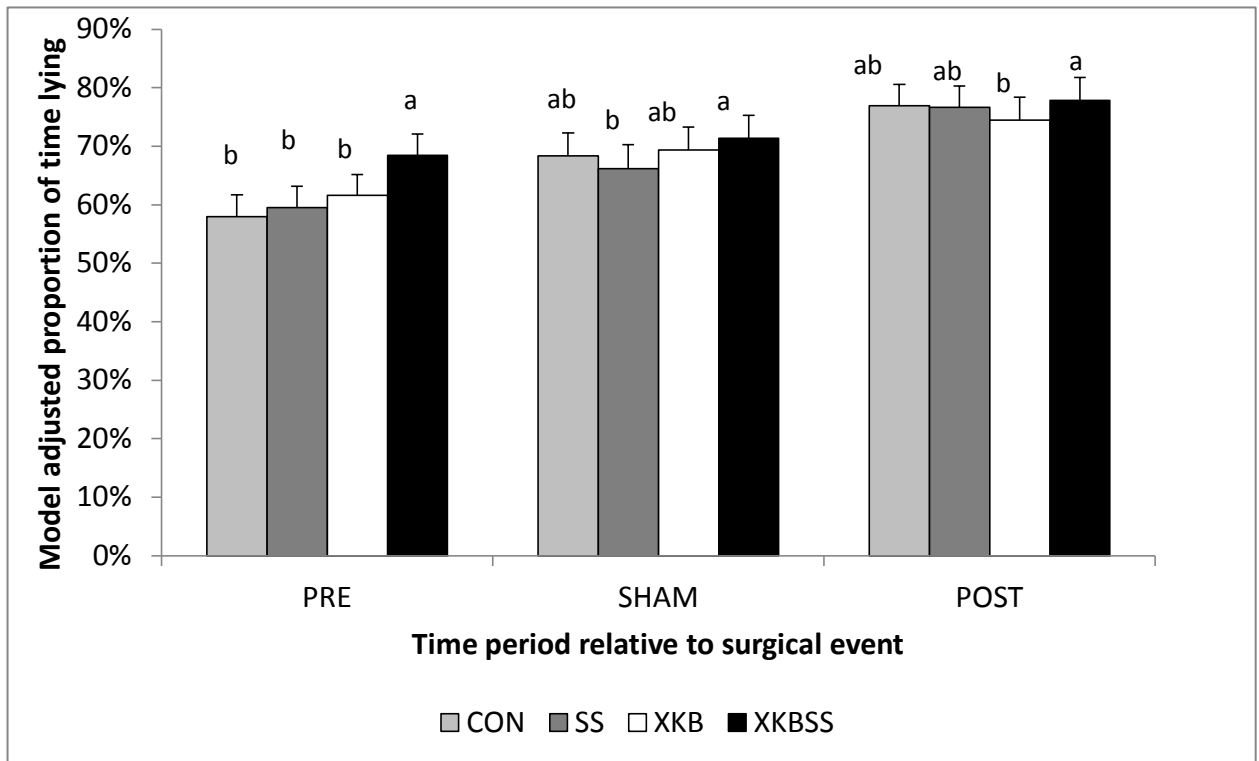
Activity	Analgesic Treatment	Time Period		
		PRE	SHAM	POST
<i>Lying down</i>				
	CON	58.0 <sup>a</sup> (3.7)	68.4 <sup>b</sup> (3.9)	77 <sup>c</sup> (3.6)
	SS	59.5 <sup>a</sup> (3.6)	66.2 <sup>b</sup> (4.1)	76.7 <sup>c</sup> (3.7)
	XKB	61.6 <sup>a</sup> (3.6)	69.3 <sup>b</sup> (3.9)	74.5 <sup>c</sup> (3.9)
	XKBSS	68.5 <sup>a</sup> (3.3)	71.3 <sup>a</sup> (3.7)	77.8 <sup>b</sup> (3.6)
<i>Walking</i>				
	CON	0.5 <sup>a</sup> (0.1)	0.3 <sup>b</sup> (0.1)	0.10 <sup>c</sup> (0.0)
	SS	0.5 <sup>a</sup> (0.1)	0.5 <sup>a</sup> (0.1)	0.2 <sup>b</sup> (0.0)
	XKB	0.4 <sup>a</sup> (0.0)	0.4 <sup>a</sup> (0.1)	0.1 <sup>b</sup> (0.0)
	XKBSS	0.3 <sup>a</sup> (0.0)	0.3 <sup>a</sup> (0.1)	0.1 <sup>b</sup> (0.0)

<sup>1</sup> Model included effects for repeated measures on individual calves, trial replicate and hour of the day data was collected. Differences ( $P < 0.05$ ) between time periods within analgesic treatment group are represented by differing superscripts within rows.

<sup>2</sup> The four pre-operative treatments were: negative controls (CON, no analgesia), sodium salicylate (SS), a combination of xylazine, ketamine and butorphanol (XKB), and a combination of the last two treatments (XKBSS).

<sup>3</sup> Time periods relative to surgical event are defined as: PRE = trial days 0-4 (trial initiation to sham surgery); SHAM = trial days 5-6 (sham to actual surgery); POST = trial days 6-10 (surgery to trial end).

**Figure 3-1.** Model adjusted<sup>1</sup> proportion of time lying by analgesic treatment group<sup>2</sup> and study period.<sup>3</sup>

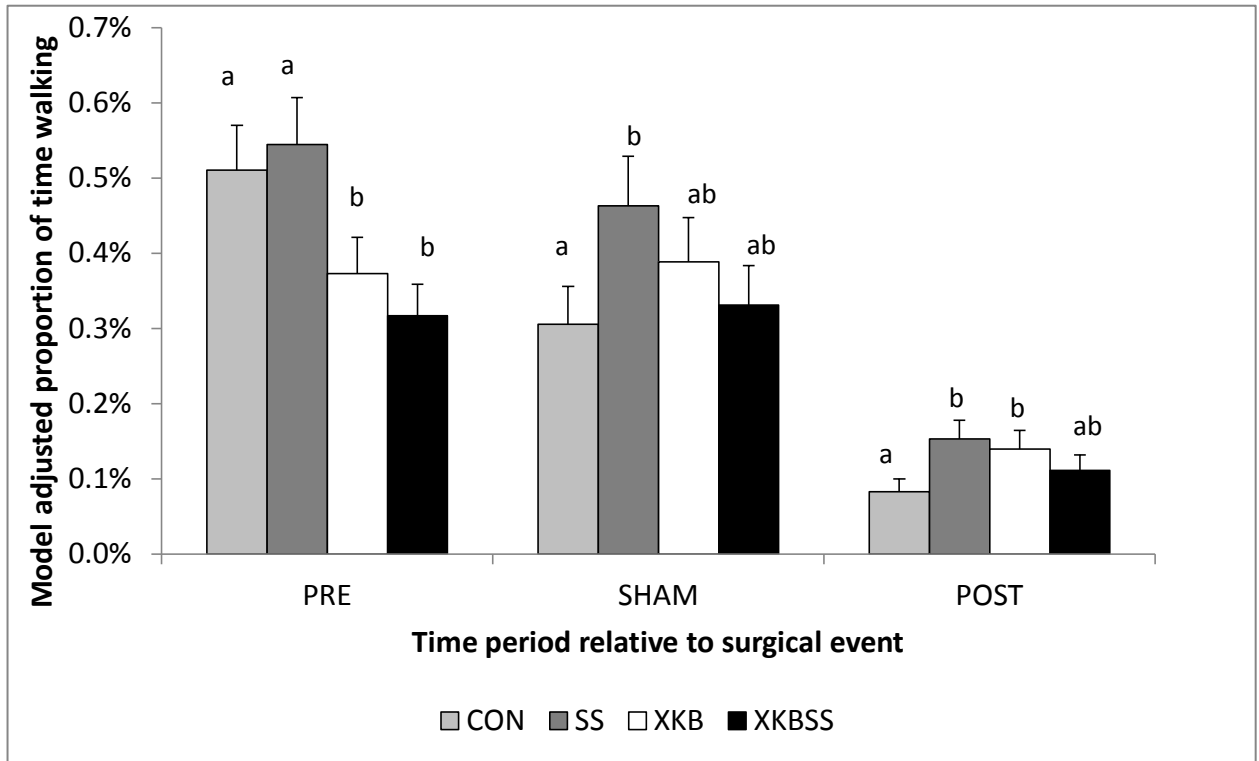


<sup>1</sup> Model included effects for repeated measures on individual calves, trial replicate and hour of the day data was collected. Differences ( $P < 0.05$ ) between analgesic treatments within each time point are represented by differing superscripts.

<sup>2</sup> The four pre-operative treatments were: negative controls (CON, no analgesia), sodium salicylate (SS), a combination of xylazine, ketamine and butorphanol (XKB), and a combination of the last two treatments (XKBSS).

<sup>3</sup> Time periods relative to surgical event are defined as: PRE = trial days 0-4 (trial initiation to sham surgery); SHAM = trial days 5-6 (sham to actual surgery); POST = trial days 6-10 (surgery to trial end).

**Figure 3-2.** Model adjusted<sup>1</sup> proportion of time walking by analgesic treatment group<sup>2</sup> and study period.<sup>3</sup>



<sup>1</sup> Model included effects for repeated measures on individual calves, trial replicate and hour of the day data was collected. Differences ( $P < 0.05$ ) between analgesic treatments within each time point are represented by differing superscripts.

<sup>2</sup> The four pre-operative treatments were: negative controls (CON, no analgesia), sodium salicylate (SS), a combination of xylazine, ketamine and butorphanol (XKB), and a combination of the last two treatments (XKBSS).

<sup>3</sup> Time periods relative to surgical event are defined as: PRE = trial days 0-4 (trial initiation to sham surgery); SHAM = trial days 5-6 (sham to actual surgery); POST = trial days 6-10 (surgery to trial end).

## **Chapter 4 - The effects of castration and dehorning on cattle behavior.**

### **Abstract**

Castration and dehorning are very common husbandry practices in cattle. These procedures may be done independently, but they are commonly performed concurrently in many production systems. Each of these procedures is considered painful; however, limited information exists evaluating the potential advantages or disadvantages of performing castration and dehorning at the same time or independently. The purpose of this clinical trial is to assess differences in cattle behavior following castration only, dehorning only, and castration with dehorning at the same time compared to negative controls that received no surgery. The hypothesis was that performing both procedures at once would have a greater impact on behavior than each procedure independently and performing any of the procedures would result in differing behavior from the negative control group. Forty Holstein calves were randomly allocated into one of the four procedures groups: negative control (no procedures, Con), castrated only (CO), dehorned only (DO), both castrated and dehorned (CD). Behavior (walking, lying down, and standing) was monitored for 6 days following treatment using accelerometers. Calves that were dehorned and castrated spent less time walking one day after the procedure compared to controls, but very few other behavioral differences were identified. The cattle from all treatment groups for each replicate were housed in a single pen, and pen behavioral patterns may have influenced the lack of differences between procedural groups.

## Introduction

Castration is a very common procedure worldwide in the cattle industry.(AVMA 2009) Castration decreases aggressive behavior and improves carcass characteristics.(Faulkner, Eurell et al. 1992; Stafford 2007) Dehorning is also a common procedure and will probably continue to be a necessity until all cattle are polled.(Stafford and Mellor 2005) Detrimental effects of horns include increased muscle bruising, other injuries inflicted by horns, and an increased requirement for feeding and transport space.(Faulkner and Weary 2000) Producers often perform both procedures at the same time(Coetzee, Nutsch et al. 2010) to decrease animal handling and help lower veterinary cost.(Schwartzkopf-Genswein, Booth-McLean et al. 2005)

Pain has been associated with both castration and dehorning (Faulkner and Weary 2000; Stafford and Mellor 2005) as judged by behavior.(Weary, Niel et al. 2006) Behavior may be a valid indicator of pain in cattle and previous research has illustrated behavioral changes following these procedures. Studies have been performed to determine behavioral differences cattle may exhibit following castration or dehorning.(Schwartzkopf-Genswein, Booth-McLean et al. 2005) The relationship between behavior and pain has been examined in previous research.(Molony, Kent et al. 1995; Morisse, Cotte et al. 1995; Doherty, Kattesh et al. 2007) However, research in behavioral response is sparse comparing these two procedures done at the same time compared to performing each individually.

The following project is unique because it not only provides behavioral comparisons for the separate and combined procedures but also implements accelerometers for a monitoring device. Accelerometers have been shown to accurately and remotely monitor cattle behaviors (standing, lying, walking). (Robert, White et al. 2009) Previous research has also validated the



use of accelerometers to monitor behavior post castration.(White, Coetzee et al. 2008) The objective of this experiment is to determine behavioral differences (standing, walking, lying) between castration and dehorning done at the same time (CD), castration only (CO), dehorning only (DO), in comparison to control cattle (Con). Our hypothesis was that the behavioral effects are additive when both surgical procedures are performed at the same.

### **Materials and Methods**

Forty Holstein bull calves were handled in accordance with a protocol approved by the Kansas State University Institutional Animal Care and Use Committee (IACUC). The day after arrival the following measurements were recorded and used to block calves into treatment groups: weight, horn-base diameter, horn length, and scrotal circumference. Calves were blocked and randomly assigned to one of four treatment groups: control (Con), castrated only (CO), dehorned only (DO), both castrated and dehorned (CD). The study was performed in 5 replicates with each replicate group consisting of 8 calves with two calves in each replicate receiving each of the four treatments.

Calves were housed in two large pens until initial processing, blocking and assignment to treatment groups. After treatment group assignments, calves were randomly assigned to replicate and each replicate group was housed in a single pen from the time of assignment until trial completion. Each replicate group was assigned a pen and calves stayed in their respective pen throughout the experiment except to be walked to the working chute for procedures. All calves were fed the same grain ration with free choice prairie hay.

The study was completed in three continuous weeks following the study schedule described in Table 4-1. All calves were haltered in their pen the day before their respective sham

procedure (Day -1) to allow for acclimation of the halter. The sham procedure was done on all groups the day previous (Day 0) to the actual treatments. The sham procedure for the group 1 was completed on the Day 0 following arrival and the sham for the group 2 was later in the week and so on until group 5 was completed. This allowed for actual surgical procedures to be done on Day 1 mornings beginning at 6:30 am. The calves were ran through the chute according to their respective treatments with the CD calves going first followed by the CO, DO, and Con respectively for both the sham and the actual surgeries.

**Table 4-1.** Study procedures by trial day as completed for each replicate.

<b><u>Study Day</u></b>	<b><u>Procedure</u></b>
<b>-1</b>	Acclimatization of cattle
<b>0</b>	Sham castration / dehorn
<b>1</b>	Dehorning and castration (by treatment group); begin accelerometer monitoring
<b>7</b>	Accelerometer monitoring ends

#### ***Castration and dehorning procedures***

All of the procedures, both sham and surgical, were done by the same individual in the same facility using restraint via squeeze chute, halter, and administration of tail elevation when the scrotum was approached. The sham procedure consisted of the calves processed through the facility and the different surgical procedures being mimicked. The sham castration was performed by stimulating the scrotum by palpation with a rag of dilute chlorhexidine solution (VetOne). The sham dehorning was done by stimulating the horn bud by clipping (Oster Golden A5® Single Speed Vet Clipper Jarden Corporation) the hair around the base of the horn. The control group was just restrained in the head catch for a brief period of time then released.

At the time of actual procedures, castration was performed first followed by dehorning in the DC group. Castration was done with a number 21 scalpel; the bottom third of the scrotum was cut across excised and the testicles were removed by hand traction and testicular vessels cut with the scalpel if protruding beneath the cut scrotum. This procedure was used because of its report of it being the most common procedure used by veterinarians in the U.S.(Coetzee, Nutsch et al. 2010)

The calves were dehorned using a scoop type dehorner (Stone Precision Barnes Dehorner, Stone Mfg, Kansas City, Mo, USA) and the bleeding base of the horn was cauterized using a electric hot iron (Stone Electric Dehorner 110/120 Volt ; 270 watts; Model 24210 Stone Mfg, Kansas City, Mo, USA.) Blood stop powder (Blood Stop Powder. Agri Laboratories, Ltd., St. Joseph, MO, USA) was then applied to control the hemorrhages. This procedure was also the most common method of dehorning with U.S. veterinarians.(Coetzee, Nutsch et al. 2010) The control treatment groups went through the same sham procedure (Day -1) but during the actual procedure day (study Day 0) they were just restrained in the chute with a halter and no procedures were performed.

### ***Behavioral data collection***

A tri-axial capacitive accelerometer (Sensr GP1 Programmable Accelerometer, Reference LLC., Elkader, IA) was affixed to the lateral aspect of the right rear leg just proximal to the fetlock on each calf. The accelerometers recorded five variables including average acceleration in the X,Y, and Z axes along with the maximum and average vector magnitude as previously described.(Robert, White et al. 2009) The accelerometers were placed on the calves the morning before the sham procedure but all data taken from this time to 5 pm the following day (surgical procedure) were not analyzed as this period of time was used as an acclimatization phase for the

accelerometers. Accelerometer data were organized to have six 24 hour periods (days) that started at 5 pm of actual procedure day. This time was the beginning of accelerometer study (Study Day 1). This allowed for acclimation of the accelerometers to the calf and also gave time to monitor placement. This concurrently certified consistency for comparison between replicates with decreased human interaction beginning at 5 pm of the actual procedure. The accelerometers were and left on for 7 days following the surgical procedures. After the completion of the data collection the accelerometers were removed and data was retrieved using a laptop computer as previously described.(Robert, White et al. 2009) The data went through a previously described classification system(Morisse, Cotte et al. 1995) to classify the calf's activity into lying down, standing, or walking.

### *Statistical analysis*

Accelerometer data were aggregated to hourly periods within each day to allow for comparisons of activity among treatment groups and over time. Potential associations between the number of days post-surgery, treatment group and the percent of time lying and walking were analyzed using generalized logistic regression (SAS 9.1, SAS Institute Inc., Cary, NC). Replicate group and calf identification were utilized as random effects in the models to account for lack of independence due to repeated measures on individuals and calves within each replicate.

## **Results**

The 40 Holstein bull calves had mean measurements with standard deviations as follows: body weight 143.85 kg (+/- 40.07); horn base diameter 33.09 mm (+/- 7.58 mm); horn length 35.15 mm (+/- 10.16 mm); scrotal circumference 17.8 mm (+/- 2.0 mm). No cattle were removed from the trial at any point due to health or any other parameters. All accelerometer data points for the 6 study days were analyzed without any being discarded.

There were significant interactions between treatment group and study day ( $P < 0.05$ ) in both walking and lying behavior patterns. (Figures 4-1 and 4-2) The CD treatment group spent less time walking than DO and CO treatment groups on day 2 ( $P < 0.05$ ) and less time than DO on day 3 ( $P < 0.05$ ). The DO group spent less time lying on study day 5 compared to CD group; however, no other significant differences within day between treatment groups were identified.

## **Discussion**

This research illustrated that lying and walking behavior did not vary much between cattle that were castrated, dehorned, or had both procedures performed simultaneously when compared with negative controls. Although significant interactions were identified between treatment group and study day, differences between treatment groups within each study day were sparse. Cattle were housed by replicate group; therefore, cattle from each treatment group were in the same pen and the social effect in the pen may have modified the behavior displayed by individuals in each group. Weather should have not been a confounder as the study was completed over a 5 week period using the replicate groups where the procedural groups were represented equally.

The significant differences found between time spent walking on day 2 between CD and DO/Con may be due to an effect of castration decreasing activity as pertained to walking (Figure 4-1). The CO group, however, is not significantly different than any of these groups. Currah et al (2009) used pedometers to measure activity 24 hours before and after castration and found that there was less activity in the cattle not receiving analgesia between these time points. This agrees with our data pertaining to decreased activity but there is a discrepancy in the time frame. It may be that there is an additive effect of dehorning with castration to lower walking activity and compared with dehorning alone but this is only during day 2. The lack of observed differences throughout the study period may be related to the fact that all calves from the different treatment groups were housed in the same pen. The sample size in the experiment may also be inadequate to be able to determine significant differences that may be seen with more observations.

There is only one significant difference between treatment groups within study days in the lying behavior between CD and DO on study day 5 (Figure 4-2). This finding was in disagreement with our expectation that calves castrated would spend more time standing than the ones not being castrated. This expectation was due to a finding by White et al (2009) in which castrated calves spent more time standing 24 hours post castration than 24 hours pre castration. In the aforementioned study all the calves being observed were castrated and individually housed. Our findings were similar to other work (Currah, Hendrick et al. 2009) that found no behavioral differences in time spent lying down at visual assessments at 4, 8, 12, and 24 hours post castration.

The pen effect may be a large influence on behavior meaning the behaviors are socially facilitated as stated by Currah et al (2009). Since cattle are prey species there may be a disadvantage to show injury to potential predators. If cattle are housed together then it would be

plausible that the animals in pain due to the procedures mask these effects do to an inherent biological response making them try to fit in with the group. Anecdotally, we noticed that all animals within the pen followed common standing and lying patterns regardless of treatment group. However, during the standing periods some were noticed to just be standing in the shaded area of the pen and the others were standing at the bunk eating. In this study, the accelerometers are not capable of distinguishing between calves that are standing in a single location compared to cattle that are standing and eating. Other parameters need to be measured in order to determine if other behaviors differ when surgical castration and dehorning when done currently or separately.

The high variability in behavioral measures that has been identified by Robert et al (2010) is evidence that even though cattle follow a circadian rhythm individual animals can have erratic behaviors that can construe observations. This large variation in individual cattle behavior combined with only having 10 calves per treatment group is also a probable cause that there are not more significant differences between procedural groups.

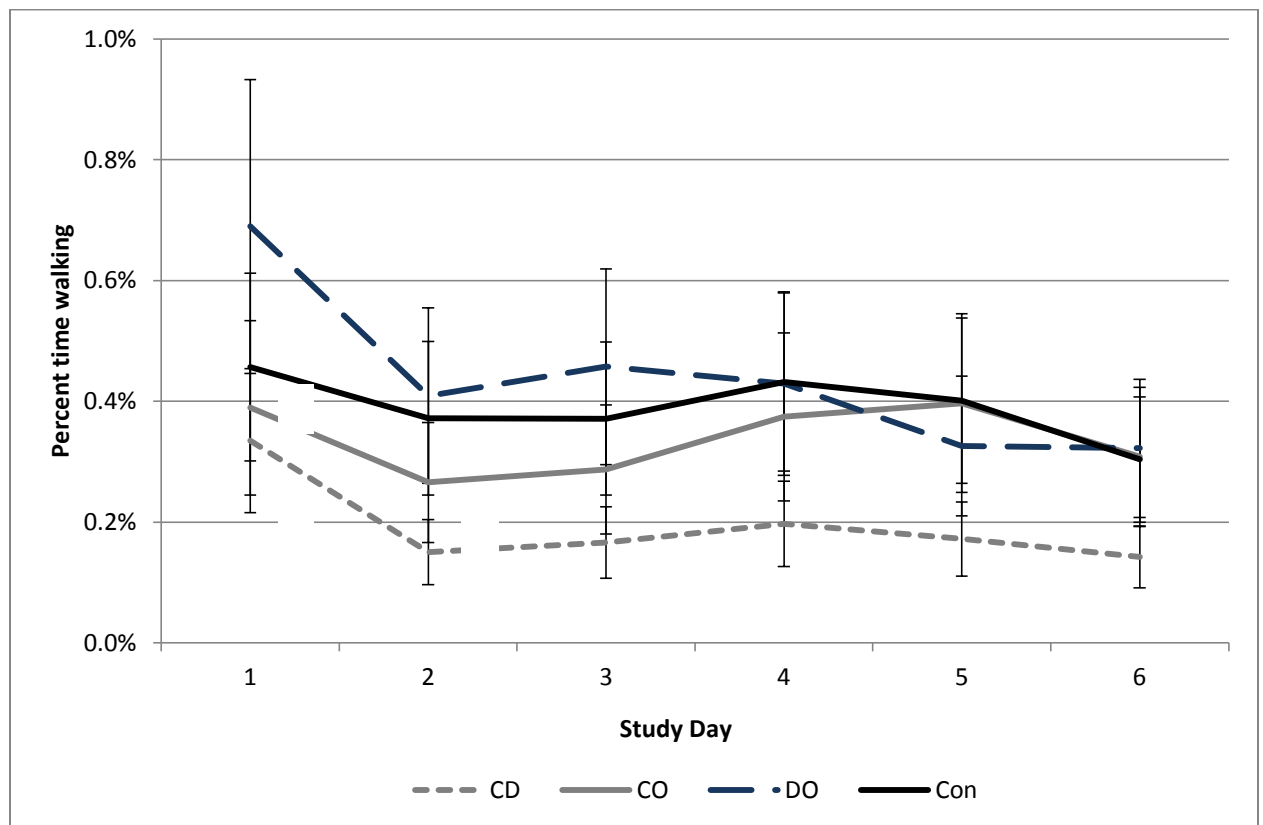
### **Conclusions**

This study found few differences in cattle behavior pertaining to lying, standing, and walking for the treatments of castration, dehorning, both in combination and comparison to a control. The lack of differences can lead to the hypothesis that there are no deleterious effects if these procedures are done concurrently pertaining to behavior. However, differences may have been masked by inherent biological and social behavioral cofounders such as prey species mentality or highly variable individual behavior among calves. We may have also have had an inadequate number of cattle to indicate differences in behavior. The differences that were found,

however, should be evaluated further by future studies that follow more cattle for a longer period of time before the above assumptions can be verified.



**Figure 4-1.** Model adjusted<sup>1</sup> proportion of time walking by treatment group<sup>2</sup> and study day.<sup>3</sup>

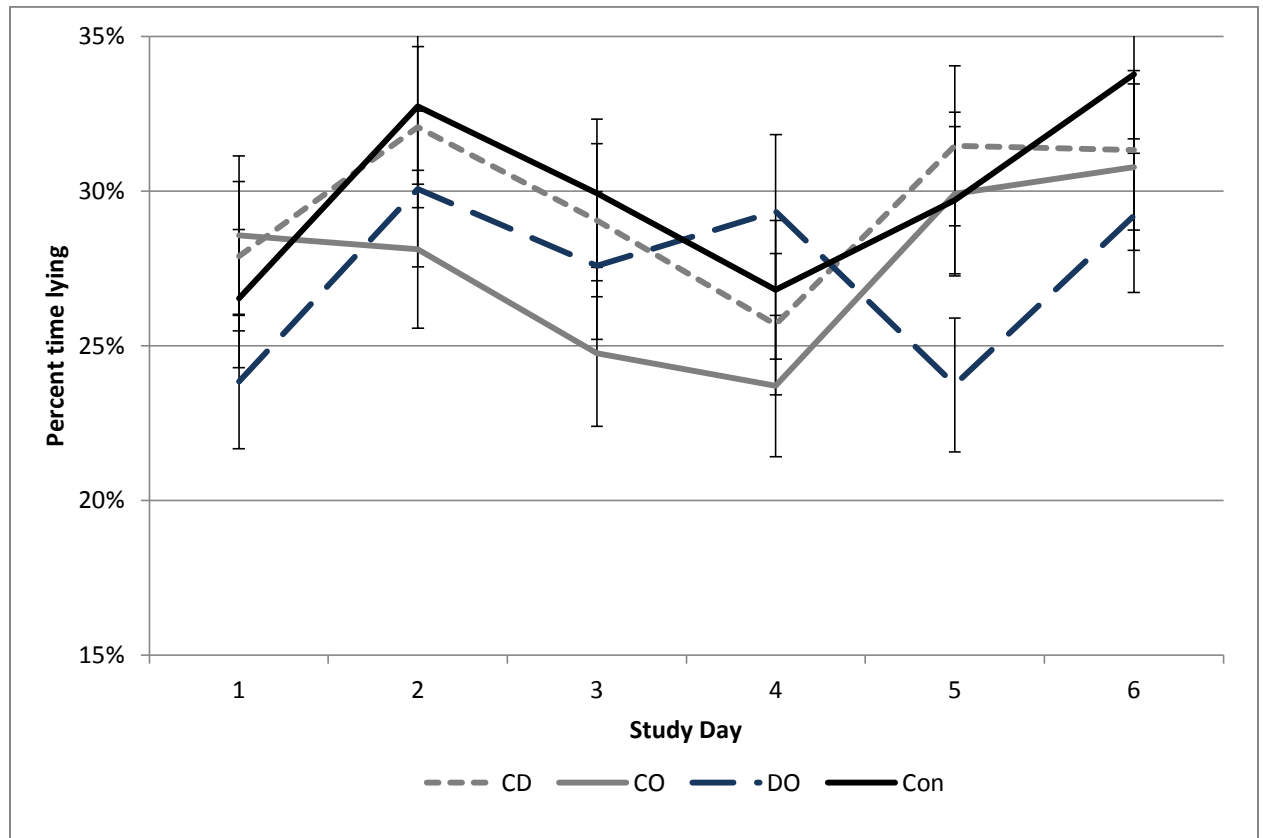


<sup>1</sup> Model included effects for repeated measures on individual calves, trial replicate and hour data was collected. Differences ( $P < 0.05$ ) between treatments within each time point are represented by differing superscripts. On the percent time lying down by day there is a treatment by study day interaction ( $p = <0.001$ ). Only one significant difference ( $p = 0.022$ ) was noted between CD and DO on day 5.

<sup>2</sup> The four treatments were: Castrated and Dehorned (CD), Castrated only (CO), Dehorn only (DO), and a negative control (Con).

<sup>3</sup> Time periods relative to surgical event are defined as beginning at 5pm of that day and followed for six 24 hour periods.

Figure 4-2. Model adjusted<sup>1</sup> proportion of time lying by treatment group<sup>2</sup> and study day.<sup>3</sup>



<sup>1</sup> Model included effects for repeated measures on individual calves, trial replicate and hour data was collected. Differences ( $P < 0.05$ ) between treatments within each time point are represented by differing superscripts.

<sup>2</sup> The four treatments were: Castrated and Dehorned (CD), Castrated only (C), Dehorn only (D), and a negative control (Con).

<sup>3</sup> Time periods relative to surgical event are defined as beginning at 5pm of that day and followed for six 24 hour periods.

## **Chapter 5 – Thesis Conclusion**

By assessing and analyzing behavior, inferences can be made on ways to decrease pain by using either analgesic protocols or differing procedural practices. Accelerometers have proven to be an objective way to measure cattle behavioral activities in the two trials performed in this thesis. Accelerometers were able to monitor the activities of walking, lying down, and standing and allowed for analysis of differences between study time frames and individual calves. They proved to be versatile in collecting behavior in individually and group housed cattle while being remote and removing behavioral changes that may have been seen with video monitoring. Due to previous studies validating the accelerometers these monitoring devices allowed us to collect behavioral data over longer periods of time than previous research. This allowed the benefit of monitoring behavior objectively over the elongated time periods is necessary for proper pain mitigation. The benefit of being less labor intense as video analysis was also advantageous when monitoring data for the allotted time. These studies illustrate the benefits of using accelerometers to monitor cattle behavior.

The first study found limited differences between the analgesic protocols administered. The change in behavior noted after the procedures may be an effective way of monitoring pain and the analgesics used had no differing effect during time periods pertaining to behavior. In the second study, the way the animals were housed may have impacted interpretation of behavioral findings. The fact that not many differences were found in group housed cattle in correlation with the treatments administered acts as important information on further study design. This research is valuable for comparison with further research and contains sound study designs.

Without further research in attempt to measure pain in cattle legislation or recommendations pertaining to castration and dehorning may not be established on evidence based medicine.

## Chapter 6 - References

- AVMA (2007). "Welfare Implications of the Dehorning and Disbudding of Cattle." Retrieved August 2, 2009 from [http://www.avma.org/reference/backgrounders/dehorning\\_cattle\\_bgnd.pdf](http://www.avma.org/reference/backgrounders/dehorning_cattle_bgnd.pdf)
- AVMA. (2009). "Welfare Implications of Castration of Cattle." Retrieved August 2, 2009 from [http://www.avma.org/reference/backgrounders/castration\\_cattle\\_bgnd.pdf](http://www.avma.org/reference/backgrounders/castration_cattle_bgnd.pdf)
- Coetzee, J. F., R. Gehring, et al. (2010). "Effect of sub-anesthetic xylazine and ketamine ('ketamine stun') administered to calves immediately prior to castration." *Vet Anaesth Analg* 37(6): 566-578.
- Coetzee, J. F., B. KuKanich, et al. (2009). "Pharmacokinetics of Intravenous and Oral Meloxicam in Ruminant Calves." *Veterinary Therapeutics* 10(4).
- Coetzee, J. F., A. L. Nutsch, et al. (2010). "A survey of castration methods and associated livestock management practices performed by bovine veterinarians in the United States." *BMC Vet Res* 6: 12.
- Currah, J. M., S. H. Hendrick, et al. (2009). "The behavioral assessment and alleviation of pain associated with castration in beef calves treated with flunixin meglumine and caudal lidocaine epidural anesthesia with epinephrine." *Can Vet J* 50(4): 375-382.
- Doherty, T. J., H. G. Kattesh, et al. (2007). "Effects of a concentrated lidocaine solution on the acute phase stress response to dehorning in dairy calves." *J Dairy Sci* 90(9): 4232-4239.

- Faulkner, D. B., T. Eurell, et al. (1992). "Performance and health of weanling bulls after butorphanol and xylazine administration at castration." *J. Anim Sci.* 70(10): 2970-2974.
- Faulkner, P. M. and D. M. Weary (2000). "Reducing Pain After Dehorning in Dairy Calves." *J. Dairy Sci.* 83(9): 2037-2041.
- Heinrich, A., T. F. Duffield, et al. (2010). "The effect of meloxicam on behavior and pain sensitivity of dairy calves following cautery dehorning with a local anesthetic." *Journal of Dairy Science* 93(6): 2450-2457.
- Huzzey, J. M., D. M. Veira, et al. (2007). "Prepartum Behavior and Dry Matter Intake Identify Dairy Cows at Risk for Metritis." *Journal of Dairy Science* 90: 3220-3233.
- Mitlohner, F. M., J. L. Morrow-Tesch, et al. (2001). "Behavioral sampling techniques for feedlot cattle." *J. Anim Sci.* 79(5): 1189-1193.
- Molony, V., J. E. Kent, et al. (1995). "Assessment of acute and chronic pain after different methods of castration of calves." *Appl Anim Behav Sci* 46: 33-48.
- Morisse, J. P., J. P. Cotte, et al. (1995). "Effect of dehorning on behaviour and plasma cortisol responses in young calves." *Appl Anim Behav Sci* 43(4): 239-247.
- Robert, B., B. J. White, et al. (2009). "Evaluation of three dimensional accelerometers as a method to categorize and classify behavior patterns in cattle " *Comput Electron Agric* 67: 80-84.
- Robert, B. D., B. J. White, et al. (2011). "Determination of lying behavior patterns in healthy beef cattle by use of wireless accelerometers." *Am J Vet Res* 72(4): 467-473.

- Schwartzkopf-Genswein, K., M. Booth-McLean, et al. (2005). "Physiological and behavioural changes in Holstein calves during and after dehorning or castration." *Can J Anim Sci* Volume 85(2): 131-138.
- Stafford, K. (2007). "Alleviating the pain caused by the castration of cattle." *The Veterinary Journal* 173(2): 245-247.
- Stafford, K. J. and D. J. Mellor (2005). "Dehorning and disbudding distress and its alleviation in calves." *The Veterinary Journal* 169(3): 337-349.
- Stewart, M., J. M. Stookey, et al. (2009). "Effects of local anesthetic and a nonsteroidal antiinflammatory drug on pain responses of dairy calves to hot-iron dehorning." *J. Dairy Sci.* 92(4): 1512-1519.
- USDA (2008). *Beef 2007–08, Part I: Reference of Beef Cow-calf Management Practices in the United States, 2007–08.* USDA:APHIS:VS. Fort Collins, Co.
- Weary, D. M., L. Niel, et al. (2006). "Identifying and preventing pain in animals." *Appl Anim Behav Sci* 100(1-2): 64-76.
- White, B. J., J. F. Coetzee, et al. (2008). "Evaluation of two-dimensional accelerometers to monitor beef cattle behavior post-castration." *Amer J Vet Res* 69(8): 1005-1012.