Prevention and Management of Surgical Pain in Cattle

David E. Anderson, DVM, MS[a,*], Misty A. Edmondson, DVM, MS[b]

KEYWORDS

• Surgery • Pain • Cattle • Prevention

KEY POINTS

- Management of pain continues to be an important consideration in livestock on which surgical procedures are performed.
- A balance must be achieved between the need to mitigate discomfort and the economic constraints of the production enterprise.
- Moral and ethical dilemmas have increased among consumers and these concerns have stimulated interest to reexamine the methods used to achieve the shared goals of humane production of safe, affordable animal products for human consumption.

Management of pain continues to be an important consideration in livestock on which surgical procedures are performed.[1,2] In these animals, a balance must be achieved between the need to mitigate discomfort and the economic constraints of the production enterprise. Moral and ethical dilemmas have increased among consumers and these concerns have stimulated interest to reexamine the methods used to achieve the shared goals of humane production of safe, affordable animal products for human consumption. Administration of drugs to mitigate pain is variable among veterinarians. In a survey of Canadian veterinarians' practices regarding the use of analgesics in livestock, piglets received analgesics for castration in less than 0.001% of procedures compared with 6.9% for beef calves and 18.7% of dairy calves less than 6 months old.[3] In another survey, the surgical procedure least likely to be done after administration of analgesia was castration of calves less than 6 months old (<34%); the procedure most likely to be done after administration of analgesia was cesarean section (C-section; >99%).[4] In that study, the drugs most commonly used for mitigation of pain associated with surgery were nonsteroidal antiinflammatory drugs (NSAIDs; eg, flunixin meglumine), local anesthetics (eg, lidocaine HCl), and α-2 agonists (eg, xylazine HCl). Similar results were reported for opinions of veterinarians in New Zealand who considered surgery for claw amputation, C-section, and displacement of the

[a] Large Animal Clinical Sciences, College of Veterinary Medicine, University of Tennessee, 2407 River Road, Knoxville, TN 37996, USA; [b] Department of Clinical Sciences, College of Veterinary Medicine, Auburn University, 1500 Wire Road, Auburn, AL 36849, USA
* Corresponding author.
E-mail address: david.anderson@utk.edu

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abomasum to be the most painful procedures.[5] In that study, both gender and age bias regarding pain in cattle was revealed, with female respondents and recent graduates assigning higher pain scores to various procedures compared with older and male respondents. These results were similar to those of a previous survey of veterinarians in the United Kingdom.[6] Pain management for performance of on-farm surgical procedures needs more education and research to define optimal guidelines for veterinarians and producers.

In field settings, surgical procedures are performed both on an elective and emergency basis. These surgeries are expected to cause variable degrees of pain or distress. Pain and the biological responses to it are part of a highly integrated multidimensional system that causes animals to react to protect themselves from the noxious stimulus.[7–9] Pain perception (nociception) is not considered to fully represent the pain experience and may help to explain the relationship between painful experiences and pain behaviors in animals. In this context, pain can be broadly categorized as either adaptive or maladaptive.[10] Adaptive pain increases the potential for survival by protecting the animal from injury and by promoting healing. Adaptive pain is expected with surgical procedures performed in healthy tissue, such as castration, dehorning, and laparotomy. By contrast, maladaptive pain is a disease created by pathologic processes that result in the persistence of pain long after the initiating cause(s) have been removed. Examples of maladaptive pain include septic arthritis, claw amputation for deep digital infections, tendon and muscle laceration, and fractures with tissue destruction. With prolonged, intense stimuli, the recognition of pain by the patient can transform into pathologic pain (**Fig. 1**).[11] Tissue damage and the associated inflammatory response lead to the production and release of nociceptor activators and/or sensitizers including hydrogen and potassium ions, prostaglandins, histamine,

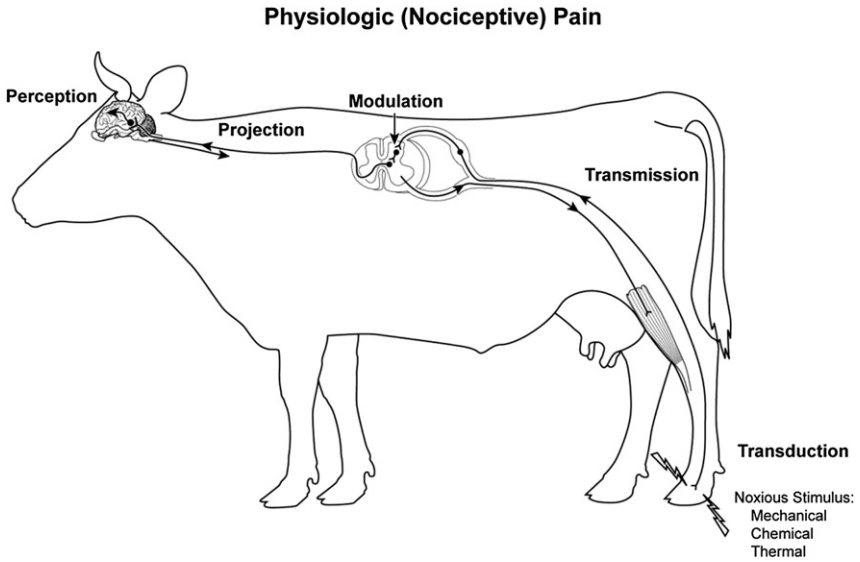

Fig. 1. The neurophysiology of acute, physiologic pain. A noxious stimulus is transduced, transmitted, modulated, projected, and perceived, resulting in the brain generating a response that travels via descending nerve pathways that facilitate or inhibit (modulate) sensory input to the spinal cord. (*From* Anderson DE, Muir WW. Pain management in ruminants. Vet Clin North Am 2005;21:19–31; with permission.)

bradykinin, nerve growth factor, cytokines, and chemokines. Together these factors convert high-threshold nociceptors into low-threshold nociceptors and activate quiescent nocireceptors, resulting in a zone of primary hyperalgesia (**Fig. 2**).[11,12] Local vasodilation and plasma extravasation result in a further amplification of the inflammatory response and the spread of hypersensitivity to surrounding tissues (secondary hyperalgesia). Central sensitization occurs when the cumulative effects of frequent or severe peripheral nociceptor input release excessive quantities of central nervous system neurotransmitters (substance P, neurokinin A, brain-derived neurotrophic factor [BDNF]), including glutamate, which remove the normally present magnesium (Mg^{-2}) block of *N*-methyl-D-aspartate (NMDA), thereby activating these and other receptors in the superficial layers of the dorsal horn of the spinal cord and resulting in an increase in their sensitivity (see **Fig. 2**).[12] Activation of NMDA receptors leads to an increase in calcium (Ca^{+2}) in dorsal horn neurons, resulting in increased excitability and spontaneous ectopic discharge. Sensitization of dorsal horn neurons can last for hours and is thought to be responsible for pain outside the area of tissue injury (secondary hyperalgesia) and allodynia. Central sensitization is different from peripheral sensitization in that it enables low-intensity stimuli to produce pain sensations when pain is chronic and enables sensory fibers that normally transmit no painful stimuli (low threshold Aβ fibers) to produce pain as a result of changes in sensory processing in the spinal cord. Together, the development of peripheral sensitization, wind-up, and central sensitization represent a continuum of the pain process that exists as consequence of continuous, unrelenting, and untreated pain.

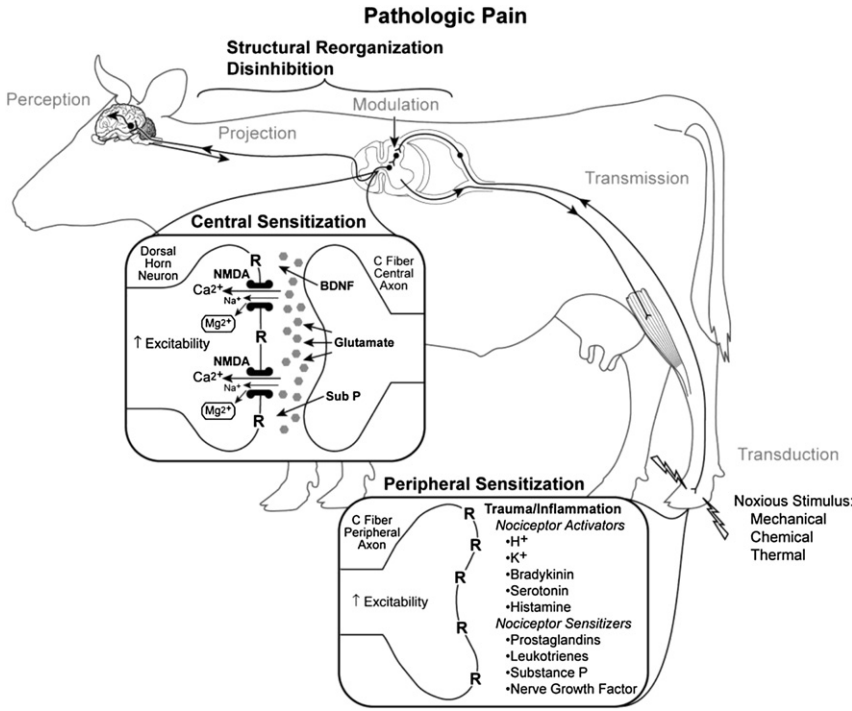

Fig. 2. The neurophysiology of pathologic pain associated with severe and chronic pain conditions. BDNF, brain-derived neurotrophic factor; NMDA, *N*-methyl-D-aspartate; R, receptor. (*From* Anderson DE, Muir WW. Pain management in ruminants. Vet Clin North Am 2005;21:19–31; with permission.)

The pain system includes sensors, neural pathways, and processing centers that are responsible for detecting, transmitting, and actualizing biological and behavioral responses to noxious events (see **Fig. 1**).[11,13,14] Understanding these pathways allows selection of specific strategies (eg, peripheral nerve blockade, central nerve blockade, systemic analgesia or anesthesia) and selection of appropriate drugs or drug combinations to prevent or treat the perception of pain. Drug selection and strategy should be tailored to minimize or prevent unwanted side effects such as changes in distribution of blood flow. Drug therapy for pain or distress should be chosen in combination with the overall management of the case to optimize patient comfort, restore function, and minimize adverse events. Pain is responsible for stress and can lead to distress.[15,16] Stress is an adaptive pattern of behavioral, neural, endocrine, immune, hematological, and metabolic changes directed toward the restoration of homeostasis. The stress response prepares the animal for an emergency reaction and fosters survival in circumstances of immediate threats (fight or flight). Acute pain is capable of producing a significant stress response by initiating activation of the sympathetic nervous system, secretion of glucocorticoids (primarily cortisol), hypermetabolism, sodium and water retention, and altered carbohydrate and protein metabolism.[17–19] The maintenance of normal homeostatic balance to an acute stress-producing event (pain) is maintained by negative feedback controls that act at multiple levels within the brain (amygdala) and sympathoadrenal and hypothalamic-pituitary-adrenal (HPA) axes, thereby increasing catecholamines and glucocorticoids and leading to enhanced arousal, appraisal, and cardiorespiratory and cognitive performance in order to deal with the immediate threat. Increases in corticotrophin-releasing hormone (CRH), plasma cortisol, and vasopressin often directly correlate with the stressful or painful event(s) and help to restore homeostasis. However, severe or prolonged pain resulting in severe stress eventually becomes maladaptive, producing depression and immunosuppression (sickness syndrome), which, if not controlled, can lead to distress and the activation of self-sustaining cascades of neural and endocrine responses that derail physiologic homeostasis.[20] Prolonged stress impairs the animal's ability to interact and learn and changes the animal's behavioral phenotype.[7] Severe pain produces behavioral, autonomic, neuroendocrine, and immunologic responses that can result in self-mutilation, immune incompetence, and a poor quality of life, potentially leading to gradual deterioration and death.

Apparent anxiety may be observed in ruminants.[21,22] This form of pain-free distress may adversely affect the animal's response to therapy. Anxiety states are most commonly observed in cattle with limited human contact or having had adverse human contact, such as beef heifers in dystocia that have not been handled since calfhood. Another example is beef neonates abruptly separated from the dam. Anxiety states can be observed from isolation in stalls or hospital environments. Social isolation is common among species with intense herd instincts (eg, sheep, llamas, alpacas) but also has been observed among dairy cattle and goats. Use of drugs for anxiolytic effects may result in improved efficacy and duration of effect compared with analgesic drug therapy alone. A recent study regarding behavior of dairy cows in isolation and restraint is noteworthy.[23] In this study, dairy cows were subjected to isolation, head restrain, exposure to new herdmates, and compared with the control group of resident cows in response to adverse stimuli. Dairy cows subjected to social stress showed hypoalgesia, decreased response to stimuli, decreased ruminations, and increased serum cortisol. Thus, some behavioral observations classically used to assess pain in ruminants may lead to errors in judgment. Instead of pain, these cows may be suffering psychological stress and changes in clinical management will likely be more successful than drug therapy. This possibility is supported by our clinical

observations that some cows do not return to normal in an expected time frame after surgery until they have been returned to the herd setting. However, anxiolytic drugs must be administered with caution. The most clinically available anxiolytic is acepromazine. Although acepromazine may be administered in low dosages (0.02–0.04 mg/kg), this drug is contraindicated when the potential for profound hypotension is present (eg, abomasal volvulus, hypovolemia, hemorrhagic shock).

Although drug therapy is a useful tool for mitigation of pain or distress, this must be done with consideration for violative drug residues in meat and milk. Observation of appropriate withholding times in accordance with the Animal Medical Drug Use and Clarification Act (AMDUCA) is vital to the veterinary-client-patient relationship, to the preservation of a safe and wholesome food supply, and to the preservation of consumer trust. The Food Animal Residue Avoidance Database should be consulted for current withholding guidelines for anesthetic and analgesic drugs when used in food animals (www.farad.org).

RECOGNITION OF PAIN

Ruminants, especially cattle, differ in behaviors associated with pain.[21,23] Ruminants often become subdued, spend more time lying down, spend less time eating and ruminating, fail to clean the nostrils as frequently, and so forth when in pain or stressed. Galindo and Broom[24] observed that lame cows had more lying time, less eating time, more lying time outside of cubicles, and performed fewer aggressive behavior actions despite having the same frequency of aggressive behavior interactions. These lame cows licked other cows less, and were themselves licked more. Many social and environmental factors influence pain perception and responses in cattle. Rushen and colleagues[25] showed that cows subjected to social isolation, alone, had increased vocalization, heart rate, and cortisol. Strategies for recognizing pain in ruminants are described by Millman ST and colleagues elsewhere in this issue.

TREATMENT AND PREVENTION OF PAIN

The easiest type of pain to prevent is that which is induced.[1,2,26] The magnitude of surgical pain is influenced by the procedure, the methods used, and the experience and skill of the practitioner. Some strategies to inhibit or minimize pain before it occurs (eg, preemptive) are obvious: local anesthesia, general anesthesia, sedation, and tranquilization. Careful assessment of cardiovascular status and hemodynamic balance must be done during the drug selection process. Drugs that adversely affect homeostasis or may be counterproductive in the management of shock should not be used to address pain. A detailed discussion of the drugs used in sedation and general anesthesia protocols for cattle are presented by Theurer ME and colleagues elsewhere in this issue. The current article focuses on antiinflammatory drugs and various forms of selective (eg, local, regional, epidural) anesthesia. Some thought should be given to the physiologic processes that are induced by tissue injury and that may lead to pathologic pain after surgery. Sedatives, tranquilizers, narcotics, anesthetics, and so forth inhibit detection or perception of pain by interfering with pain pathways, but these drugs should not be considered therapeutic beyond the clinical benefit of lessening the distress caused by the pain stimulus,[26] because these drugs do not treat the disease or processes (eg, inflammation) causing the noxious stimuli. Multimodal therapy refers to the simultaneous treatment of the disease, physiologic side effects of the disease or treatment used, and pain. Multimodal pain management often refers to administration of a combination of drugs of different pharmacologic classes and or different routes of administration to achieve more effective analgesia and return to

normal. NSAIDs can be a critical link to multimodal therapy for pain (**Table 1**). The clinician should not have elimination of all pain as the end point for therapy. Rather, the goal is to minimize pain such that the patient can return to more normal self-care activities such as eating, drinking, urination, defecation, grooming, physical activity, and milk production. However, the clinician should recognize that reactive pain management (eg, administration of analgesic drugs only after pain is recognized) is less effective and likely impedes the recovery of the patient. Preemptive pain management is more successful and optimizes animal well-being. Preemptive therapy should be done with the intention of controlling pain throughout the stimulus, which may last for hours, days, or weeks. Unwanted side effects of NSAIDs are related to nonselective prostaglandin inhibition. This inhibition may increase the risk of abomasal ulcers and renal failure, and may adversely affect healing. Prostaglandins are vital to abomasal mucosal integrity (eg, prostaglandin E-2), vascular regulation (eg, prostaglandin I), and homeostasis. The clinically beneficial effects of NSAID therapy are usually thought to be more helpful than the risks, but adjunct therapy must be instituted to minimize complications. Adjunct therapy may include the use of these drugs at the minimum required dose and frequency of administration, but may also include administration of intravenous (IV) fluids or gastrointestinal protectants during the course of therapy.

PERIOPERATIVE USE OF ANTIINFLAMMATORY DRUGS

A variety of antiinflammatory drugs are available for clinical use.[1,2,26] Steroids and NSAIDs may have benefits to the patient such as mitigation of pain, lessening of swelling, diminishing inflammation at the incision site and/or damaged tissues, and more rapid patient recovery after the procedure. Pain, uncontrolled inflammation, excessive swelling, local ischemia, and tissue injury can suppress immune system function and allow the establishment of infection or slow the rate of wound healing by prolongation of the phases of wound response and repair.

Glucocorticoids have profound inhibition of the inflammatory cascade (**Fig. 3**). The use of steroids for management of pain and inflammation associated with surgery is discouraged because of concerns for increased risk of infection either at the site of the surgical wound or associated with the disease process necessitating surgery. Although steroids can have inhibitory effects on the migration and function of white blood cells, many clinicians think that the benefits of a single dose of steroid with

Table 1
NSAIDs used to alleviate surgical pain in ruminants

Drug	Dose (mg/kg)	Route	Frequency
Na-salicylate	50–100	Oral	Every 12 h
Flunixin meglumine	1–2	IV	Every 12–24 h
Ketoprofen	1.5	IV or IM	Every 24–48 h
Carprofen	1.4	IV or SC	
Phenylbutazone	5	Oral	Every 24–48 h
	10	Oral	Every 48–72 h
Meloxicam	0.5–1.0	Oral	Every 24 to 72 h

Except for flunixin meglumine, none of these NSAIDs are approved for use in cattle in the United States. Meat and milk withholding times must be cautiously estimated. Phenylbutazone is prohibited for use in lactating dairy cows.

Abbreviations: IM, intramuscular; IV, intravenous; SC, subcutaneous.

Data from Refs.[1,2,63]

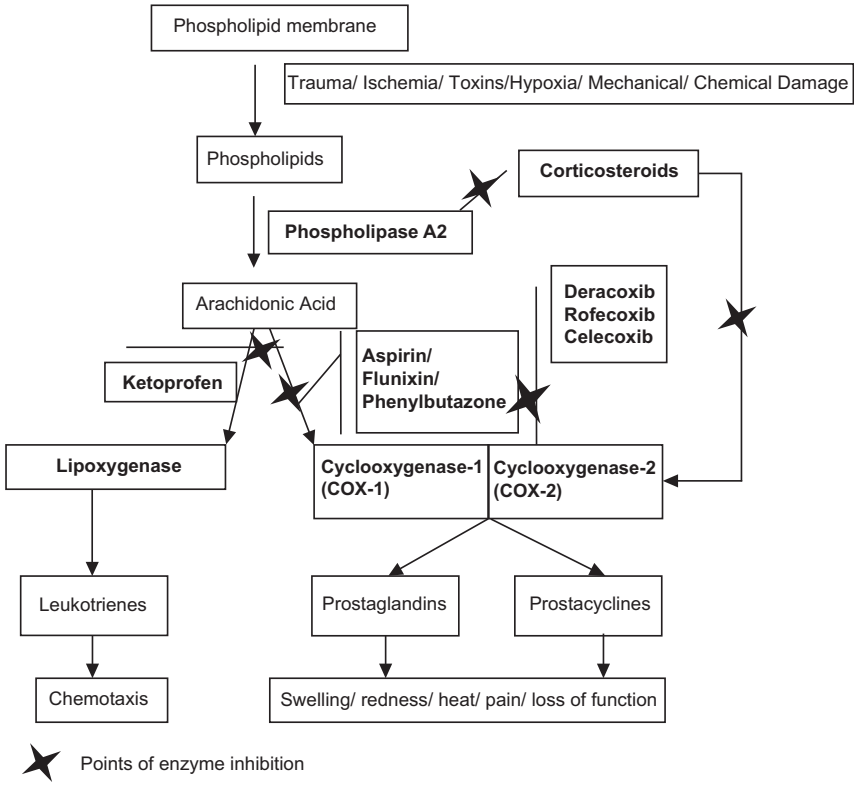

Fig. 3. Inflammatory cascade and points of enzyme inhibition of antiinflammatory drugs. (*Courtesy of* Johann F. Coetzee, BVSc, PhD, Ames, IA.)

a short to moderate duration of action (eg, dexamethasone at 0.1 mg/kg body weight) outweigh the potential adverse effects. The authors caution against the routine use of steroids perioperatively unless needed as part of the management of shock or severe, progressive deterioration of the tissues or the patient.

NSAIDs have been shown to have a beneficial effect on mitigation of pain and maintenance of normal behavioral activities in livestock. The bulk of this research has focused on routine husbandry surgical procedures such as castration and dehorning. Little research has been done to document the effects of NSAIDs administered perioperatively in livestock having surgical procedures for disease conditions such as displacement of the abomasum or C-section.

NSAIDs inhibit cyclooxygenase enzymes (COX) (see **Fig. 3**).[1,2,26] COX acts on arachidonic acids to liberate prostaglandins and other mediators of inflammation. Multiple isoforms of COX enzyme exist, with COX-1 recognized as primarily involved with normal homeostatic mechanisms and COX-2 as an enzyme induced in response to injury. COX inhibitors prevent production of these factors. Nonspecific COX inhibitors include aspirin, flunixin, and phenylbutazone. More selective COX-2 inhibitors are rapidly being developed and include etodolac, carprofen, and meloxicam. NSAIDs have differential activity because of the presence of variable receptors and variable drug effects. Our clinical experience suggests that, although these drugs may be safer for long-term use (eg, COX-2 inhibition is less likely to interfere with homeostasis of abomasal mucosa or renal perfusion), COX-2 inhibitors provide less potent analgesia.

Much of the pain research that has been performed has shown benefits of preemptive analgesia. There is a less marked effect of the administration of analgesic medication after the noxious stimulus has become established. In a study in which flunixin meglumine was administered before laparotomy for correction of abomasal displacement, cows receiving flunixin (2.2 mg/kg IV) had significantly greater rumen contracts during the first 24 hours after surgery compared with control cows.[27] This administration of flunixin may not represent preemptive analgesia because of the prior abomasal displacement. Another study was designed to investigate the effect of preoperative and 24-hour postoperative administration of flunixin meglumine (1.25 g IV) on postoperative recovery of cows having surgical correction of left displaced abomasum.[28] In that study, cows receiving flunixin meglumine immediately before and 24 hours after surgery had significantly better appetite, defecation, and milk production compared with cows that were not given flunixin. A risk-benefit analysis should be done on a case-by-case basis to determine whether an NSAID should be administerd.[29] Meloxicam has been used recently for pain management in cattle for a variety of conditions. This NSAID has been shown to be effective in mitigating the pain of castration and dehorning and the pharmacokinetics suggest that meloxicam should be effective for perioperative pain management as well.[30] Clinical experience has been positive with this drug when (0.5–1 mg/kg body weight) given orally, every 24 to 48 hours. Future research is needed to more fully elucidate the clinical indication for the use of meloxicam. Based on AMDUCA guidelines, the authors only use meloxicam when sustained effect is needed (>3 days), because the more selective COX-2 inhibition should be safe for prolonged administration compared with flunixin. In cases of severe, prolonged pain when a pathologic pain state has become established, gabapentin can be administered as a complimentary drug to meloxicam as a multimodal therapy.[31] The use of gabapentin (10 mg/kg, orally, every 12 hours) has been useful in cases of deep digital sepsis and septic arthritis as a tool to dampen the exaggerated central nervous response to the limb pain.

OPIOIDS

Opioids are useful in a wide variety of settings because there are limited cardiovascular side effects (**Table 2**). Economic constraints have limited the use of these drugs in ruminant practice.[1,2,26] The most common narcotic drug used in cattle is butorphanol tartrate (0.02–0.04 mg/kg, IV or subcutaneous [SC] every 4–6 hours). Morphine (0.05–0.1 mg/kg, SC every 4–12 hours) and buprenorphine (0.005–0.01 mg/kg, SC

Table 2
Opioids used for analgesia during surgery in ruminants

Drug	Dose	Route	Frequency
Morphine	0.5–1 mg/kg 0.05–0.1 mg/kg	IV Epidural	Every 12 h Every 24 h
Fentanyl	0.05–0.5 μg/kg	Transdermal patch	Every 72 h
Meperidine	3.3–4.4 mg/kg	SC or IM	—
Buprenorphine	0.005–0.01 mg/kg (sheep and goats)	IM	Every 6–12 h
Butorphanol	0.02–0.05 mg/kg	IV SC	Every 2–4 h Every 6–8 h

None of these drugs are approved for use in cattle in the United States. Meat and milk withholding times must be cautiously estimated.

Data from Refs.[1,2,63]

every 6–12 hours) have been used in cattle to variable effect. Although typically used at greater dosage rates in other species, fentanyl transdermal patches applied at a rate of 0.05 to 0.1 μg/kg have shown clinical benefit for up to 72 hours duration. A combination of butorphanol, xylazine, and ketamine (also known as ketamine stun) has recently been shown to provide analgesia, chemical restraint, and disassociation from the procedure.[32,33] The combination of an opioid (butorphanol at 0.025 mg/kg), α-2 agonist (xylazine at 0.05 mg/kg), and neuroleptic (ketamine at 0.1 mg/kg) seems to create an altered state of consciousness that has been very beneficial when performing surgical procedures on fractious cattle or cattle suffering extreme pain as a result of the disease condition.

LOCAL ANESTHESIA

Local anesthetics are the most common preemptive and emptive analgesic drugs used for surgery in food animal practice.[34] These drugs, especially lidocaine 2% HCl, are used to prevent pain during surgery. These drugs act locally or regionally when perineural anesthesia is performed, but have no systemic or behavioral effect except when given intravenously or at extremely high dosages. Local anesthetics block nerve fibers (B-fibers for motor/touch >C-fibers, which are nonmyelinated and are pain and temperature sensitive >A-fibers, which are primarily associated with motor function and proprioception).[35] The acuteness or severity of the perception of pain is influenced by the stimulus. Intensity of perception diminishes in the order of pain → cold → warmth → touch → deep pressure. Local anesthetic drugs act primarily by inhibiting Na channels to impede nerve conduction by preventing depolarization of the nerve fiber. These drugs must disassociate in an alkaline environment for this to occur. In infected, ischemic, or injured tissues, quality of local anesthesia is often poor because the relatively more acidic environment prevents disassociation of drug. An example of this effect is septic cellulitis associated with complicated sole ulcer complex in dairy cows. The acidic environment associated with the bacterial cellulitis may cause local administration of lidocaine to be ineffectual with continued pain sensation. One solution to this problem is to administer the block remote to infected tissues. Another consideration with local anesthetic drugs is the adverse stimuli associated with the caustic nature of the acid stable drug. Lidocaine 2% HCL has been observed and reported to be painful during administration. This noxious characteristic can be eliminated by adding Na-bicarbonate to neutralize the solution. The lidocaine can be buffered by adding 5 mL of 8.5% sodium bicarbonate with 50 mL of 2% lidocaine HCl. This practice may diminish or eliminate the sting of injection.

Local anesthetics vary in their potency, duration, toxicity, and cost.[7] Practitioners are challenged with balancing the immediate needs for anesthesia to complete the surgical procedure and the desire to have postoperative analgesia while maintaining safety and cost-effectiveness. Lidocaine hydrochloride (2%) is the most commonly used local anesthetic drug in cattle because of its consistent time of onset, efficacy, low cost, and low risk of toxicity. Lidocaine is considered to be more potent than procaine and diffuses more widely into the tissues. However, lidocaine has an intermediate duration of action of 60 to 90 minutes.[8] In cattle, procaine (1%–2%) is expected to have a longer time to onset of anesthesia compared with lidocaine and a shorter duration of action, lasting no more than 60 minutes. As an alternative, mepivacaine (1%–2%) is expected to have a similar time to onset of anesthesia but longer duration of activity (range 120–180 minutes) than lidocaine. Bupivacaine (0.25%–0.5%) is a long-acting local anesthetic (range up to 360 minutes),[36] but this drug can be toxic to cattle if given intravenously. For this reason, bupivacaine is not recommended for

routine clinical use because of the risk of inadvertent intravenous injection. The duration of action of lidocaine can be extended by adding a vasoconstrictor, such as epinephrine (5 μg/mL), to the local anesthetic solution (0.1 mL of epinephrine [1:1000] to 20 mL of local anesthetic), which increases the potency and duration of activity. Caution should be observed when using local anesthetics containing epinephrine (1:200,000) because vasoconstriction could affect revascularization of the wound edges when used peripherally or could increase the risk of producing tissue necrosis and spinal cord ischemia if used epidurally.[9,37] In a study of skin lesions occurring in cattle after the use of a combination of lidocaine and epinephrine, skin lesions were hypothesized to be caused by the low pH of the injected solution, the total volume of injection, and the effects of the epinephrine. Based on previous research in sheep, the maximum concentration of epinephrine combined with lidocaine is 12.5 μg/mL total solution.[38]

Local anesthetics can be used in a variety of techniques including local block, inverted L block, ring block, selected perineural block, regional blocks (eg, paravertebral, epidural), and intravenous regional blocks distal to a tourniquet. In our experience, topical products for inducing local anesthesia have limited efficacy in cattle. The failure of these products may be associated with the characteristics of bovine skin. Bovine skin, especially flank and dorsal skin, may be too thick or resistant to absorption of the anesthetic to induce clinically useful anesthesia. However, 5% lidocaine gel has been beneficial when applied to the skin surface of injured teats to facilitate palpation and cannulation of the teat. Clinical analgesia is expected within 10 minutes after application of the gel to dry skin.

In all patients, the toxic dose for lidocaine should be considered and preventive measures taken to ensure that overdosage does not occur. This precaution is most critical when local anesthesia is being performed in a large area, such as for C-section. In cattle, 10 mg/kg body weight may be used to estimate the maximum safe dose of lidocaine HCl. Using this threshold, the maximum safe dose of 2% (20 mg/mL) lidocaine HCl for a 700-kg cow would be 350 mL. The maximum safe dose in a 70-kg calf would be 35 mL. In small ruminants, a maximum safe dose estimate of 4 mg/kg may be used. Thus, a 70-kg goat would receive no more than 14 mL of 2% lidocaine HCl.

LOCAL INFILTRATION AND LINE BLOCK

The simplest form of anesthesia/analgesia to a specific site is the local infiltration of the drug. In North America, 2% lidocaine HCl is most commonly used for this purpose. The length and gauge of needle used is based on the skin thickness and tissue depth desired for infiltration. Most commonly, an 18-gauge needle is used because the bore diameter is small enough not to cause excessive discomfort and strong enough to minimize the risk of the needle bending or breaking during insertion or infusion. For flank laparotomy, a 3.8-cm (1.5-inch) needle is sufficient to allow subcutaneous infiltration as well as intramuscular infiltration. Although lidocaine efficiently diffuses for short distances within a tissue plane, the user must be aware that diffusion across fascial planes is less effective. This difference may account for instances of incomplete blockade of the site despite administration of an ample volume. The distance between needle insertion points should not exceed twice the length of the needle (eg, 2 insertion points of a 3.8-cm needle would be no further than 7.6 cm apart) to ensure that gaps in the area of anesthesia do not remain. Pain of successive injections may be alleviated by placing the edge of the needle into the edge of the previously desensitized area. Dissociation of lidocaine must occur to optimize Na channel blockade, which occurs efficiently at neutral pH but does not occur consistently in

acidic pH fluids. This difference may explain the absence of expected anesthesia in infected, ischemic, traumatized, and anaerobic tissues.

The initial point of insertion should be intended to achieve subcutaneous infiltration. The needle and syringe are held at a 60° angle to the skin and then advanced until resistance abruptly diminishes. The skin tenting technique can be used as an alternative, whereby the skin is pulled away from the body to form a tent and the needle directed parallel to the body and along the long axis of the tent. The syringe is used to aspirate to ensure that a vessel has not been entered before infusion of the anesthetic. Then, the needle is advanced along the plane of the proposed incision line for the full length of the needle and in both directions along the anticipated incision. In this way, the smallest number of skin insertion points can be made by maximizing the length of the needle for infusion. A sufficient volume of lidocaine should be infused to create a bleb or noticeable swelling underneath the skin (usually 1–5 mL). After the subcutaneous space has been infiltrated, a similar procedure is done to infiltrate the muscles in the plane of the anticipated incision. Lidocaine is infused as the needle is advanced into and retracted from the muscles to ensure that lidocaine is distributed among the separate muscle planes. In the case of flank laparotomy, the external abdominal oblique muscle, internal abdominal oblique muscle, and transversus abdominis muscle must be anesthetized. Line blocks are not expected to anesthetize the peritoneum and the surgeon must anticipate adverse reaction to this tissue being penetrated. The zone of anesthesia is expected to extend 2 to 3 cm on either side of the line of infiltration. Injection of large volumes of lidocaine may increase the zone of anesthesia, but the presence of large quantities of lidocaine may increase the potential for tissue toxicity and incisional morbidity.

INVERTED L BLOCK

The inverted L block is a nonspecific regional block that locally blocks the tissue bordering the caudal aspect of the 13th rib and the ventral aspect of the transverse processes of the lumbar vertebrae.[39] An 18-gauge 3.8-cm needle is used to inject up to a total of 100 mL of local anesthetic solution in multiple small injection sites into the tissues bordering the dorsocaudal aspect of the 13th rib and ventrolateral aspect of the transverse processes of the lumbar vertebrae (**Fig. 4**). This technique creates an area of anesthesia under the inverted L block. Advantages of the inverted L block include that the block is simple to perform and does not interfere with ambulation, and deposition of anesthetic away from the incision site minimizes incisional edema and hematoma.[40] Disadvantages include incomplete analgesia and muscle relaxation of the deeper layers of the abdominal wall (particularly in obese animals), possible toxicity after larger doses of anesthetic, and increased cost because of larger doses of local anesthetic.

PROXIMAL PARAVERTEBRAL BLOCK

The proximal paravertebral nerve block desensitizes the dorsal and ventral nerve roots of the last thoracic (T13) and first and second lumbar (L1 and L2) spinal nerves as they emerge from the intervertebral foramina (**Fig. 5**). To facilitate proper needle placement of anesthetic, the skin at the cranial edges of the transverse processes of L1, L2, and L3 and at a point 2.5 to 5 cm off the dorsal midline can desensitized by injecting 2 to 3 mL of local anesthetic using an 18-gauge 2.5-cm needle. A 14-gauge 2.5-cm needle is used as a cannula or guide needle to minimize skin resistance during insertion of an 18-gauge 10-cm to 15-cm spinal needle (see **Fig. 5**). Approximately 5 mL of local

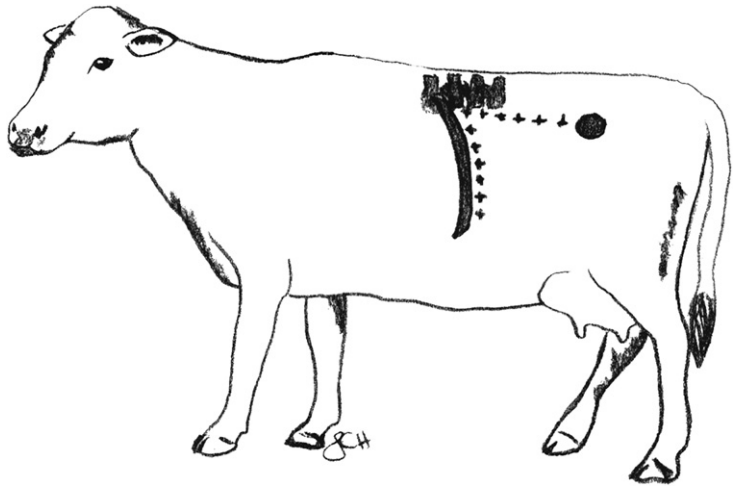

Fig. 4. Inverted L block for paralumbar anesthesia, showing multiple infusion sites (*asterisks*), the last rib, the lumbar vertebra, and tuber coxae.

anesthetic may be placed through the cannula to further anesthetize the tract for needle placement.

To desensitize T13, the cannula needle is placed through the skin at the anterior edge of the transverse process of L1 approximately 4 to 5 cm lateral to the dorsal

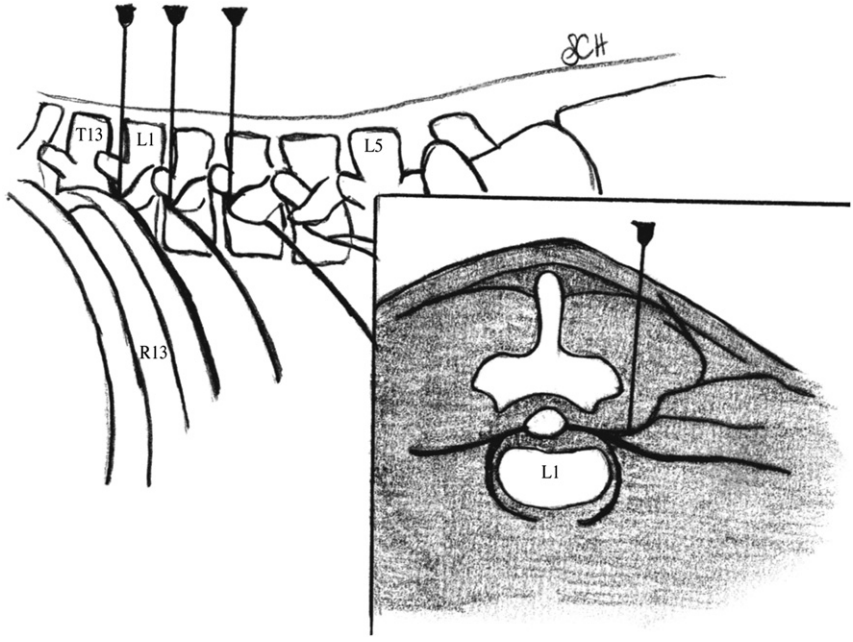

Fig. 5. Needle placement for the proximal paravertebral nerve block in cattle. Left lateral view and cranial view at the thoracolumbar junction. R13, last rib; T13, last thoracic vertebra; L1, first lumbar vertebra; L5, fifth lumbar vertebra.

midline. The 18-gauge 10-cm to 15-cm spinal needle is passed ventrally until it contacts the transverse process of L1. The needle is then walked off the cranial edge of the transverse process of L1 and advanced approximately 1 cm to pass slightly ventral to the process and into the transverse ligament. Between 6 and 8 mL of local anesthetic are injected with little resistance to desensitize the ventral branch of T13. The needle is then withdrawn 1 to 2.5 cm above the fascia or just dorsal to the transverse process and 6 to 8 mL of local anesthetic are infused to desensitize the dorsal branch of the nerve.

To desensitize L1 and L2, the needle is inserted just caudal to the transverse processes of L1 and L2. The needle is walked off the caudal edges of the transverse processes of L1 and L2, at a depth similar to the injection site for T13, and advanced approximately 1 cm to pass slightly ventral to the process and into the transverse ligament. Between 6 and 8 mL of local anesthetic are injected with little resistance to desensitize the ventral branches of the nerves. The needle is then withdrawn 1 to 2.5 cm above the fascia or just dorsal to the transverse processes and 6 to 8 mL of local anesthetic are infused to desensitize the dorsal branch of the nerves.

Ina study designed to compare proximal paravertebral anesthetic block and a combination line block plus inverted L block for flank laparotomy in cattle, the proximal paravertebral block provided significantly better clinical analgesia during the creation of the incision into the abdomen.[41] Evidence of a successful proximal paravertebral nerve block includes increased temperature of the skin; analgesia of the skin, muscles, and peritoneum of the abdominal wall of the paralumbar fossa; and scoliosis of the spine toward the desensitized side. Advantages of the proximal paravertebral nerve block include small doses of anesthetic, wide and uniform area of analgesia and muscle relaxation, decreased intra-abdominal pressure, and absence of local anesthetic at the margins of the surgical site. Disadvantages of the proximal paravertebral nerve block include scoliosis of the spine, which may make closure of the incision more difficult; difficulty in identifying landmarks in obese and heavily muscled animals; and more skill or practice required for consistent results.[39,40,42]

DISTAL PARAVERTEBRAL BLOCK

The distal paravertebral nerve block desensitizes the dorsal and ventral rami of the spinal nerves T13, L1, and L2 at the distal ends of the transverse processes of L1, L2, and L4, respectively (**Fig. 6**). An 18-gauge 3.5-cm to 5.5-cm needle is inserted ventral to the transverse process and 10 mL of local anesthetic are infused in a fan-shaped pattern. The needle can then be removed and reinserted or redirected dorsally, in a caudal direction, where 10 mL of local anesthetic are again infused in a fan-shaped pattern. This procedure is repeated for the transverse processes of the second and fourth lumbar vertebrae. Advantages of the distal paravertebral nerve block compared with the proximal paravertebral nerve block include lack of scoliosis, arguably being easier to perform, and offering more consistent results. Disadvantages of the distal paravertebral nerve block compared with the proximal paravertebral nerve block include that larger doses of anesthetic are required and variations in efficiency caused by variation in the anatomic pathways of the nerves.[39,40,42]

EPIDURAL ANESTHESIA

Epidural anesthesia has been the focus of attention of many research projects in cattle in an attempt to minimize pelvic and perineal pain (**Table 3**).[43–49] Caudal epidural anesthesia is easily applied in cattle and a variety of drugs have been shown to be beneficial. A high caudal epidural at the sacrococcygeal space (S5–Co1) desensitizes

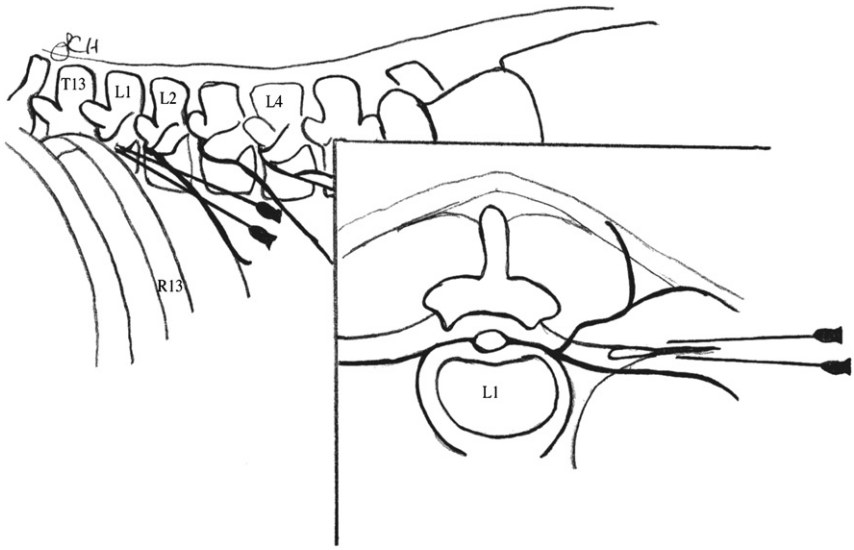

Fig. 6. Needle placement for the distal paravertebral nerve block in cattle. Left lateral view and cranial view at the thoracolumbar junction. L2, second lumbar vertebra; L4, fourth lumbar vertebra.

sacral nerves S2, S3, S4, and S5. The low caudal epidural at the first coccygeal space (Co1–Co2) desensitizes sacral nerves S3, S4, and S5; as the anesthetic dose increases, nerves cranial to S2 may also become affected.[50] If possible, the hair should be clipped and the skin scrubbed and disinfected. Standing alongside the cow, the tail should be moved up and down to locate the fossa between the last sacral vertebra and the first coccygeal vertebra or between the first and second coccygeal

Table 3
Usage of epidural anesthesia for standing paralumbar analgesia or laparotomy in cattle

Drug	Dosage	Onset of Analgesia (min)	Duration of Analgesia
Lidocaine 2%	0.2 mg/kg (5 mL)	5	10–115 min
Xylazine	0.05 mg/kg (5 mL in saline)	20–40	2–3 h
Clonidine	2–3 μg/kg diluted to 8 mL in saline	2 μg dose: 19 3 μg dose: 9	2 μg dose: 192 min 3 μg dose: 311 min Peak effect during 60–180 min
Ketamine 5%	5 mL (250 mg) 10 mL (500 mg) 20 mL (1000 mg)	5 mL: 6.5 10 mL: 5 20 mL: 5	5 mL: 17 min 10 mL: 34 min 20 mL: 62 min
Procaine HCl 5%	300 mg (6 mL)	8–20	45–127 min Mean, 83 min
Medetomidine	15 μg/kg (5 mL)	5	412 min
Detomidine	40 μg/kg	—	—
Romifidine + morphine	Romifidine: 50 μg/kg Morphine: 0.1 mg/kg	—	12 h maximum

vertebrae. An 18-gauge 3.8-cm needle (with no syringe attached) is directed perpendicular to the skin surface (**Fig. 7**). Once the skin is penetrated, place a drop of local anesthetic solution in the hub of the needle (hanging drop technique). The needle should then be advanced slowly until the anesthetic solution is drawn into the epidural space by negative pressure. The syringe may then be attached to the needle and anesthetic solution slowly injected with no resistance. Lidocaine HCl 2% can be used for perineal analgesia (low-volume: <1 mL/50 kg body weight) or pelvic and abdominal analgesia (high volume: 1 mL/5 kg). The duration of clinically apparent analgesia after low-volume caudal epidural anesthesia is expected to be 60 to 90 minutes. Ropivacaine 0.75% is administered via caudal epidural injection at a rate of 0.11 mg/kg body weight.[51] In that study, the time of onset for analgesia of the perineum ranged from 9 to 15 minutes but the duration of analgesia was 359 (±90) minutes. Although slight ataxia was observed in some cows, adverse events were not noted.

High-volume caudal epidural anesthesia refers to the infusion of large volumes of drugs via the standard caudal epidural site as per perineal anesthesia. The standard low-volume caudal epidural uses lidocaine 2% HCl with or without α-2 agonists (recommended volume 0.5 mL/50 kg body weight; maximum volume 1 mL per 50 kg body weight with mild ataxia). This volume is sufficient for procedures involving the tail, perineum, and vagina (eg, rectovaginal fistula repair, urethral extension surgery, tail amputation). High-volume epidurals use injection volumes of 1 mL per 5 kg body weight, but volumes up to 0.5 mL/kg body weight have been used in calves without adverse events noted.[52] When high-volume epidurals use local anesthetics such as lidocaine, recumbency is required because of loss of motor control of the rear limbs. High-volume epidural anesthesia is advantageous because surgical anesthesia is attained with little to no adverse cardiovascular effect when given within the safe dosage range. This technique has been described for surgery of the rear limbs and umbilicus in calves.[52–54] One of the authors (DEA) has used high-volume epidural anesthesia with lidocaine HCl 2% at a dose of 1 mL per 5 kg body weight (eg, a 500-kg cow would receive 100 mL lidocaine HCl 2%) to facilitate ventral midline C-section, preputial

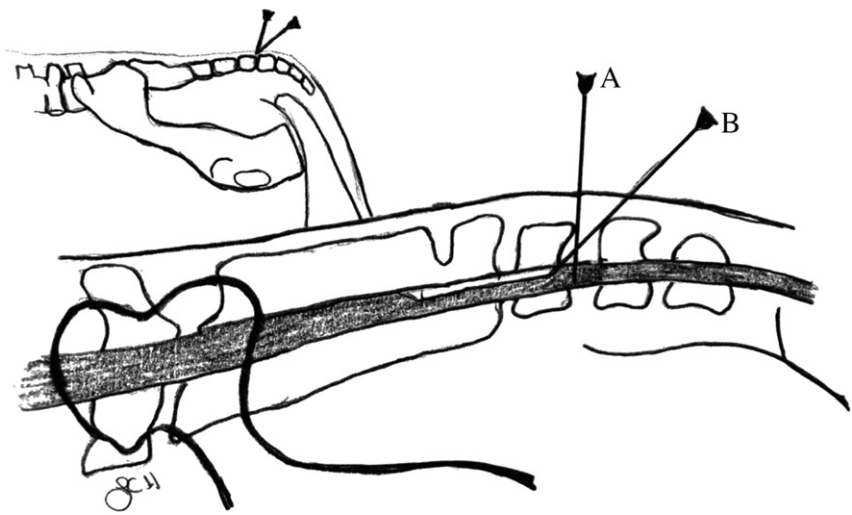

Fig. 7. Needle placement for caudal epidural anesthesia (*A*) and for continuous caudal epidural anesthesia (*B*) located between the first and second coccygeal vertebrae.

translocation for teaser bull preparation, and for placement of transfixation pin-casts for tibia fractures. The patient is nonambulatory for 4 to 6 hours after administration of the epidural. Therefore, postoperative management is crucial to minimize the risks of self-trauma during the period of ataxia. The patient should be placed in a small area with excellent footing (eg, sand bedded stall or small grass pen) and remain undisturbed until standing unassisted. Hobbles are placed on the rear limbs to prevent splaying of the rear limbs, which could cause hip luxation or muscle injury. Bupivacaine is not recommended for epidural use in cattle despite its prolonged duration of analgesia. In a study in goats, the patients were unable to stand for up to 11 hours after administration of bupivacaine 0.75% (1 mL per 4 kg body weight).[55]

Several other drugs have been used for epidural analgesia in cattle. Of particular interest are drugs such as α-2 agonists.[43] These drugs cause analgesia by stimulation of α-2 receptors in the spinal cord and inhibit norepinephrine and substance P release. These drugs may optimize analgesia with minimal motor nerve interference such that the patient may remain standing and stable throughout surgery. Chevalier and colleagues[56] showed that heifers having epidural xylazine administered before preparation for laparotomy had reduced distress in response to paravertebral anesthetic injection and surgical manipulations. Minimal to no postoperative benefit was found. Epidural administration of clonidine (2–3 μg/kg body weight), an α-2 agonist, was evaluated in bulls.[45] Both doses produced perineal analgesia for 192 minutes (2 μg/kg) and 311 minutes (3 μg/kg), but sedation was also dose dependent. No adverse cardiovascular effects were noted. In a study comparing epidural and intramuscular administration of detomidine (40 μg/kg body weight) in cattle, both routes of administration resulted in similar degrees of analgesia of the perineum and flank.[48] Use of α-2 agonists under emergency conditions is discouraged because the risk of profound cardiovascular instability or recumbency exceeds the benefits observed with the use of these drugs.

Opioids have been used in cattle but clinical results have been variable. Opioids act on μ, δ, and κ receptors, inhibit neurotransmitter release, and increase potassium influx into the neuron, thus hyperpolarizing the membrane.[2] Epidural administration of opioids, such as morphine (0.1 mg/kg) diluted in 20 mL of sterile saline, is used to provide analgesia for a prolonged period (approximately 12 hours) without interfering with motor function. Disadvantages of using opioids for epidural anesthesia are that the analgesia is not as potent as lidocaine and the maximum effect of a morphine epidural may not occur for 2 to 3 hours. Caudal epidural administration of morphine may be used to help alleviate pain in the perineal area and straining.[57] In our clinical experience in ruminants, morphine causes mild to moderate clinical analgesia.[47] Tramadol has been investigated as a complimentary drug for epidural use in cattle. Although the onset of analgesia was slower (14.1 minutes) than lidocaine (3.9 minutes), tramadol induced a prolonged period of analgesia (307 minutes) compared with lidocaine (69 minutes) and tramadol-lidocaine combination (174 minutes).[58]

Use of the NMDA receptor antagonist ketamine for epidural administration has shown promise in cattle. Ketamine noncompetitively binds to NMDA receptors and prevents response to adverse stimuli transmitted by C-fibers. Lee and colleagues[46] administered 5% ketamine by caudal epidural injection in volumes of 5, 10, or 20 mL. Cows having 5-mL injections had perineal analgesia for 17 minutes with no ataxia. Cows having 10-mL injections showed mild ataxia for 30 minutes, but had analgesia for 34 minutes. Cows with 20-mL injections had ataxia for 48 minutes, with 1 cow becoming recumbent. Analgesia lasted for 62 minutes. Heart rate, respiratory rate, rectal temperature, rumen motility, and mean arterial pressures did not change throughout the study.

CONTINUOUS CAUDAL EPIDURAL

Continuous caudal epidural anesthesia is used in cattle with chronic rectal and vaginal prolapse that experience continuous straining after the initial epidural. This procedure is performed by placing a catheter into the epidural space for intermittent administration of local anesthetic. A 17-gauge 5-cm spinal needle (Tuohy needle) with stylet in place is inserted into the epidural space at Co1 to Co2 with the bevel directed craniad. The stylet is removed and 2 mL of local anesthetic are injected to determine whether the needle is in the epidural space. A catheter is inserted into the needle and advanced cranially for 2 to 4 cm beyond the needle tip. The needle is then withdrawn while the catheter remains in place. An adapter is placed on the end of the catheter and the catheter secured to the skin on the dorsum. Local anesthetic solution may then be administered as needed.[58] This method of inducing continuous epidural anesthesia was used in a Brown Swiss cow suffering complex regional pain syndrome caused by severe, prolonged infections of a rear foot in which digit amputation failed to resolve clinical pain.[59] This cow received a mixture of methadone, ketamine, and bupivacaine continuously over a 17-day period.

ANESTHESIA OF THE FOOT

In many cases, intravenous regional anesthesia is the preferred technique for surgery of the foot. A tourniquet is placed proximal to the fetlock just before injection when the vein is maximally distended (**Fig. 8**). In the thoracic limb, intravenous regional analgesia can be performed using the dorsal metacarpal vein, the plantar metacarpal vein, and the radial vein (see **Fig. 9**). In the pelvic limb, the lateral saphenous vein or lateral plantar digital vein may be used for injection. Approximately 20 mL of local anesthetic are injected intravenously as close to the surgical site as possible using a 20-gauge 3.3-cm needle or 21-gauge butterfly catheter. It is only necessary to administer anesthetic into 1 vein to provide anesthesia to the area distal to the tourniquet. The tourniquet can be safely left in place for up to 1 hour to provide hemostasis during surgical procedures of the foot. Anesthesia of the foot occurs within 5 to 10 minutes. Once the surgical procedure is complete, the tourniquet is released.

In cases of severe cellulitis, local intravenous anesthesia can be difficult to perform. In these cases, a simple ring block or 4-point nerve block may also be performed. A ring block is a simple method for regional anesthesia distal to the injection sites. Using a 22-gauge 2.5-cm needle, a total of 10 to 15 mL of local anesthetic is injected at multiple sites around the limb adjacent to the superficial and deep digital flexor tendons and medially and laterally to the extensor tendons. The ring block should be performed at the junction of the proximal and middle metacarpus or metatarsus. Although a simple technique to perform, multiple injection sites increase the risk of infection. Problems achieving satisfactory or complete anesthesia of the digit may also be a concern when using a ring block. The 4-point nerve block anesthetizes the area from the pastern distally. A 20-gauge 3.8-cm needle is inserted into the dorsal aspect of the pastern, in the groove between the proximal phalanges, just distal to the fetlock. Five milliliters of local anesthetic injected deep and another 5 mL of local anesthetic are injected superficially. This injection is then repeated on the palmar or plantar aspect of the pastern, just distal to the dewclaws. Five milliliters of local anesthetic are then used to block the digital nerve on both the medial and lateral aspects of the fetlock, which are approximately 2 cm dorsal and proximal to the dewclaw. The 2 interdigital injections performed in the 4-point block may also be used for removal of an interdigital fibroma.[57]

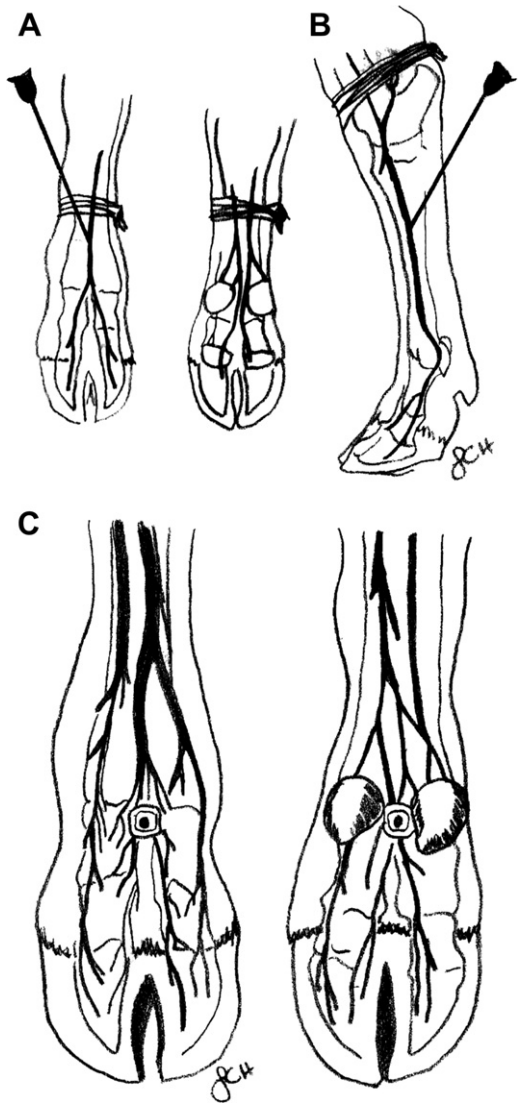

Fig. 8. Proper application of a tourniquet and placement of needle for intravenous administration of local anesthetic. (*A*) Plantar metacarpal vein. (*B*) Plantar metacarpal vein. (*C*) Radial vein.

ANESTHESIA OF THE EYE

Multiple techniques are available for anesthesia of the eye, eyelids, and orbit. Reasons for choosing 1 block rather than another should include the surgeon's comfort and skill at performing the blocks, the disease process present, and a knowledge of the risks associated with each block. Although the Peterson eye block is considered more technically challenging, it is associated with less risk of trauma to the orbit for penetration of the globe, hemorrhage, and damage to the optic nerve.

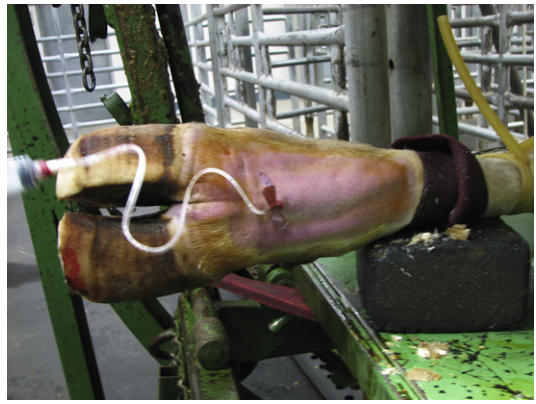

Fig. 9. Intravenous regional anesthesia of the foot. Lidocaine 2% HCl (20 mL) is infused into the dorsal common digital vein distal to a rubber tourniquet.

However, there is risk of neurologic signs or death because of cardiopulmonary arrest if lidocaine is injected into the optic nerve meninges or nasal turbinates. The 4-point block is technically less challenging to perform and seems to yield better anesthesia of the periocular tissues. Although there is risk of intrameningeal injection, the authors' clinical experience has shown it to be less of an issue than with the Peterson nerve block.

AURICULOPALPEBRAL NERVE BLOCK

Surgical manipulation of the eye is facilitated by nerve blockade of the eyelids. Auriculopalpebral nerve block can be placed to reduce upper eyelid movement before performing a Peterson or retrobulbar block. The auriculopalpebral nerve can be palpated as it crosses the zygomatic arch, roughly 5 to 6 cm behind the supraorbital process (**Fig. 10**). Inject 5 mL of 2% lidocaine HCl subcutaneously on the dorsal aspect of the zygomatic arch at this location.

PETERSON NERVE BLOCK

After performing a small local skin block over the intended site of puncture, a 3.8-cm 14-gauge needle is inserted through the skin as a cannula for introduction of an 18-gauge 9-cm needle for the nerve block. The cannula is inserted caudal to the junction of the supraorbital process and zygomatic arch and is introduced through the skin (**Fig. 11**). Then, the 18-gauge 9-cm needle is introduced through the cannula needle and is directed in a horizontal and slightly dorsal direction until the coronoid process is encountered. The needle is walked off the rostral aspect of the coronoid process and advanced in a ventromedial direction along the caudal aspect of the orbit until the needle encounters the bony plate encasing the foramen orbitorotundum. Once the needle is advanced to the foramen, it is advised that the needle be drawn back a few millimeters to reduce the risk of intrameningeal injection. After aspirating to ensure that the needle is not in the internal maxillary artery, 10 to 15 mL of lidocaine (2%) are deposited, with an additional 5 mL of lidocaine deposited as the needle is slowly withdrawn. Mydriasis indicates a successful block.

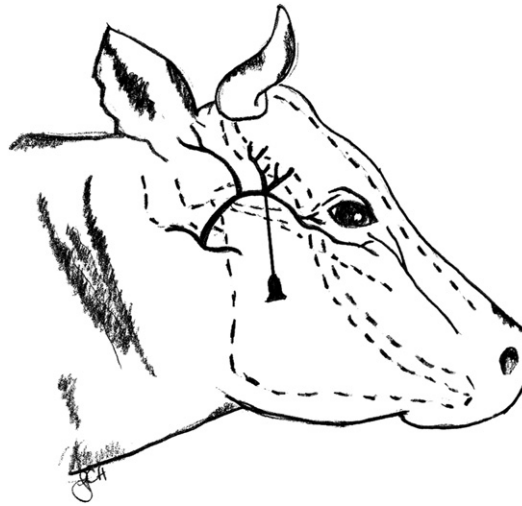

Fig. 10. Needle placement for desensitizing the auriculopalpebral nerve in cattle.

FOUR-POINT RETROBULBAR NERVE BLOCK

The 4-point retrobulbar block is technically easier and can be done more rapidly than the Peterson eye block. In this technique, an 18-gauge 9-cm needle is introduced through the skin on the dorsal, lateral, ventral, and medial aspects of the eye, at 12, 3, 6, and 9 o'clock positions, respectively. Introduction of the needle through the conjunctiva should be avoided to reduce the risk of ocular contamination. The needle is directed behind the globe using the bony orbit as a guide. When the needle is introduced into the retrobulbar sheath, the eye moves slightly with the tug of the needle. After this location is reached and aspiration is performed to ensure that the needle is not in a vessel, 5 to 10 mL of lidocaine (2%) are deposited at each site. Mydriasis indicates a successful block.

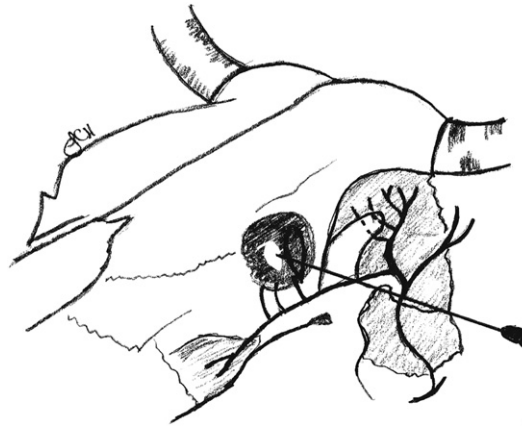

Fig. 11. Needle placement for the Peterson eye block.

RETROBULBAR BLOCK

An alternative to the 4-point retrobulbar block is the single retrobulbar block (**Fig. 12**). In this technique, the 9-cm 18-gauge needle is bent into a half circle. The needle is inserted immediately ventral to the dorsal orbital rim and directed such that the needle makes contact with the bone of the orbit. Then the needle is advanced as it is rotated ventrally in a progressive manner such that the needle remains in close proximity to the bone. After the needle is inserted to the caudal aspect of the eye, 20 mL of 2% lidocaine HCl are administered after aspiration to ensure that the needle is not positioned in a vessel or other fluid structure. Successful deposition of lidocaine causes mild proptosis of the globe.

RING BLOCK

Additional local anesthesia of the eyelids is recommended because the Peterson and retrobulbar blocks typically result in incomplete analgesia of the eyelids. Between 5 and 10 mL of lidocaine (2%) are infiltrated subcutaneously 2.5 cm from the eyelid margins as a ring block.

ANESTHESIA OF THE TEAT

Because most dairy cattle are accustomed to handling and restraint for milking, surgeries of the teat can often be performed with the animal standing and with minimal restraint. Because standing procedures are always preferred in order to prevent udder trauma, most surgical procedures of the teat are performed using local anesthesia.

INVERTED V BLOCK

The inverted V block is used primarily for specific lesions of the teat such as a teat laceration or wart. Using a 25-gauge 1.5-cm needle, approximately 5 mL of local anesthetic are injected into the skin and musculature dorsal to the surgical site in an inverted V pattern (**Fig. 13**).[39]

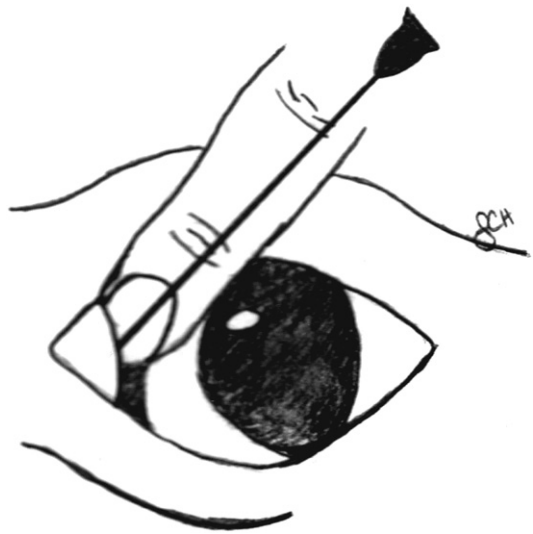

Fig. 12. Retrobulbar needle placement through the medial canthus of the eye in cattle.

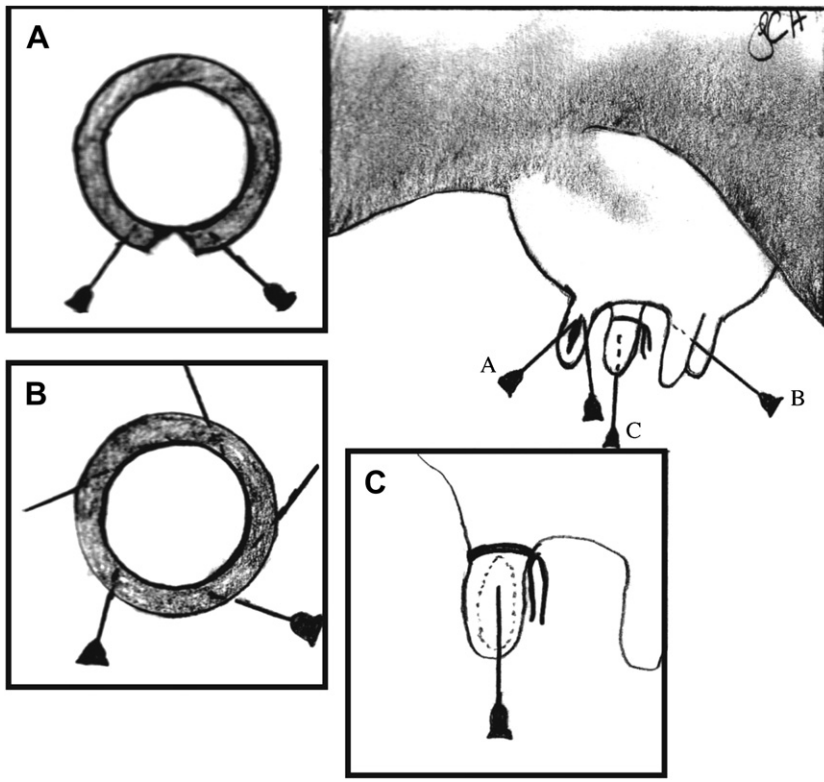

Fig. 13. Needle placement for teat anesthesia in cattle. (*A*) Inverted V block. (*B*) Ring block. (*C*) Placement of a tourniquet and teat cannula for infusion of local anesthetic into the teat cistern.

RING BLOCK

The ring block is a commonly used procedure for teat surgeries. Using a 25-gauge 1.5-cm needle, approximately 5 mL of local anesthetic are injected into the skin and musculature encircling the base of the teat (see **Fig. 13**).[39]

INFUSION OF THE TEAT CISTERN

The teat cistern may be infused with local anesthetic to assist in surgical conditions that only involve the mucous membranes (eg, removal of polyps). Before infusing the teat, the cistern should be milked out and the orifice thoroughly cleaned with alcohol. A tourniquet (rubber band) is then placed on the base of the teat with adequate tension to prevent leakage between the udder and teat cistern. A sterile teat cannula is introduced and approximately 10 mL of local anesthetic are infused to fill the teat (see **Fig. 13**). The teat cannula is removed, and the remaining anesthetic is milked out. Once the surgery is finished, the tourniquet is removed. The musculature and skin are not desensitized using this technique.

INTERNAL PUDENDAL NERVE BLOCK

The procedure for bilateral internal pudendal (pudic) nerve block was first described by Larson[60] to facilitate relaxation of the bull's penis without causing locomotor

impairment. The internal pudendal nerve block can be used in the standing bull for penile relaxation and analgesia distal to the sigmoid flexure and examination of the penis. In the standing female, the internal pudendal nerve block can be used to relieve straining caused by chronic vaginal prolapse. This technique may also be used for surgical procedures of the penis such as repair of prolapses, removal of perianal tumors, removal of penile papillomas or warts, and other minor surgeries of the penis and prepuce.

This procedure involves desensitizing the internal pudendal nerve and the anastomotic branch of the middle hemorrhoidal nerve using an ischiorectal approach. The internal pudendal nerve consists of fibers originating from the ventral branches of the third and fourth sacral nerves (S_3 and S_4) and the pelvic splanchnic nerves. The skin at the ischiorectal fossa on either side of the spine is clipped, disinfected, and desensitized with approximately 2 mL of local anesthetic. A 14-gauge 1.25-cm needle is inserted through the desensitized skin at the ischiorectal fossa to serve as a cannula (**Fig. 14**). An 18-gauge 10-cm spinal needle is then directed through the cannula to the pudendal nerve. The operator's left hand is placed into the rectum to the level of the wrist and the fingers directed laterally and ventrally to identify the lesser sacrosciatic foramen. The lesser sciatic foramen is first identified by rectal palpation as a soft depression in the sacrosciatic ligament. The internal pudendal nerve can be readily identified lying on the ligament immediately cranial and dorsal to the foramen and approximately 1 finger's width dorsal to the pudendal artery passing through the foramen. The internal pudendal artery can be readily palpated a finger's width ventral to the nerve. The spinal needle is held in the operator's right hand and introduced through the cannula in the ischiorectal fossa. The spinal needle is directed medial to the sacrosciatic ligament and directed cranioventrally. The needle cannot be felt until it has been introduced approximately 5 to 7 cm, and it can then be repositioned to the nerve. Once at the pudendal nerve, 20 mL of local anesthetic are deposited at the nerve. The needle is then partially withdrawn and redirected 2 to 3 cm caudodorsally where an additional 10 mL of local anesthetic are deposited at the cranial aspect of the foramen to desensitize the muscular branches and the middle hemorrhoidal nerve. The needle is then removed and the sites of deposition are massaged to aid in dispersal of the local anesthetic. This procedure is then repeated on the opposite

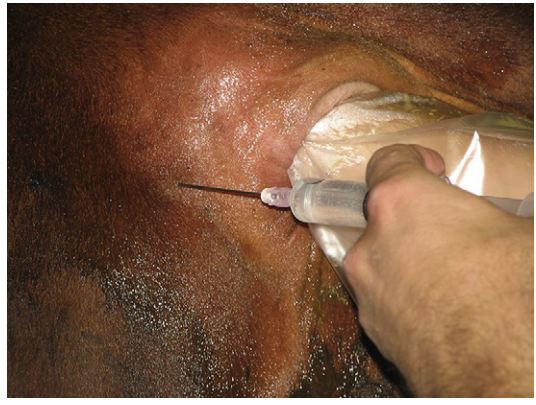

Fig. 14. Needle being inserted into the pararectal fossa of a bull for the purpose of blocking the pudendal nerve. Pudendal nerve block achieves paralysis of the retractor penis muscles and facilitates extension, manipulation, and surgery of the penis and prepuce.

side of the pelvis. Relaxation of the penis varies and may take as long as 30 to 40 minutes for full effect. The duration of the internal pudendal nerve block is from 2 to 4 hours.

ANESTHESIA FOR DEHORNING

The cornual nerve block is used for anesthesia for dehorning cattle. The horn and the skin around the base of the horn are innervated by the cornual branch of the lacrimal or zygomaticotemporal nerve, which is part of the ophthalmic division of the trigeminal nerve. The cornual nerve passes through the periorbital tissues dorsally and runs along the frontal crest to the base of the horns. Approximately 5 to 10 mL of a local anesthetic agent are deposited subcutaneously and superficially midway between the lateral canthus of the eye and the base of the horn along the zygomatic process (**Fig. 15**). Complete anesthesia may take 10 minutes. Larger cattle with well-developed horns require additional anesthetic infiltration along the caudal aspect of the horn, in the form of a partial ring block, to desensitize subcutaneous branches of the second cervical nerve.

NASAL ANESTHESIA

The infraorbital nerve block may be used for the repair of nasal lacerations and the placement of a nose ring. The infraorbital nerve is the continuation of the maxillary branch of the fifth cranial nerve after it enters the infraorbital canal. The infraorbital nerve has only sensory function and emerges on the face as a flat band through the infraorbital foramen where it is covered by the levator nasolabialis muscle. The infraorbital nerve is blocked as it emerges from the infraorbital canal. The nerve is difficult to palpate but is located rostral to the facial tuberosity on a line extending from the nasomaxillary notch to the second upper premolar. From 20 to 30 mL of local anesthetic agent are injected deep into the levator nasolabialis muscle with an 18-gauge 3.8-cm needle (**Fig. 16**). The injection should be repeated on the opposite side.

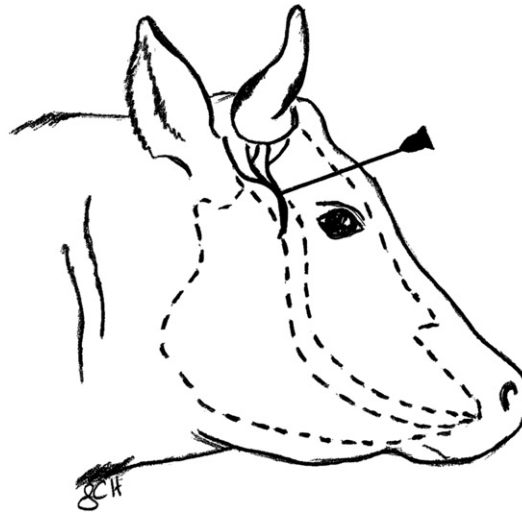

Fig. 15. Needle placement for desensitizing the cornual branch of the zygomaticotemporal nerve in cattle.

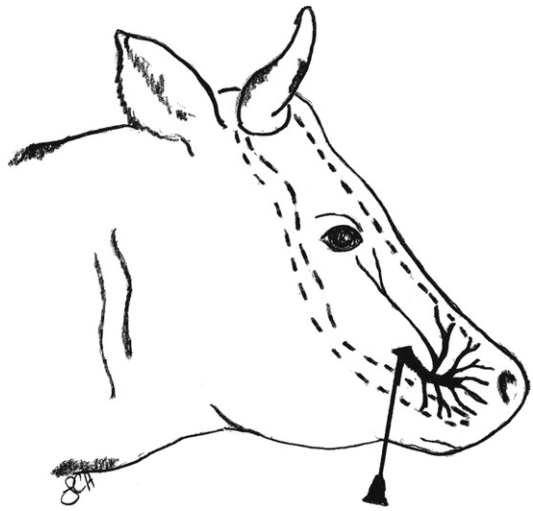

Fig. 16. Needle placement for desensitizing the infraorbital nerve in cattle.

ELECTROACUPUNCTURE AND ELECTROIMMOBILIZATION

Few scientific data are available for the use of acupuncture techniques in critical cases in cattle. Our clinical experience with acupuncture is limited to attempts to ameliorate chronic pain. Although we have observed profound short-term improvement in pain in cases of arthritis, myopathy, and a variety of injuries, we have not attempted to use acupuncture for surgery or management of critical cases. Kim and colleagues[61] evaluated the use of electroacupuncture for induction of analgesia for surgery in cattle. Cattle were assigned to (1) the dorsal acupoint (GV-20 and GV-5), (2) the lumbar acupoint (BL-21, BL-23, BL-24, and BL-25), (3) the combined dorsal and lumbar (BL-21, BL-23, BL-24, and GV-5), or (4) the control group. Analgesia was most profound after dorsal acupoint, followed by the combined group and then the lumbar group. The investigators stated that the dorsal acupoints cause recumbency and are only suitable for recumbent surgery in cattle, but that the combined or lumbar acupoints would be useful for standing surgery.

Electroimmobilization for surgical procedures is controversial. The ideal balance of control and inhibition of pain is difficult to achieve and monitor. In a study designed to examine the physiologic responses of heifers to spaying, flank ovariectomy was performed using electroimmobilization as the sole means of analgesia but administered by a veterinarian skilled in the use of the immobilizer.[62,63] Significant increases in serum cortisol were found compared with control heifers. Humane, effective use of electroacupuncture requires intensive training of the operator. Routine use of this technology is not recommended without special training.

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