Standing exploratory abdominal surgical procedures are routine in adult cattle. They are commonly performed to correct left or right displaced abomasum, cesarean sections, and rumenotomies. The most common of these are displaced abomasum. It is estimated that at least 200,000 cows develop abomasal displacement on US dairy farms annually.1

Local anesthetics are used for regional infiltration and perineural blocks to facilitate abdominal exploration through the paralumbar fossa in cattle. The most common techniques implemented to desensitize the paralumbar fossa include proximal/distal paravertebral and inverted L blocks. Distal paravertebral blocks are used frequently due to the technique’s simplicity, ease, and reliability compared to proximal paravertebral blocks. In addition, the risk of penetrating vital structures, such as the aorta and thoracic longitudinal vein on the left side and the caudal vena cava on the right side, is significantly less during a distal approach versus a proximal paravertebral approach.2 Furthermore, anesthesia achieved via the paravertebral approach may be superior to an inverted L block during incision of all layers of the body wall.3

The distal paravertebral block desensitizes the dorsal and ventral spinal nerves of T13, L1, and L2. The nerve roots are blocked at the distal ends of the transverse processes of L1, L2, and L4. This technique provides sensory blockade to the entirety of the paralumbar fossa. The local anesthetic used most for this technique is lidocaine because it is labeled for cows and it is inexpensive, relatively safe, and has an established withdrawal time. The duration of action of lidocaine is relatively short (approx 90 minutes).4 While most procedures can be performed during this time, the duration of action can be unpredictable after distal paravertebral block.

Adjunctive agents, such as epinephrine and α2-adrenoceptor agonists, have been investigated to determine their effect on onset time and duration of local/
regional blocks in the human and veterinary medical literature. Epinephrine has been shown to prolong the duration of local anesthesia by producing vasoconstriction and limiting systemic absorption of coadministered local anesthetics. \(^2\) \(\alpha_2\)-Adrenoceptor agonists, such as dexmedetomidine and clonidine, have also been shown to prolong local anesthetic action. In humans, when dexmedetomidine was added to a lidocaine-ropivacaine supraclavicular brachial plexus block, it produced a longer duration of action and improved postoperative analgesia. \(^6\) Furthermore, brachial plexus blockade in humans with bupivacaine was superior when clonidine was added compared to epinephrine. \(^7\) The addition of xylazine to lidocaine in caudal epidurals has been shown to prolong analgesic action of the epidural in cattle, horses, llamas, and camels. \(^8\)-\(^11\) Lastly, the addition of dexmedetomidine to a supraclavicular bupivacaine block resulted in a shorter onset time of sensory blockade in humans. \(^12\) From this information, we hypothesized that a lidocaine plus xylazine distal paravertebral block would have a shorter onset time and lengthen the duration of action/anesthesia compared to a lidocaine-only block.

**Methods**

**Animal selection**

A statistical a priori power analysis (type II error = 0.8; type I error = 0.05) showed that 6 animals were necessary to detect significant differences in duration of blockade on the basis of results of a previously performed study that evaluated the effect of xylazine on the duration of action of lidocaine in the epidural space. \(^9\) Healthy adult Holstein university-owned cows were sourced. Their weights ranged from 641 to 809 kg. The use of these animals was approved by an institutional IACUC. Due to an unexpectedly high incidence of failure of complete blockade in the first 6 cows, 4 more cows were added to the study. A randomized crossover design was utilized to assign treatments to cows. Six cows underwent all 3 treatments—xylazine hydrochloride, 2% lidocaine hydrochloride, and 2% lidocaine hydrochloride plus xylazine hydrochloride (LX)—and 4 cows underwent 2 treatments (lidocaine and LX). There was a washout period of at least 1 week between treatments for all cows.

**Preparation and administration of paravertebral blocks**

Each cow was weighed the day before the experiment was conducted. The cows were restrained in a head gate and chute and had free access to hay and water for the duration of data collection. A baseline heart rate (HR) was obtained via auscultation after an acclimation period in the head gate. A cardboard blind-er was placed on both sides of the head of each cow to prevent the animal from viewing the data collectors.

The right paralumbar fossa was clipped free of hair and aseptically prepared by 5 alternating applications of chlorhexidine scrub and alcohol. If a scar was observed in the paralumbar fossa (indicating a previous surgical site) the left paralumbar fossa was used instead. A 30-cm line was drawn with a marker along with the traditional laparotomy incision site to identify the area used to test desensitization.

A distal paravertebral block was performed as described by Edmondson. \(^13\) The blocks were performed by a novice veterinarian with no experience performing these blocks. They were blinded to the treatment administered. Briefly, the tuber coxae of the pelvis was identified by palpation. The transverse process of L5 was identified and used to identify the transverse processes of L1, L2, and L4. A 7.6-cm 18-gauge hypodermic needle was inserted perpendicu-lar to the skin plane at the lateral and mid aspect of the transverse process in question. The needle was inserted approximately 7.6 cm directed dorsal to the transverse process, toward the midline, and as close to the bone as possible. After aspiration to identify and prevent inadvertent intravascular injection, the test solution was injected along the dorsal surface of the transverse process in a fan-shaped pattern by removing the needle approximately 1 cm and then redirecting the needle first cranial and then caudal. The needle was then redirected ventral to the transverse process by withdrawing the needle until the tip remained just under the skin, and the process was repeated. In total, 6 injections were used to anesthetize the dorsal and ventral spinal nerves of T13, L1, and L2 as they crossed the transverse processes of L1, L2, and L4.

A total of 90 mL of test solution was used in each cow (15 mL at each dorsal and ventral site). Ninety milliliters of 2% lidocaine hydrochloride was used in the lidocaine treatment, and 0.8 mL of 20 mg/mL xylazine hydrochloride was added to 89.2 mL of 0.9% saline for the xylazine treatment. This amount of xylazine was chosen to administer approximately 0.025 mg kg\(^{-1}\) of xylazine to the average 700-kg adult female Holstein cow. Lastly, for the LX treatment, 0.8 mL of xylazine hydrochloride was added to 89.2 mL of 2% lidocaine hydrochloride to achieve a total volume of 90 mL.

**Assessment of onset and duration of action**

The sensory blockade of the skin and musculature of the paralumbar fossa was assessed via a series of needle pricks. A 2.5-cm 22-gauge hypodermic needle was inserted approximately 1.2 cm deep through the skin and into the underlying musculature every 5 cm along the previously drawn 30-cm vertical line. The line extended from the dorsal to the ventral border of a traditional laparotomy incision in the center of the paralumbar fossa.

Rapid movements of the tail, directed movements of the feet, or turning of the head toward the site of the needle pricks were considered a positive response to the stimulus. \(^14\) Twitching of the skin was not regarded as a positive response, as this could represent the panniculus reflex. The researcher who observed for a positive response was blinded to the treatment. The presence of a response to just 1 needle prick (out of the 6 pricks at each time point) was defined as the end of anesthesia. The location of the pin prick that resulted in the end of anesthesia was not recorded.

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Time from injection to the observation of a diminished avoidance response was recorded as the time of onset of action. The paralumbar area was stimulated, as described above, every minute for the first 15 minutes and then every 15 minutes until return of sensation. If anesthesia was demonstrated, the return of a response to the needle prick was defined as the end of anesthesia and further evaluation was discontinued. If anesthesia was not demonstrated within 30 minutes, the assessment was terminated and the block was considered a failure. The interval from the onset of anesthesia to the return of sensation at the site was considered the duration of action of the block.

Sedation scoring
Degree of sedation was assessed before administration of the drugs (baseline) and then at 5-minute intervals for 30 minutes and then at 15-minute intervals until it was determined that the local anesthetic was no longer effective. The researcher who graded sedation was blinded to the treatment. Sedation was graded on a numeric scale, as follows: 1 = mild sedation (slight lowering of the head and/or protrusion of the lower lip), 2 = moderate sedation (signs of mild sedation plus presence of prolapsed third eyelid and ptalism), or 3 = marked sedation (signs of moderate sedation plus need to lean on a structure for support).

Heart rate
Heart rates were determined by auscultation for 15 seconds, then multiplying that number by 4. The researcher who obtained HR was blinded to the treatment. A baseline HR was determined prior to injections. Another HR was reported immediately after injections. Then, the HR was obtained every 15 minutes until the return of sensation.

Statistical analysis
Parametric data were analyzed with a paired t test. When data were not normally distributed or if unequal variance was present, a Wilcoxon signed rank test was used. To compare the success rate of the block between each treatment, a Fisher exact test was used. Data were presented as mean ± SD when normal theory testing was employed and as median (range) when nonparametric testing was used. A P value < .05 was considered statistically significant. All analyses were done using SAS 9.4 software.

Results
The study was initially designed to include 6 cows. None of the 6 cows showed evidence of blockade after xylazine administration (0% success rate). The success rates of lidocaine and LX treatments in the first 6 cows were 33% and 83%, respectively. Due to the high number of cows that failed to exhibit anesthesia after injection of lidocaine or LX, 4 more cows were added to the study to provide better statistical power. Because xylazine was without effect in all 6 cows, and local anesthetic effects were not expected after this treatment, the 4 additional cows only received 2 treatments (lidocaine and LX). The overall success rate for all injections that included lidocaine or LX was 75% (15/20). The success rate for lidocaine was 60%, whereas the success rate for LX was 90%; however, this finding was not statistically significant ($P = .303$).

Data were only analyzed in cows that were observed to have successful anesthesia in both lidocaine and LX treatments ($n = 5$). The onset of nerve blockade was 5 minutes (1 to 15 minutes) and 5 minutes (3 to 14 minutes) for lidocaine and LX treatments, respectively ($P = .563$). Duration of anesthesia was 105.8 ± 35.9 minutes and 251.6 ± 96.94 minutes for lidocaine treatment and LX, respectively, which was significantly different ($P = .01$, Figure 1).

No sedation was observed in cows after lidocaine treatment. All cows exhibited signs of sedation after LX treatment; 4 cows were assigned a sedation score of 1, and 1 cow was assigned a sedation score of 2. The max sedation score was not different between treatments ($P = .063$).

Baseline HRs were 60 beats/min (bpm; 50 to 60 bpm) and 60 bpm (56 to 60 bpm) in the lidocaine and LX treatments, respectively ($P = .500$). Average HRs throughout the observation period were 59 ± 3 bpm and 56 ± 3 bpm in the lidocaine and LX treatments, with HR in the LX treatment significantly lower ($P = .045$). Minimum HRs were 54 bpm (50 to 60 bpm) and 48 bpm (40 to 52 bpm) and time to minimum HR was 60 minutes (15 to 90 minutes) and 30 minutes (30 to 105 minutes) in lidocaine and LX treatments, respectively, and were not different ($P = .063; P = 1.0$).

Discussion
In this study, anesthesia did not occur when xylazine, an $\alpha_2$-adrenoceptor agonist, was administered...
alone in a distal paravertebral block. This was expected on the basis of the mechanism of action of the drug. Yet when xylazine was coadministered with lidocaine, a significantly prolonged duration of anesthesia was observed compared to lidocaine alone. Our finding was consistent with previous investigations showing the addition of an α₂-adrenoceptor agonist to a local anesthetic increased duration of action of peripheral blocks in human beings. 16,17 In addition, α₂-adrenoceptor agonists have been shown to increase duration of local anesthetic effects after epidural administration in cattle, horses, llamas, and camels. 18-21 α₂-Adrenoceptor agonists may decrease vascular uptake or removal of local anesthetics as a result of either local vasoconstriction or inhibition of local anesthetic-induced vasodilation. Their ability to decrease release of norepinephrine from nerve terminals inhibits propagation of nerve fiber action potentials and may also cause analgesia. 22 Other work has shown that centrally α₂-adrenoceptor agonist produces analgesia by inhibiting the production of substance P in the nociceptive pathway at the level of the dorsal root neuron. 23 Lastly, it has been shown that dexmedetomidine is administered perineurally it causes hyperpolarization of activated cation channels. Hyperpolarization prevents the nerve from returning to the resting membrane potential state and therefore prevents the propagation of an action potential. 24 The exact mechanism in which α₂-adrenoceptor agonists prolong blockade is still unknown, but it is likely multifactorial. 25

To test sensation, the paralumbar fossa was pricked every minute for the first 15 minutes and then every 15 minutes until return of sensation. There is a chance that peripheral sensitization could have occurred, due to repeated pricks causing inflammation, resulting in a change to nociception. However, since every animal was treated similarly, it is not believed that a change in nociception would have influenced treatment effects. There was no outward appearance of inflammation at the test site as a result of needle pricks.

The average HRs for the LX treatment were significantly lower over the observation time compared to the lidocaine treatment. This finding indicates that the xylazine was absorbed systemically after distal paravertebral injection. Bradycardia is frequently associated with α₂-adrenoceptor agonists and may be a reflex response to drug-induced hypertension and/or a result of decreased central sympathetic activity. The observed change was relatively mild, and bradycardia was not observed in any animal. The normal range of HRs in dairy cattle is reported to be between 38 and 96 bpm. 19 Thus, this finding may be inconsequential from a physiological and clinical standpoint.

All cows that received LX in their distal paravertebral block exhibited sedation based on the scoring system. In contrast, none of the cows were observed to be sedated after lidocaine treatment. Sedation scores were not significantly different between the 2 treatments, most likely due to an underpowered sample size. Four cows that exhibited sedation received a score of 1 = mild (slight lowering of the head and/or protrusion of the lower lip), and 1 cow received a score of 2 = moderate (signs of mild sedation plus presence of prolapsed third eyelid and ptalysmal). Therefore, sedation would be characterized as relatively mild. It is important to note that in some instances, cows undergoing standing exploratory laparotomies may receive systemic xylazine or other sedative agents prior to local or regional block to facilitate local anesthetic injection and the surgical procedure. In this case, xylazine in the local anesthetic block could contribute to additional sedation. However, when considering the low dose of xylazine administered in the regional block and mild sedation observed in this study, it is not anticipated that the level of sedation seen in cattle would be excessive when combined with systematically administered xylazine.

To the authors’ knowledge, the success rate of blind distal paravertebral blocks in cattle has never been reported. Re et al 19 compared paravertebral blockade techniques with and without ultrasound guidance in calves but only reported a success rate of proximal paravertebral blockade. When using lidocaine and epinephrine, their onset time was longer and their duration of action was shorter compared to this study. 19 In this study, data collection was discontinued at 30 minutes if anesthesia of the paralumbar fossa was not observed. Re et al 19 demonstrated that following some distal paravertebral blocks, anesthesia of the paralumbar fossa was not noted until after 30 minutes. This indicates that some of the block failures in this study may have been successful, but data were not collected for a long enough period to make that determination. This timeline was chosen because in clinical medicine, many practitioners would not wait longer than 30 minutes for the onset of blockade and would administer local anesthetics by an alternative route to facilitate abdominal exploration.

In this study, the overall success rate (75%) was not significantly different between treatments. Treatment failures could be explained by alterations in individual cow nerve anatomy at the L1, L2, and L4 transverse processes, 25 the inherent ineffectiveness of the block when performed as described, the use of 15 mL of local block at each site compared to 20 mL used in other studies, 19 and the novice skill of the investigator performing the blocks. Re et al 25 used 20 mL of local anesthetic at each site, but 15 mL was used in this study according to Edmondson’s description. 25

The largest weakness of this study was related to the low statistical power. Despite enrolling 10 cows in the study, statistical power was limited by inclusion data from only 5 cows that were observed to have regional anesthesia after both the lidocaine and LX treatments. A Wilcoxon signed rank test was used whenever assumption of normality was not met by data. However, a Wilcoxon signed rank test cannot define a P value below .063 with n = 5. Therefore, our conclusions were limited for variables analyzed using a nonparametric analysis.

In conclusion, an LX distal paravertebral block had a significantly longer duration of action compared to lidocaine alone. The addition of xylazine provided mild to moderate sedation and may cause a decrease in HR of the cow. Additionally, it may improve the success rate of the block. More research is needed to determine whether the same findings would be observed in
other common blocks to facilitate abdominal standing surgery in dairy cows such as the proximal paravertebral block and in the inverted L or “7” block. In future studies, it would be beneficial to increase the sample size to improve statistical power.

Acknowledgments

The authors acknowledge all faculty and staff from the University of Missouri who contributed to this project.

Disclosures

The authors have nothing to disclose. No AI-assisted technologies were used in the generation of this manuscript.

Funding

The authors would like to thank the USDA for funding the project and publication through a USDA Formula Fund Award.

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