Epidural and intrathecal anesthesia are frequently used as alternatives to general anesthesia for procedures involving the tail, perineum, anus, rectum, flank, and pelvic limbs in small ruminants. These techniques can reduce potential complications, such as ruminal bloating, regurgitation, and aspiration, following general anesthesia in the caprine species. Local anesthetics, such as lidocaine (LIDO) and bupivacaine (BUPI), provide excellent analgesia, are cost effective, and are readily available due to their lack of potential substance abuse. However, LIDO has a short duration of action that may prevent it from providing analgesia for the entirety of a procedure. When used in the epidural space, BUPI provides extended analgesia but also causes prolonged motor blockade, which can lead to recumbency for up to 6 hours. This prolonged recumbency can lead to ruminal tympany, gastrointestinal stasis, nerve or muscle injury, and loss of production.

Subarachnoid injection of local anesthetic provides a higher intensity of blockade but shorter duration when compared to epidural injection. Studies investigating subarachnoid BUPI and LIDO in goats have historically used high doses (1.5 mg/kg and 2.5 mg/kg, respectively). According to Rizk et al., motor blockade and subsequent recumbency after subarachnoid BUPI were unacceptably long (160.2 ± 60.3 minutes). Therefore, the authors concluded that

**OBJECTIVE**
This study aimed to compare the effects of low-dose subarachnoid injections of 2% lidocaine (LIDO) and 0.5% bupivacaine (BUPI) in goats.

**ANIMALS**
6 healthy, privately owned female goats.

**METHODS**
In this randomized blind crossover clinical trial, each goat received 0.05 mL/kg −1 of LIDO, BUPI, or sterile saline solution into the lumbosacral subarachnoid space, with a seven-day washout. Cardiorespiratory variables, rectal temperature, and somatosensory (pinprick) and motor (ataxia) functions were recorded at baseline (time 0) and 2, 5, 10, 15, and 30 minutes after injection, then every 20 minutes until the goat was standing and able to walk. Time to regain somatosensory and motor functions was compared between treatments using Kaplan-Meier survival curves and the Cox proportional hazards model. Linear mixed-effects models were used to compare cardiorespiratory variables between treatments and over time. A P value ≤ .05 was considered significant.

**RESULTS**
Somatosensory recovery was longer with BUPI, though not statistically significant. The median time to stand was 50 (50, 67) minutes after LIDO injection and 104 (101, 156) minutes after BUPI injection (P = .031). The median time to walk was 72 (54, 85) minutes after LIDO versus 225 (220, 245) minutes after BUPI injection (P = .031). Cardiovascular and respiratory variables showed no significant differences between treatments.

**CLINICAL RELEVANCE**
Despite prolonged ataxia with BUPI, pinprick sensation recovery did not differ. At reduced doses, both LIDO and BUPI are deemed acceptable for short procedures of the flank, pelvic limb, or tail in healthy goats.

**Keywords:** caprine, lidocaine, bupivacaine, subarachnoid, motor blockade
BUPI was inappropriate for use in the caprine species. However, low-dose BUPI has been used to provide pain control for the entirety of surgical procedures in humans9–14 and bovine calves15,16 without observing prolonged motor blockade.

The effects of low-dose subarachnoid BUPI and LIDO have not been compared in goats. Providing the caprine patient with quality analgesia during surgical procedures while allowing them to regain mobility shortly after would benefit the animal, the practitioner, and the owner or producer. Therefore, the main objective of this study was to compare the duration of somatosensory and motor blockade in goats injected with low doses of subarachnoid BUPI (0.5% BUPI hydrochloride injection; 0.25 mg/kg), LIDO (2% LIDO hydrochloride; 1 mg/kg), or sterile saline solution (0.9% sterile saline solution; 0.05 mL/kg total volume). We also aimed to compare heart rate (HR), mean arterial blood pressure (MAP), respiratory rate (RR), SpO₂, and rectal temperature (RT) between treatments and over time. We hypothesized that in goats treated with BUPI, the duration of somatosensory and motor blockade would be longer compared to goats treated with LIDO or saline. Additionally, we hypothesized that lower doses of LIDO and BUPI would result in a shorter duration of motor blockade as opposed to higher doses used in previous studies.

Methods

This single-center, randomized, blinded crossover experimental study was approved by the IACUC at the University of Florida College of Veterinary Medicine. A group of 6 client-owned adult female goats of various breeds, weights, and ages were recruited for this study. Each goat was deemed healthy by physical examination, blood work screening (complete blood count, serum biochemistry, and electrolytes), and parasite (McMaster’s fecal analysis) and bacterial testing (Coxiella burnetii). During the experimental period, the goats were group housed on grass pastures with wood board and mesh wire fencing. The animals were provided commercial pelleted grain and coastal Bermuda hay once daily and free-choice access to grass and fresh water. An IACUC approved room designed for general surgery preparation was used for sedation, subarachnoid injections, and monitoring. Eight hours before subarachnoid injections and study monitoring, the goats were housed in isolated stalls and fasted, with free access to water.

Before the beginning of the study, a free online software application, Research Randomizer Version 4.0 (www.randomizer.org), was used to determine the order of treatments for each goat. Study drugs were administered by a single researcher unaware of the treatment allocation. Each treatment was followed by a one-week washout period. The treatments consisted of subarachnoid injections of 0.25 mg/kg preservative-free BUPI (0.5% BUPI hydrochloride injection, USP), 1 mg/kg preservative-free LIDO (2% LIDO HCl, USP) to a 0.05-mL/kg final volume, or an equal volume of 0.9% sterile saline (sterile saline solution, USP). The dose of LIDO selected had been deemed an effective dose when used in the clinical setting in female goats undergoing cesarean section surgeries.17 An equipotent dose of BUPI was selected using information from Webb et al18 in the 9th edition of Veterinary Pharmacology and Therapeutics, stating that BUPI is 4 times more potent than LIDO. Using commercially prepared concentrations of LIDO (2%) and BUPI (0.5%) at the specified study doses, the volume administered was thus standardized at 0.05 mL/kg.

The goats were sedated with 0.25 mg/kg IV midazolam (midazolam hydrochloride injection; 5 mg/mL). After sedation, IV jugular catheterization was performed using a 20-gauge, 5-cm over-the-needle catheter. The goats were placed in sternal recumbency, and the pelvic limbs were pulled cranially. The lumbosacral space was identified by palpating the depression between the spinous processes of the last lumbar (L6) and the first sacral (S1) vertebrae. The injection site was slightly caudal to the line connecting the iliac crests at the midline. The area was clipped and steriley prepared using 0.5% chlorhexidine scrub and isopropyl alcohol before 1 mL of 2% LIDO was injected into the SC tissues overlying the lumbosacral space. A 20-gauge, 8.89-cm spinal needle was guided into the subarachnoid space with the spinal needle almost perpendicular to the skin surface, with the bevel directed cranially. Once the skin and intercospinous ligament were penetrated, the stylet was pulled out. Correct positioning was confirmed by the appearance of CSF in the hub of the needle. The blinded researcher administered the assigned study drug at a rate of 1 mL per 30 seconds. After the successful injection of the intended subarachnoid study drug, goats were given 0.025 mg/kg of IV flumazenil (flumazenil injection; 0.1 mg/mL) to antagonize the effects of the midazolam. Goats were maintained in sternal position for 5 minutes to prevent unilateral distribution of the drug. Still, it was noted if the goats attempted to stand within 5 minutes following reversal.

HR and rhythm was recorded using an ECG in lead 2 configuration. The HR was then confirmed using digital palpation of the femoral artery. Noninvasive MAP was measured using a commercial oscillometric device (petMAP; Ramsey Medical Inc) and an appropriately sized cuff with a width approximately 40% of the circumference of the antebraeuchium. SpO₂ was measured with a transmission pulse oximeter attached to the skin of the inguinal fold. The RT was measured using a rectal probe in degrees Fahrenheit. Continuous ECG, SpO₂, and RT monitoring were established with a multparameter monitor (Philips Medizin Systeme Boeblingen GmbH). RR was measured by observing the movement of the chest. Baseline RT, HR, MAP, RR, and SpO₂ were recorded before sedation, then at 2, 5, 10, 15, and 30 minutes following subarachnoid injection, and then every 20 minutes until the goat was able to stand.

Somatosensory blockade (response to pinprick) and motor blockade (ataxia) were assessed and scored by a blinded investigator. To assess
somatosensory blockade, a 24-gauge, 2.5-cm needle was used to prick the skin of the tail, perineum, pelvic limbs, flanks, and caudodorsal to the ribs. If the animal did not respond to the pinprick, a deeper puncture (approx 20 to 25 mm) into the muscle of the respective area was performed. A positive response was considered if the animal moved away from the stimulus, looked at the area that was stimulated, or vocalize during the stimulus. Using a criterion adapted from DeRossi et al., the animal response was scored as: 1, strong reaction to stimulus; 2, depressed response to stimulus; 3, no response to skin prick; and 4, no response to muscle penetration. If the goat recorded 2 consecutive scores ≤ 2, the stimulation was immediately ceased and the time recorded. Ataxia was scored as: 1, absence of ataxia (able to stand and walk); 2, mild ataxia (difficulty standing); 3, moderate ataxia (recumbency with ability to move the pelvic limbs); and 4, severe ataxia (recumbency without the ability to move the pelvic limbs). Standing was defined as a recorded ataxia score ≤ 2 and ambulation as a recorded ataxia score ≤ 1. Somatosensory and motor blockade were assessed at baseline (before sedation); at 2, 5, 10, 15, and 30 minutes after subarachnoid injection; and every 20 minutes thereafter until the goat was able to stand.

Each goat was housed in the veterinary hospital for continued observation over a twelve-hour period following their injections. The goats were released to pasture board following the monitoring period.

### Statistical analysis

Assuming a mean ± SD time to stand of 50 ± 20 minutes after subarachnoid LIDO injection, we calculated that 5 goats would have been sufficient to detect a 30-minute difference in standing time between BUPI and LIDO, with a significance level of 5% and a power of 80%. Therefore, 6 goats were used in this study to account for possible data loss. Data were assumed not normally distributed and therefore were presented as median (IQR). For the purpose of the analysis, a somatosensory score ≥ 3 was considered a negative response (somatosensory blockade) and a score ≤ 2 a positive response. Time to regain skin sensitivity was compared by body parts and treatments using the Cox proportional hazards model. Time to stand and walk were compared between LIDO and BUPI using Kaplan-Meier survival curves and a Wilcoxon signed-rank test. The data underwent rank transformation for ataxia score, HR, MAP, RR, SpO₂, and RT before conducting comparisons. Mixed-effect regression models were employed, with goat serving as the random effect and time, and their interaction as fixed effects. All analysis was performed with Stata/BE version 17.0 for Mac (StataCorp LLC).

### Results

A sample of 6 adult female goats of various breeds, 24.0 to 73.5 kg in body weight and 28 to 72 months old, were recruited for this study (Table 1). All goats injected with saline and one goat injected with LIDO stood within 5 minutes of flumazenil injection. The median (IQR) time to stand was 50 (50, 67) minutes after LIDO injection and 104 (101, 156) minutes after BUPI injection (P = .031). The median (IQR) time to walk was 72 (54, 85) minutes after LIDO injection and 225 (220, 245) minutes after BUPI injection (P = .031) (Figure 1).

The mixed-effect linear model for pinprick response was significant (log likelihood, 4,140.544; P < .0001). Regardless of the body area, both LIDO and BUPI caused loss of pinprick response with respect to the saline treatment (likelihood ratio chi-square test LRχ² = 774.60; P < .0001). There was a significant interaction between treatment and body part (LRχ² = 42.38; P < .0001). Specifically, pinprick response recovered faster in the flank and rib regions than the tail after LIDO (hazard ratio, 3.06; SE, 0.79; 95% CI, 1.84 to 5.08 and hazard ratio, 3.24; SE, 0.84; 95% CI, 1.95 to 5.40, respectively; P < .0001). Pinprick response also recovered faster in the rib area than the tail after BUPI (hazard ratio, 2.24; SE, 0.72; 95% CI, 1.30 to 3.86; P = .004). In the BUPI treatment, 1 goat did not recover pinprick response in the pelvic limb and in the flank by the end of the study period (150 minutes). When considering each body area individually, pinprick sensation took longer to recover after BUPI than after LIDO. However, this difference did not reach statistical significance for any of the body areas. The median (IQR) time (in minutes) to recover pinprick response in the different body parts by treatment is presented (Table 2).

Median (IQR) ataxia scores recorded at any given time point are reported (Table 3). For 70 minutes post-LIDO (P < .0001) and 130 minutes post-BUPI (P < .0001), the ataxia score was significantly higher than the control group. Ataxia score was higher after BUPI than LIDO injection between 50 and 130 minutes (P < .0001).

There was no statistically significant difference in HR (P = .37), RR (P = .21), and MAP (P = .23) between treatments or over time. Regardless of

### Table 1—Distribution of age (mo), weight (kg), and breed; doses of midazolam and flumazenil in mg; and doses of lidocaine, bupivacaine, and saline in mg and mL.

<table>
<thead>
<tr>
<th>Goat #</th>
<th>Age (months)</th>
<th>WT (kg)</th>
<th>Breed</th>
<th>Midazolam dose (mg)</th>
<th>Flumazenil dose (mg)</th>
<th>Lidocaine dose (mg)</th>
<th>Bupivacaine dose (mg)</th>
<th>Saline dose (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28</td>
<td>38</td>
<td>Nubian</td>
<td>9.5</td>
<td>0.95</td>
<td>38</td>
<td>9.5</td>
<td>1.9</td>
</tr>
<tr>
<td>2</td>
<td>38</td>
<td>32.5</td>
<td>Nigerian dwarf</td>
<td>8.1</td>
<td>0.8</td>
<td>32</td>
<td>8</td>
<td>1.6</td>
</tr>
<tr>
<td>3</td>
<td>36</td>
<td>47</td>
<td>Boer</td>
<td>11.8</td>
<td>1.2</td>
<td>48</td>
<td>12</td>
<td>2.4</td>
</tr>
<tr>
<td>4</td>
<td>36</td>
<td>43</td>
<td>Nubian</td>
<td>10.8</td>
<td>1.1</td>
<td>44</td>
<td>11</td>
<td>2.2</td>
</tr>
<tr>
<td>5</td>
<td>38</td>
<td>24</td>
<td>Nigerian dwarf</td>
<td>6</td>
<td>0.6</td>
<td>24</td>
<td>6</td>
<td>1.2</td>
</tr>
<tr>
<td>6</td>
<td>72</td>
<td>73.5</td>
<td>La Mancha</td>
<td>18.4</td>
<td>1.8</td>
<td>74</td>
<td>18.5</td>
<td>3.7</td>
</tr>
</tbody>
</table>
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Treatment (LRχ² = 0.52; P = .77), SpO₂ was significantly lower (P ≤ .032) than baseline at 15, 30, 50, 70, 110, 130, and 150 minutes after injection. However, the median (IQR) SpO₂ was 100% (98%, 100%) at 15 and 30 minutes postinjection; 99% (98%, 100%) at 50, 70, and 110 minutes postinjection; 98% (98%, 100%) at 130 minutes postinjection; and 100% (99%, 100%) at 150 minutes postinjection. So, the difference was not considered clinically relevant. Regardless of the time point (LRχ² = 10.67; P = .47), goats recorded a lower RT after LIDO (P = .013) and BUPI (P < .0001). However, the median (IQR) recorded RT was 100.9 °F (100.4, 102.3 °F) after saline injection, 100.7 °F (100.1, 101.8 °F) after LIDO, and 100.5 °F (100, 101.7 °F) after BUPI. None of the goats developed a clinically relevant decrease in body temperature.

### Discussion

In this study, the factor of interest was how subarachnoid local anesthetic dose reduction would affect motor and somatosensory blockade in healthy goats. Specifically, our hypothesis that BUPI-treated goats would have longer motor blockade than LIDO-treated goats was not rejected. Even though recovery of pinprick response (somatosensory) was longer in the BUPI group, statistical significance was not reached. In the current study, motor blockade duration was decreased from previously reported studies, thus confirming our secondary hypothesis. DeRossi et al. found that administering 2.5 mg/kg of subarachnoid LIDO required 120 minutes for the goats to stand. In contrast, our study found that at
a dosage of 1 mg/kg, a median (IQR) of 50 (50, 67) minutes was sufficient to achieve the same ataxia score. Furthermore, Rizk et al. observed that a dose of 1.5 mg/kg of BUPI led to recumbency (defined as the time from lying down to resuming weight bearing) for 160.2 ± 60.3 minutes. In comparison, our study demonstrated a shorter time to standing of only 104 (101, 156) minutes.

Drugs administered into the subarachnoid space are influenced by factors that affect how they spread into the meningeal tissues as well. The speed and force by which the drug is administered as well as patient positioning can affect drug distribution within the subarachnoid space. In the present study, the speed was uniform among the injections at a rate of 1 mL per 30 seconds, thus preventing excessive cranial distribution of the drug. Additionally, each animal was placed in sternal recumbency with the pelvic limbs pulled cranially. Care was taken to ensure that the goats stayed in sternal recumbency for a full 5 minutes after drug administration by using padded mats on each side of the goat. However, all goats in the saline group and 1 goat in the LIDO group did stand, with ease, within the five-minute period.

Besides volume and concentration of the local anesthetic, baricity of the drug when compared with the CSF affects its distribution and effectiveness as well. In the clinical veterinary setting, it is common to use “plain” local anesthetic solutions, which are slightly hypobaric in comparison to CSF fluid. The density of human CSF is reported to be 1.003 g/mL. At 37°C, the baricites of 0.9% saline, 2% LIDO, and 0.5% BUPI are 0.9990, 0.9986, and 0.9983 g/mL, respectively. The temperature of the CSF in caprine animals is higher than that of humans and could have a slight effect on the final baricity of the combined fluids, thus making the local anesthetic less dense with respect to the CSF and having a lower baricity. In people, the baricity of CSF in females is lower than males. Furthermore, the baricity of CSF during pregnancy is lower when compared to women who are not pregnant. The differences in CSF baricity have not been studied among different sexes or pregnant goats. However, this could account for the difference in standing times of the goats used in this study (nonpregnant) versus goats that underwent cesarean section in Elane et al. at the same dose of 1 mg/kg LIDO (50 minutes vs 182 minutes, respectively).

The limitations of this study include a small sample size that may have been underpowered for detecting a difference in somatosensory blockade or cardiorespiratory parameters between treatments. While somatosensory function recovers later than motor function, we would have expected to find a significant difference in somatosensory blockade between treatments. However, the sample size calculation was based on data available for recovery of motor function. Additionally, while the use of needle pin prick has been deemed acceptable to test the degree and extent of nerve blockade, it does not adequately predict response to a significantly different intensity, such as surgery. The use of needle pin prick also cannot account for phenomena such as temporal summation. Despite sedation, some of the goats moved during injection, and this may have affected the quality of the local anesthetic spread. Finally, volume and concentration of a local anesthetic affect its effectiveness. So, it is possible that similar doses of different concentrations of BUPI or LIDO may elicit different onset and duration of the somatosensory and motor blockade.

In conclusion, the use of low-dose LIDO and BUPI can be an option for subarachnoid analgesia in healthy goats. LIDO (2%) at 1 mg/kg caused somatosensory blockade for 20 to 50 minutes (depending on body region) and allowed the animal to ambulate within 72 minutes of injection. BUPI 0.5% at 0.25 mg/kg provided somatosensory blockade for a duration of 60 to 90 minutes; however, recumbency lasted for over 104 minutes, and ambulation was not achieved until 225 minutes after injection. Further study is warranted to assess the effectiveness of these doses during invasive surgical procedures.

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

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