Effective locoregional retrobulbar anesthesia in horses can enhance perioperative analgesia for adnexal, ocular, and orbital surgery. Moreover, it can facilitate standing surgery, obviating the need for general anesthesia and the associated risks. 1–5 Retrobulbar injection or “retrobulbar block” (RB) performed via the supraorbital fossa is commonly cited as an effective locoregional technique in horses. 4,5 A previous study 6 showed that RB using 10 mL of 2% lidocaine significantly reduced corneal sensitivity at 1 minute postblock and for up to 6 hours thereafter. Furthermore, a 10-mL lidocaine block significantly reduced periorcular cutaneous sensitivity dorsally and medially for 2 hours postblock, though it failed to produce a similar effect ventrally and temporally. That study also suggested that an increase in pupil diameter within 5 minutes of injection was a clinical indicator of successful retrobulbar nerve blockade.

Commercially available anesthetic solutions other than lidocaine may be advantageous for RB in horses. Mepivacaine, for example, induces less local vasodilation than lidocaine, which may enhance its duration of action and potency in tissue. 7 Bupivacaine is more lipid soluble and protein bound than lidocaine and mepivacaine, producing longer duration of action and greater potency, 8 and has also

OBJECTIVE
To compare the efficacy of low-volume (5-mL) locoregional retrobulbar anesthesia (“retrobulbar block”) by use of 3 commercial local anesthetic formulations.

ANIMALS
8 healthy adult mares.

METHODS
A block-randomized, masked, controlled design was used. A single ultrasound-guided retrobulbar block was performed with 2% lidocaine, 2% mepivacaine, or 0.5% bupivacaine (n = 5 eyes/group). Contralateral eyes served as untreated controls. End points performed at baseline and time intervals up to 24 hours postblock included the following: assessment of neuroophthalmic reflexes/responses, intraocular pressure, and vertical pupil diameter measurement, corneal and periocular esthesiometry, and observation for adverse effects.

RESULTS
Low-volume block did not result in increased intraocular pressure or other adverse effects at any time point in any treatment group. Statistically significant corneal anesthesia (P < .001) was observed 1 minute after block in all groups, persisting through 4 hours after lidocaine or mepivacaine block and through 24 hours after bupivacaine block. Clinically significant periorcular anesthesia was not observed in any group. Significant vertical pupil diameter increase (P < .05) was observed for up to 4 hours after lidocaine or mepivacaine block and 6 hours after bupivacaine block.

CLINICAL RELEVANCE
Low-volume retrobulbar block with any of the 3 local anesthetic drugs evaluated was not associated with adverse effects. In terms of efficacy, mepivacaine block showed no clinical advantage over lidocaine block. However, bupivacaine block induced comparatively rapid and sustained corneal anesthesia. In comparison to published findings using a larger injection volume, low-volume retrobulbar block with lidocaine produced clinically comparable corneal anesthesia. However, periorcular soft tissue anesthesia was not achieved with any local anesthetic drug at low volume.

Keywords: retrobulbar, anesthesia, horse, lidocaine, bupivacaine

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proven advantageous in nonocular and ocular studies in horses. Expanded knowledge regarding the comparative efficacies of local anesthetic drugs for equine retrobulbar anesthesia would be valuable to practitioners, not just for informing and optimizing locoregional anesthetic protocols but also for navigating drug backorders or other issues with commercial availability. To date, however, no studies have objectively compared these anesthetic drugs for retrobulbar anesthesia.

Retrobulbar block is largely considered a safe procedure in horses. However, risks may include transient ucartia, exposure keratitis and corneal ulceration, transient blindness in the blocked eye, retrobulbar hemorrhage, inadvertent penetration of the globe, and sudden death associated with intraneal injection and brain anesthesia. Moreover, bolus anesthetic injection to the retrobulbar space in veterinary and human patients may be associated with adverse effects such as increased intraocular pressure (IOP) and chemosis. Recommended bolus volumes currently cited in the equine literature range between 10 and 30 mL for adult horses. In the aforementioned equine study, a 10-mL lidocaine block resulted in a statistically significant increase in IOP for up to 2 hours postblock and mild to severe conjunctival swelling (chemosis) in the majority of blocked eyes between 2 and 24 hours postblock. Furthermore, a retrospective study of anesthetized horses identified a statistical correlation between RB injection volumes exceeding 9 mL and risk for postoperative adverse events including colic. Administration of a lower anesthetic volume in horses may mitigate adverse effects. However, the impacts of reduced volume and lower anesthetic dose on clinical effects with any anesthetic drug are not objectively characterized.

The study herein presents anesthetic efficacy data following low-volume (5-mL) RB in adult horses with the use of commercial formulations of 2% lidocaine, 2% mepivacaine, or 0.5% bupivacaine. Our primary hypothesis was that a 5-mL RB with mepivacaine or bupivacaine would produce prolonged corneal anesthesia compared to lidocaine. Our secondary hypotheses were that administration of a 5-mL volume would not cause adverse effects, including increased IOP or chemosis and that a reduced volume and dose of lidocaine would produce clinically comparable effects to those previously published for RB using 10 mL.

Methods
This study was conducted in accordance with a protocol (V006279-R01) approved by the University of Wisconsin (UW)-Madison IACUC and in compliance with the Association for Research in Vision and Ophthalmic and Vision Research for the Use of Animals in Ophthalmic and Vision Research.

Animal population
Animal subjects included mares from the UW-Madison School of Veterinary Medicine teaching herd. Mares were included if deemed healthy and ophthalmologically normal on the basis of physical and ophthalmic examinations performed by a board-certified veterinary ophthalmologist (JSE). Ophthalmic examinations included slit lamp biomicroscopy (SL-17 portable slit lamp; Kowa American Corp), indirect ophthalmoscopy (Vantage Plus LED; Keefer; and 20D condensing lens; Volk Optical), corneal fluorescein staining (JorVet I-Glo; Jorgensen Laboratories LLC), and rebound tonometry (TonoVet Plus; iCare). Exclusion criteria included the presence of active keratitis, uveitis, other inflammatory ocular/periorcular disease, vision-impairing ocular opacification, and/or baseline IOP measuring < 10 or > 35 mm Hg. Mares were also excluded if clinically significant nonocular abnormalities were identified (ie, lameness, auscultation abnormalities) or if sedatives, opioid analgesics, or NSAIDs had been administered within 7 days of planned RB.

Acclimation
To reduce aversion to ocular examinations, RB, and data collection, all mares were acclimated once daily for 2 weeks prior to study initiation. Acclimation involved repeated periorcular contact applied circumferentially for 2 minutes around each eye with the soft eraser end of a No. 2 graphite pencil. Mares that did not tolerate this procedure or whose temperaments were deemed unsuitable were excluded from the study.

Study design
This was a prospective, masked, controlled, block-randomized study. Mares and eyes were block-randomized (Research Randomizer; Randomizer.org) into 3 treatment groups. Each group consisted of 5 eyes receiving RB with 2% lidocaine, 2% mepivacaine, or 0.5% bupivacaine. Contralateral eyes served as untreated controls. All investigators were masked to the identity of the anesthetic drug being administered. For practical reasons, investigators could not be masked to the blocked eye. A total of 8 mares were used. To achieve a total of 5 eyes for each treatment group, 6 of 8 mares were used more than once, with a ≥ 7-day washout period between blocks. Five mares were used twice, receiving blocks in opposite eyes, and 1 mare was used 3 times, receiving blocks behind the right eye twice and left eye once.

Retrobulbar blocks
All blocks were performed by the same board-certified veterinary ophthalmologist (JSE) following sedation with 0.010 to 0.015 mg/kg IV detomidine (Dormosedan). The supraorbital fossa of the eye to be blocked was aseptically prepared using 1.25% povidone iodine solution and rinsed with sterile eyewash (Rugby Laboratories). The supraorbital fossa of the eye to be blocked was aseptically prepared using 1.25% povidone iodine solution and rinsed with sterile eyewash (Rugby Laboratories). As previously described, a 22-gauge, 2.5-inch Quincke-type spinal needle (Becton Dickinson) was positioned with the point first directed ventrally, immediately posterior to the central dorsal orbital rim. Following the injection technique described by Berge and Lichtenstern, the needle shaft orientation was then angled medially, pointing toward the
contralateral caudal upper molar teeth (Figure 1). The needle and stylet were slowly advanced through the skin and orbital soft tissue until within 5 to 10 mm of the needle hub. Transpalpebral ultrasound guidance using a 10-MHz linear array probe (Logiq e Vet; GE Healthcare) was used to verify central positioning of the needle tip within the retrobulbar cone. The stylet was removed and the syringe

![Figure 1](image)

**Figure 1**—Diagrammatic (panels A and B) and photographic (panels C and D) illustrations of retrobulbar block via the supraorbital fossa. The tip of a 22-gauge, 2.5-inch spinal needle is positioned immediately posterior to the central dorsal orbital rim (blue dashed lines in panels A and C). The needle shaft is angled medially, pointing toward the contralateral caudal upper molar teeth (red dashed lines in panels B and D). Once positioned, the needle and stylet are advanced through the skin and orbital soft tissue until within 5 to 10 mm of the needle hub.
containing anesthetic attached. Following aspiration to verify extravascular placement, 5 mL of the anesthetic formulation was injected over 15 to 30 seconds. Timing for data collection began at needle withdrawal.

Data collection

All procedures and data collection were carried out in large windowless indoor animal facilities at the UW-Madison School of Veterinary Medicine. Data for 7 mares were collected under the same conditions by use of stock restraint in a large animal teaching laboratory familiar to the herd. Data for 1 mare were collected in a windowless stall in the UW-Madison Morrie Waud Large Animal Teaching Hospital without stocks.

Data were collected in both eyes over a 24-hour period, beginning prior to block at baseline (presedation, “P”) and following sedation (sedated, “S”), and at intervals between 1 minute and 24 hours following block (Supplementary Table S1). When performed simultaneously, assessments and data collections were carried out in the same order, as follows: (1) neuroophthalmic reflexes and responses (palpebral reflex, menace response, dazzle reflex, and direct pupillary light reflex [PLR]), (2) fundus examination, (3) vertical pupil diameter (PD) measurement, (4) Cochet-Bonnet corneal esthesiometry, (5) periocular esthesiometry, (6) rebound tonometry, and (7) heart rate and respiratory rate. A single investigator (JCT) assessed all neuroophthalmic reflexes and responses and performed periocular esthesiometry measurements. Another investigator (JSE) performed all fundus examinations, PD measurements, corneal esthesiometry, and rebound tonometry. Heart and respiratory rates were obtained by coinvestigators (SMG and SMI).

Palpebral reflex, menace response, and dazzle reflex were scored according to response to medially canthal touch stimulus, hand gesture toward the eye, and bright light stimulation, respectively. The brightest light setting and largest circular beam on the slit lamp were used to elicit the dazzle reflex. Ordinal scores of each reflex/response were assigned as follows: normal (complete palpebral closure), partial (incomplete palpebral closure), or absent (lack of palpebral movement). Reduction at any time point was defined as a score of “partial” or “absent.”

Direct PLR was elicited using the slit lamp’s circular beam on the brightest setting. Ordinal scores were assigned from 1 to 4 as follows: (1) brisk pupil excursion with complete pupil constriction, (2) slow pupil excursion with complete constriction, (3) brisk or slow excursion without complete constriction, and (4) fixed and dilated pupil with no observable constriction. Reduction of direct PLR at any time point was defined as a score of 3 or 4. Due to the short intervals between early time points, neuroophthalmic responses/reflexes were not assessed at 1 or 5 minutes postblock.

Vertical pupil diameter was measured in millimeters with digital calipers held approximately 5 mm anterior to the central cornea. Corneal esthesiometry was performed with a Cochet-Bonnet corneal esthesiometer (Western Ophthalmics) by use of a previously published technique. Briefly, the instrument’s nylon filament was extended to 60 mm. The filament tip was brought into perpendicular contact with the central cornea 5 times, each time creating a slight bend in the filament shaft. Filament length was reduced by 5-mm increments until a complete blink reflex (complete palpebral closure) was elicited in ≥3 of 5 touch stimuli; at that time, the filament length was recorded in millimeters. Conical esthesiometer readings were reported in millimeters reflecting a direct relationship with lower measurements correlating to lower central corneal sensitivity. The same esthesiometer was used for the duration of the study.

Periocular esthesiometry was performed using a digital von Frey force gauge (Electronic von Frey Aesthesiometer; IITC Life Science Inc) fitted with a rigid plastic tip (Supplementary Figure S1). Esthesiometry was performed at 4 periocular sites in 3 rounds, with each round following the same sequence: (1) dorsal, (2) lateral, (3) ventral, and (4) medial. Dorsally and ventrally, the plastic tip was placed in contact with the skin, approximately 15 and 20 mm from the upper and lower eyelid margin, respectively. Lateral and medial sites were approximately 10 mm from the ends of the lateral and medial canthi, respectively. At all sites, the tip was placed to avoid inadvertent stimulation of clia or vibrissae. Force was steadily increased at each respective site until a nociceptive head withdrawal response was elicited. The maximum force applied at each site displayed by the device was recorded in grams. Due to the tendency for the instrument’s plastic tip to bend and the risk for cutaneous trauma at higher levels of applied pressure, the stimulus was withdrawn when a reading reached 600 g before a response and the measurement was recorded as 600 g. Unlike corneal esthesiometry, periocular esthesiometry readings indicate an inverse relationship, with higher measurements correlating to lower sensitivity.

Tonometry was performed in triplicate by use of a TonoVet Plus rebound tonometer to measure IOP with the instrument’s horse-specific calibration setting. Measurements were only accepted if the instrument’s digital display indicated low error for the measurement (6 green segments in a circle around the IOP reading). At all time points, investigators ensured head position above the thoracic inlet to guarantee accuracy of IOP measurements.

Fluorescein staining (Jor-Vet I-Glo; Jorgensen Labs) was performed at baseline and 6 and 24 hours after block, assessed as positive or negative on the basis of presence or absence of stain retention, respectively. On the basis of previously published results, chemosis was scored at each time point following injection according to the following criteria: (0) no swelling, (1) swelling spanning ≥50% the length of 1 eyelid, (2) swelling spanning ≥50% the length of 1 eyelid with or without swelling spanning <50% the length of the second eyelid, and (3) swelling spanning ≥50% the length of both eyelids. A commercial ophthalmic lubricant (Optixcare; Avertix) was applied to both eyes following data collection at the 6- and 24-hour time points.
Data analysis

Sample size (n = 5 eyes/group) was chosen on the basis of convenience sampling from the orthopedically sound and behaviorally suitable mares available at the time of the study. Mean (SD) horse age, detomidine dose, and event timing were calculated for each treatment group. All results for continuous measurement end points and duration of neurophthalmic parameter reduction were analyzed by use of a longitudinal data analysis model with random effect for horse. All analyses were conducted in R version 4.0 with the lmer function from the lme4 package. Results are presented as mean (95% CI) as estimated from the EMMEANS function of the emmeans package. All analyses were conducted with a significance level of \( P = .05 \).

Results

Mean (SD) age of all 8 mares was 19.4 years (4.6 years) with mean (SD) body weight of 578 kg (96 kg). Detomidine dose for all 8 eyes ranged from 5.52 to 9.28 mg. For each group, summaries of mean (SD) age, detomidine dose administered, time in minutes from sedation to collection of sedated ("S") data, and time in minutes from sedation to RB are shown in Table 1. Six breeds were represented, including Hanoverians (n = 2), Thoroughbreds (2), and 1 each of quarter horse, Missouri Fox Trotter, Draft cross, and Arabian cross. In the 7 instances of mares being used for > 1 RB, 4 occurred 7 to 8 days after the previous RB and 3 occurred 53 to 55 days after the previous RB.

Neurophthalmic reflexes/responses were variably reduced in both treated and control eyes. Palpebral reflex and menace response reduction were observed in all blocked eyes, and reduction of each was observed in 13 of 15 and 10 of 15 control eyes, respectively. Dazzle reflex reduction was observed in 4 of 5 lidocaine-blocked eyes, 4 of 5 mepivacaine-blocked eyes, 1 of 5 bupivacaine-blocked eyes, and 3 of 15 controls. Direct PLR reduction was observed in all blocked eyes and 2 of 15 control eyes. Mean duration of reduction for each reflex/response (the interval between onset of reduced score and recovery to nonreduced score) for each treatment group are compared in Table 2. For palpebral reflex, menace response, and dazzle reflex, there were no statistically significant differences between groups with respect to mean duration of reduction. For direct PLR, duration of reduction was statistically significantly longer in bupivacaine-blocked eyes compared to lidocaine-blocked eyes.

Longitudinal plots of mean PD for all treatment groups and controls are shown in Figure 2. In all treatment groups, PD increased significantly compared to controls following RB. In lidocaine- and mepivacaine-blocked eyes, significant increase was observed at 1 minute and persisted through 4 hours. Onset mean increase occurred 90 minutes following lidocaine block (17.6 mm; 95% CI, 16.6 to 18.5) and 60 minutes following mepivacaine block (16.1 mm; 95% CI, 14.2 to 18.1). In bupivacaine-blocked eyes, significant increase was observed at 5 minutes and persisted through 6 hours, with peak mean increase at 2 hours (14.5 mm; 95% CI, 12.2 to 16.7). Analyzing the mean difference between blocked and control eyes, lidocaine block produced a significantly greater mean PD increase than bupivacaine block at 5 minutes (+3.9 mm; 95% CI, 0.4 to 7.3; \( P = .025 \)), and at 10, 30, and 60 minutes (+3.6 mm; 95% CI, 0.1 to 7.1; \( P = .04 \) for each). Mean PD increase following bupivacaine block was significantly higher compared to lidocaine and mepivacaine at 4 hours (+4.9 mm [95% CI, 1.4 to 8.4]; \( P = .003 \); and +5.3 mm [95% CI, 1.8 to 8.7]; \( P = .001 \), respectively) and 6 hours (+7.1 mm [95% CI, 3.6 to 10.6]; \( P = .001 \); and +7.0 mm [95% CI, 3.5 to 10.4]; \( P < .001 \), respectively).

Longitudinal plots of mean corneal esthesiometry for all treatment groups and controls are shown in Figure 3. In all treatment groups, corneal sensitivity decreased significantly compared to controls following block. Onset of significant decrease occurred at 1 minute in all groups. Significant corneal sensitivity reduction persisted through

### Table 1—Mean (SD) age, detomidine dose, and time from sedation to collection of sedated data and to retrobulbar block for each treatment group (n = 5 eyes/group).

<table>
<thead>
<tr>
<th></th>
<th>Lidocaine (2%)</th>
<th>Mepivacaine (2%)</th>
<th>Bupivacaine (0.5%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>18.2 (4.1)</td>
<td>18.2 (5.5)</td>
<td>19.8 (4.0)</td>
</tr>
<tr>
<td>Detomidine dose (mg)</td>
<td>6.3 (0.8)</td>
<td>7.7 (1.5)</td>
<td>6.5 (0.7)</td>
</tr>
<tr>
<td>Time from sedation to collection of sedated data (min)</td>
<td>7.0 (1.0)</td>
<td>6.4 (1.5)</td>
<td>7.2 (2.2)</td>
</tr>
<tr>
<td>Time from sedation to retrobulbar block (min)</td>
<td>30.6 (4.8)</td>
<td>27.6 (4.0)</td>
<td>29.8 (3.6)</td>
</tr>
</tbody>
</table>

### Table 2—Mean (95% CI) duration (minutes) of reduction for palpebral reflex, menace response, dazzle reflex, and direct pupillary light reflex (PLR) following retrobulbar block with lidocaine, mepivacaine, or bupivacaine (n = 5 eyes/group).

<table>
<thead>
<tr>
<th></th>
<th>Lidocaine (2%)</th>
<th>Mepivacaine (2%)</th>
<th>Bupivacaine (0.5%)</th>
<th>( P ) value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palpebral reflex</td>
<td>239.0 (–124.5 to 602.5)</td>
<td>116.0 (–279.2 to 511.2)</td>
<td>421.0 (25.8 to 816.2)</td>
<td>.432</td>
</tr>
<tr>
<td>Menance response</td>
<td>98.0 (–278.3 to 474.3)</td>
<td>100.0 (–309.1 to 509.1)</td>
<td>356.0 (–53.1 to 765.1)</td>
<td>.474</td>
</tr>
<tr>
<td>Dazzle reflex</td>
<td>69.0 (–40.3 to 178.3)</td>
<td>117.0 (–1.8 to 235.8)</td>
<td>46.0 (–72.8 to 164.8)</td>
<td>.577</td>
</tr>
<tr>
<td>Direct PLR</td>
<td>278.0 (–162.7 to 718.7)†</td>
<td>532.0 (52.9 to 1,011.1)</td>
<td>1,192.0 (712.9 to 1,671.1)†</td>
<td>.042</td>
</tr>
</tbody>
</table>

*\( P \) value calculated by use of repeated-measures ANOVA. †The difference in direct PLR reduction duration between lidocaine and bupivacaine was statistically significant (\( P = .04 \)).
4 hours after lidocaine and mepivacaine block ($P < .001$ for all time points between 1 minute and 4 hours, inclusive) and 24 hours after bupivacaine block ($P < .001$ for all time points between 1 minute and 24 hours, inclusive). Absolute corneal anesthesia (Cochet-Bonnet reading of 0 mm) was achieved in all treated eyes. Mean durations of absolute corneal anesthesia for lidocaine, mepivacaine, and bupivacaine were 90 (95% CI, 10 to 170) minutes, 76 (95% CI, 11 to 163) minutes, and 202 (95% CI, 115 to 289) minutes, respectively. Analyzing the mean difference between treated and untreated controls, bupivacaine block produced significantly greater mean reduction in corneal sensitivity compared to lidocaine and mepivacaine at 1 minute ($–19.0$ mm [95% CI, $–32.0$ to $–6.0$]; $P = .002$; and $–25.0$ mm [95% CI, $–38.0$ to $–12.0$]; $P < .001$, respectively) and 5 minutes ($–15.0$ mm [95% CI, $–28.0$ to $–2.0$]; $P = .018$; and $–16.0$ mm [95% CI, $–29.0$ to $–3.0$]; $P = .011$, respectively). Bupivacaine block also produced significantly greater mean reduction in corneal sensitivity compared to lidocaine and mepivacaine at 4 hours ($–35.0$ mm [95% CI, $–48.0$ to $–22.0$]; $P < .001$; and $–25.0$ mm [95% CI, $–38.0$ to $–12.0$]; $P < .001$, respectively), 6 hours ($–35.0$ mm [95% CI, $–48.0$ to $–22.0$]; $P < .001$; and $–30.0$ mm [95% CI, $–43.0$ to $–17.0$]; $P < .001$, respectively), and 24 hours ($–15.0$ mm [95% CI, $–28.0$ to $–2.0$]; $P = .018$ for both).

Longitudinal plots of mean IOP for all treatment groups and controls are shown in Supplementary Figure S2. As previously observed, an immediate decrease in
mean IOP was observed in treated and control eyes in all groups after sedation. However, no significant increase in IOP was observed between groups or relative to controls following block in any group. Longitudinal plots of mean periocular esthesiometry at all 4 periocular sites for all treatment groups and controls are shown in Figure 4. As previously observed, an immediate decrease in periocular sensitivity was observed in treated and control eyes in all groups at all sites after sedation. Ten minutes following lidocaine block, a significant decrease in mean medial sensitivity was observed in the blocked eye compared to the control (139.9 g; 95% CI, 62.2 to 217.7; \( P = .007 \)). However, a significant effect was not sustained at subsequent time points. Regardless of treatment group or periocular site, there were no other time points where periocular sensitivity differed significantly between treatment groups or relative to controls in any group.

No events considered adverse were observed at any time point in any eye or horse. Chemosis was observed in 1 mare that developed a score 2 (moderate) chemosis between 2 and 6 hours after lidocaine block.

**Discussion**

This study was the first to report objective data comparing the clinical effects of different local anesthetic drugs when administered via RB in horses. These data confirmed that each drug significantly

![Figure 4](image)

*Figure 4—Longitudinal plots of mean (95% CI) periocular sensitivity at 4 sites (dorsal [A], lateral [B], ventral [C], and medial [D]) in eyes receiving retrobulbar block and controls. *Statistically significant increase compared to respective controls.
decreased corneal sensitivity and produced clinically significant periods of complete corneal anesthesia. Furthermore, all injections resulted in increased pupil dilation. However, no injections decreased periorcular cutaneous sensitivity at any site at a low-volume dose.

Despite mepivacaine’s efficacy, these data do not support a clinical advantage of mepivacaine over lidocaine for RB, as their clinical effects were largely the same. This finding may have practical relevance to equine practitioners given the typically higher price of mepivacaine compared to lidocaine. In a previous study comparing injectable anesthesia for equine distal limb blocks, mepivacaine was superior to lidocaine, producing an anesthetic effect with comparatively faster onset and greater duration of action. The reason for the lack of advantage in the present study is not known. Mepivacaine has a very similar pharmacologic profile to lidocaine but with a slightly longer duration of effect, possibly due to its less intrinsic vasodilatory properties. It is possible that the greater relative vasodilatation associated with lidocaine in the sparse soft tissues of the distal limb expedites elimination and reduces duration of action in comparison to mepivacaine. In the complex and robust soft tissue compartments of the equine orbit, however, the influence of an anesthetic agent’s vasomotor properties on elimination may be reduced. Further studies would be needed to confirm this. It is noteworthy that similar findings have been reported in human studies involving peribulbar and sub-Tenon anesthesia, techniques similarly indicated to produce retrobulbar nerve blockade.

As hypothesized, RB with bupivacaine produced a clinically and statistically significantly longer duration of corneal anesthesia compared to lidocaine and mepivacaine. Therefore, it may be a more suitable choice for perioperative anesthesia for ophthalmic surgery, particularly corneoscleral conjunctival procedures. Unexpectedly, onset of decreased corneal sensitivity was significantly faster with bupivacaine than the 2 other drugs for up to 10 minutes after injection. This is difficult to explain given the characteristically delayed properties attributed to bupivacaine’s lipid solubility, particularly when injected into soft tissue compartments containing adipose tissue like the equine intraconal space. Similar findings, however, have been reported in comparative studies of retrobulbar injection in human patients.

It should be considered that factors other than choice of drug may influence RB efficacy. The primary mechanism of action of local anesthetic drugs involves blockade of voltage-gated sodium channels within the lipid bilayer of the neuronal axons and thus physical proximity of any drug to the nerve may influence the speed of onset as well as the overall effect. Ultrasound guidance in this study verified an approximately central intraconal location of the needle prior to injection. However, variability in tissue volumes and injectate distribution were not measured and could have influenced local effects.

Local anesthetic effects may also be impacted by the inherent anatomical and physiologic properties of the target nerves. Despite bupivacaine’s unexpectedly rapid induction of corneal anesthesia, for example, it had a more characteristic slower onset with respect to pupil dilation, and the peak magnitude of pupil dilation was lowest for all 3 drugs tested. Due to the phenomenon of differential nerve blockade, autonomic nerves like the oculomotor should be more rapidly affected by local anesthetics than sensory nerves like the trigeminal and the magnitude of effect should be highest for bupivacaine. Moreover, the autonomic fibers of the oculomotor nerve responsible for PLR are situated at the nerve periphery and should theoretically be anesthetized more rapidly. This study was not designed to determine the cause of these discrepancies. However, these findings illustrate that the complex anatomy of tissue compartments like the retrobulbar space may complicate pharmacokinetics, pharmacodynamics, and predictability of effects.

These data support the hypothesis that RB with a 5-mL anesthetic volume does not adversely increase IOP. While iatrogenic IOP increase is not necessarily of immediate concern in eyes undergoing enucleation, it may risk globe rupture in eyes undergoing repair for fragile corneal lesions or open globe injuries. This may complicate surgery and adversely affect postoperative outcome. Moreover, acute expansion of retrobulbar volume may result in transient ischemia to the optic nerve and retina, risking adverse effects to the health of eyes undergoing globe-sparing procedures with concurrent glaucoma or other inflammatory diseases such as uveitis. Chemosis was also only observed in 1 eye, representing a lower incidence than observed in a previous study using a 10-mL RB. Though chemosis does not risk immediate adverse ocular consequences, it can complicate ophthalmic procedures such as conjunctival grafting, keratoplasty, and episcleral or suprachoroidal implant placement. Severe chemosis may also impair palpebral closure, risking corneal exposure postinjection.

Reduction of bolus volume for RB is a direct and plausible explanation for mitigation of IOP increase and lower chemosis incidence. However, this study was not designed to differentiate the potential contribution of other drug-associated variables. For example, drugs like lidocaine and bupivacaine have known local vasodilatory effects, which could expand intraocular vascular volume and increase IOP. Furthermore, the respective pharmacologic profiles of anesthetic drugs could contribute to chemosis. For example, lidocaine has a comparatively lower pH, which may contribute to local tissue irritation following injection. Interestingly, the single horse that developed chemosis in this study after lidocaine injection had received a mepivacaine injection 1 week prior in the contralateral eye with no chemosis observed.

These data also support the hypothesis that the effects of a 5-mL lidocaine RB would be clinically comparable to those published for a 10-mL dose. In the present study, corneal sensitivity was statistically significantly reduced for up to 4 hours postblock, as opposed to the 6 hours previously published following a 10-mL injection. However, most equine corneoscleral conjunctival surgeries are unlikely to
require > 4 hours of surgical time, so this difference may not have practical clinical significance. These data also verify that duration of pupil dilation was the same following 5- and 10-mL injections with lidocaine, remaining statistically significant for up to 4 hours. Though pupil status is not necessarily of immediate importance with respect to perioperative anesthesia, onset within the first 5 minutes after a 10-mL lidocaine block may be a useful clinical parameter for assessing the adequacy of retrobulbar blockade. Furthermore, adequate pupil dilation is required for specialized posterior segment surgeries such as vitrectomy, which are performed with some regularity in the treatment of equine recurrent uveitis. Interestingly, maximum pupil diameter was comparatively greater in the present study using a lower-volume lidocaine block. However, comparison between studies should be done cautiously. Despite largely identical methods between the two, ultrasound guidance was only performed in the present study. It is plausible that greater consistency of intracanal needle placement and injectate distribution in the present study led to a greater effect on the oculomotor nerve.

Despite the lack of clinically significant impact on corneal anesthesia and pupil dilation, reduction of RB lidocaine volume does lessen periocular anesthetic effects. In the present study, no clinically significant periocular anesthesia was observed after a 5-mL lidocaine RB. It is noteworthy, however, that reduced periocular sensitivity previously published after a 10-mL lidocaine RB was only significant at 2 periocular sites and only for up to 2 hours after injection. The findings from both studies underscore the influence of injected volume on periocular anesthesia. For this reason, some small animal studies have advocated the superiority of larger-volume peribulbar injections for routine procedures like enucleation. Correspondingly, the collective results of the present data and those previously published in horses support the conclusion that a single RB ≤ 10 mL does not provide sufficient analgesia for equine surgeries that involve the adnexa (ie, blepharoplasty, enucleation, exenteration). Therefore, use of complementary local block techniques to ensure adequate periocular anesthesia is imperative for those procedures.

Interpretation of the neuroophthalmic findings in this study should be done with consideration to the small sample size and inherent variability between individual horses. Furthermore, finitely differentiating the effects of sedation and RB on reflexes and responses is very difficult, particularly at earlier time points after injection. However, these data do identify some trends that may be of clinical significance. Though not statistically significantly different, mean duration of palpebral reflex and menace response reduction was higher for bupivacaine in comparison to lidocaine and mepivacaine. This difference may be clinically significant, as transient impairment of palpebral closure and reduced corneal sensitivity following RB pose some degree of risk for corneal exposure and erosion. Even though no corneal adverse events were observed in this study, these findings underscore the need for vigilant monitoring of the cornea following blockade with any drug, particularly bupivacaine.

As previously shown, the neuroophthalmic data presented here suggest that RB with any drug does not necessarily reduce optic nerve function in all blocked eyes. While direct PLR was invariably reduced in all blocked eyes, dazzle reflex was not. Both reflexes share an afferent stimulus, mediated by the optic nerve (cranial nerve II). This suggests that PLR reduction is more likely a result of efferent blockade of the oculomotor nerve (cranial nerve III). Interestingly, dazzle reflex reduction was observed in only a single bupivacaine-blocked eye. As mentioned previously, this could be influenced by variations in injectate distribution. However, compared to other retrobulbar nerves, the optic nerve is larger in diameter and ensheathed by meninges. These morphologic variations that may influence the penetration and/or activity of different anesthetics. While this finding suggests a possible clinical and safety advantage of bupivacaine, larger studies would be indicated to verify this. It is also noteworthy that maintenance of optic nerve function assessed by brainstem-mediated reflexes can only be used to extrapolate conclusions about visual function as they do not assess the entire visual pathway, which could be influenced by other factors like sedation.

The foremost limitation of our study was the small sample size used to measure multiple clinical endpoints between groups. However, we were able to show statistically significant differences from controls and for change from control between drugs at some follow-up time points. The nonstatistically significant results presented should be considered in the context of clinical relevance to the equine practitioner. Ultimately, closer examination of nonstatistically significant results would necessitate further study with future prospective studies with larger sample sizes. The impact of administering multiple RBs to horses in a single study is also unknown. However, we incorporated washout periods between injections consistent with what has been cited in human studies of RBs and deemed sufficient. It is also noteworthy that, despite use of acclimation in these horses, esthesiometry end points in any nonverbal species inherently rely on subjective criteria for nociceptive behaviors and animal learning of the procedure may influence results as any study progresses. Finally, α2 agonist sedatives like detomidine have known analgesic effects, which are difficult to tease out from drug effects early on after injection and should be considered when examining these data.

In conclusion, low-dose RB with mepivacaine shows no clinical advantage over lidocaine. However, bupivacaine block rapidly induces corneal anesthesia with a statistically significant effect sustained for up to 24 hours postinjection. In comparison to previously published data, a 50% reduction in injected volume improves the safety margin for RB with no adverse increase in IOP and a low incidence of postinjection chemosis. A reduced dose of lidocaine does not clinically compromise duration of corneal sensitivity nor pupil dilation.
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**Supplementary Materials**

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