Effects of peribulbar anesthesia (sub-Tenon injection of a local anesthetic) on akinesia of extraocular muscles, mydriasis, and intraoperative and postoperative analgesia in dogs undergoing phacoemulsification

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Objective—To evaluate the effects of peribulbar anesthesia (sub-Tenon injection of lidocaine hydrochloride) on akinesia of extraocular muscles, mydriasis, and intraoperative and postoperative analgesia in dogs undergoing phacoemulsification.

Animals—14 Beagles with ophthalmically normal eyes.

Procedures—A blinded randomized controlled trial was performed. Dogs were anesthetized and assigned to 2 treatments: concurrent sub-Tenon injection of 2% lidocaine hydrochloride solution (2 mL) and IV injection of saline (0.9% NaCl) solution (0.02 mL/kg; lidocaine group [n = 7]) or concurrent sub-Tenon injection of saline solution (2 mL) and IV injection of 0.2 mg of atracurium/kg (0.02 mL/kg; control group [7]). Pupils were dilated by topical application of a combined tropicamide and phenylephrine ophthalmic solution. Ten minutes after the injections, pupil diameter was measured and phacoemulsification was performed. End-tidal isoflurane concentration was used to evaluate intraoperative pain. Subjective pain scores were recorded during the postoperative period.

Results—Akinesia was induced and maintained throughout the surgery in all eyes. Mean ± SD pupil diameter was significantly greater in the lidocaine group (13.7 ± 0.7 mm) than in the control group (12.2 ± 0.8 mm). Isoflurane requirements were significantly lower in the lidocaine group than the control group. However, postoperative pain scores were not significantly different between the groups.

Conclusions and Clinical Relevance—Sub-Tenon injection of lidocaine was an effective method for inducing akinesia of extraocular muscles, mydriasis, and intraoperative analgesia for phacoemulsification in dogs. Therefore, this could be another option for surgical field exposure and pain management during phacoemulsification in dogs. (Am J Vet Res 2013;74:1126–1132)
such as atracurium is widely used in veterinary medicine for akinesia of extraocular muscles.⁶,⁷ Even though neuromuscular blocking agents effectively induce akinesia, they also cause paralysis of respiratory muscles, which requires positive-pressure ventilation and close monitoring of respiratory function.⁷,⁸ Mydriasis is usually achieved with topically applied anticholinergics or sympathomimetic agents (or both), such as tropicamide and phenylephrine.⁹,¹⁰ However, their effects can sometimes be insufficient for maximal exposure of the lens, especially in patients with uveitis.¹¹,¹²

Peribulbar anesthesia (ie, sub-Tenon injection; injection of a local anesthetic beneath the bulbar sheath [vagina bulbi; commonly known as Tenon’s capsule¹³]), is effective in humans for perioperative analgesia, akinesia, and pupil dilation.¹³,¹⁴ Local anesthetic agents administered via sub-Tenon injection spread to the retrobulbar space, where sensory nerves and extraocular muscles and their motor nerves are located.¹⁴,¹⁵ Because a blunt cannula is inserted into the orbital cavity, it eliminates risks (eg, globe perforation) related to the use of a sharp needle.¹⁵,¹⁶ Therefore, sub-Tenon injection of a local anesthetic is becoming more popular in human medicine.¹⁶ The purpose of the study reported here was to evaluate efficacy of sub-Tenon injection of lidocaine on akinesia and mydriasis during phacoemulsification and intraoperative and postoperative analgesia in dogs.

Materials and Methods

Animals—Fourteen healthy adult female Beagles with no ocular abnormalities were enrolled in the study. Dogs had a mean ± SD age of 6.1 ± 1.1 years and mean body weight of 9.6 ± 1.5 kg. The eyes were assessed as ophthalmically normal on the basis of complete ophthalmic examinations, including slit-lamp biomicroscopy,¹⁷ rebound tonometry,¹⁸ and indirect ophthalmoscopy.¹⁹ All animal care and experimental procedures were in accordance with guidelines for the care and use of laboratory animals of Seoul National University and were approved by the Institutional Animal Care and Use Committee of Seoul National University (SNU-121205-3).

Study design—A blinded randomized controlled trial was performed. Dogs were assigned into 2 treatment groups by drawing lots (7 dogs/group). For each dog of the lidocaine group, 2 mL of a 2% solution of lidocaine hydrochloride¹⁴ was administered via sub-Tenon injection of the left eye and saline (0.9% NaCl) solution (0.02 mL/kg) was simultaneously injected IV. For each dog of the control group, 2 mL of saline solution was administered via sub-Tenon injection of the left eye and 0.2 mg of atracurium/kg (0.02 mL/kg) was simultaneously injected IV. Atracurium was selected to induce akinesia in the control group because it does not have analgesic or sedative effects.⁷,¹⁶ The dose of lidocaine for sub-Tenon injection was determined on the basis of results of a previous study.⁸ Phacoemulsification was subsequently performed in the left eye of each dog.

Anesthesia and surgical procedures—One drop of ophthalmic solution¹⁷ (a combination of 0.5% tropicamide and 0.5% phenylephrine) was instilled into the left eye of each dog every 5 minutes for 20 minutes prior to anesthetic induction. The dogs were administered lactated Ringer’s solution (10 mL/kg/h, IV) throughout the anesthetic period. Dogs were premedicated with cefazolin¹⁹ (30 mg/kg, IV) and acepromazine maleate¹⁰ (0.03 mg/kg, SC) 30 minutes prior to induction of anesthesia with propofol¹⁰ (6 mg/kg, IV). After endotracheal intubation, anesthesia was maintained with isoflurane¹⁰ in oxygen. During anesthesia, the dogs were mechanically ventilated with a ventilator¹⁰ to maintain the end-tidal carbon dioxide concentration between 35 and 45 mm Hg. Electrocardiography, pulse oximetry, respiratory gas analysis, invasive MAP measurement in the dorsal pedal artery; determination of MAC of isoflurane, and measurement of rectal temperature were performed with an anesthetic monitor system¹⁰ every 2 minutes throughout the anesthetic period.

Sub-Tenon injection of lidocaine and phacoemulsification were performed by the same investigator (JA) in all dogs; that author was unaware of the treatments administered to each dog. Each dog was placed in dorsal recumbency, and the head was stabilized with a vacuum pillow. The left eye was aseptically prepared with 0.5% povidone-iodine solution. The mediadorsal portion of the bulbar conjunctiva (approx 5 mm from the limbus) was incised with tenotomy scissors, and the conjunctiva and sub-Tenon capsule were bluntly dissected from the underlying sclera. The appropriate IV solution was injected; simultaneously, the assigned solution (lidocaine or saline solution) was administered via sub-Tenon injection with a 19-gauge, curved, blunt irrigating cannula³ and syringe (Figure 1). Gentle digital ocular massage on the closed eyelids was performed for 1 minute to promote distribution of the injected solution. Ten minutes after the injections, horizontal pupil diameter was measured with a caliper, and routine 1-handed phacoemulsification¹⁰ was performed. At the end of the surgery, the incision created in the bulbar conjunctiva to assist with sub-Tenon injection was apposed with 8-0 polyglactin 910 in a simple continuous suture pattern. Then, 4 mg of triamcinolone acetonide³ and 4 mg of gentamicin sulfate¹⁰ were injected subconjunctivally. A nerve stimulator¹⁰ was placed on the ulnar nerve, and anesthesia was discontinued when the train-of-four twitch response was fully recovered. Duration of anesthesia (from intubation to extubation) and surgery (from corneal incision to conjunctival suture), mean elapsed ultrasonographic time, and phacoemulsification power were recorded.

Evaluation of intraoperative analgesia—Intraoperative analgesia was assessed by evaluating the end-tidal isoflurane concentration required for maintenance of heart rate and MAP within a baseline range. The baseline range was defined as the value obtained immediately before corneal incision ± 10%. End-tidal isoflurane concentration was maintained at 1.0% for at least 5 minutes before the beginning of surgery. After the start of the corneal incision, the inhaled isoflurane concentration was adjusted every 2 minutes on the basis of the heart rate and MAP in response to surgical stimuli: the inhaled isoflurane concentration was increased by 0.25% when heart rate or MAP increased by > 10% of...
the baseline value, and the inhaled isoflurane concentration was decreased by 0.25% when heart rate or MAP decreased by > 10% of the baseline value. The end-tidal isoflurane concentration was recorded every 2 minutes and at the time the following surgical procedures were started: making of the corneal incision, phacoemulsification, irrigation-aspiration, corneal suturing, and conjunctival suturing. End-tidal isoflurane concentration for each surgical procedure and mean end-tidal isoflurane concentration during the surgery were compared between the groups.

**Evaluation of postoperative analgesia**—A subjective pain score2,17 (6 categories; scale for each category, 0 to 3 or 0 to 4; total pain score scale, 0 to 21; Appendix) was determined by a trained observer (EL) immediately before each dog was premedicated; this score was used as a baseline value. At the end of surgery, dogs were transferred to a quiet room. The pain score was determined 0.25, 0.5, 1, 2, 4, 6, 8, and 24 hours after extubation by the same trained observer, who was not aware of the treatment group for each dog. Inadequate pain control was defined as a total pain score ≥ 9 or a score ≥ 3 for any category at any time point. Dogs with inadequate pain control received tramadol (4 mg/kg, IV) as a rescue analgesic; those dogs were excluded from further pain score evaluations and considered as treatment failures. The pain scores at each time point and time to treatment failure were compared between the 2 groups.

**Statistical analysis**—Results were expressed as mean ± SD. All analyses were performed by use of statistical software. Differences in intraoperative physiologic data (heart rate, MAP, end-tidal isoflurane concentration, and pupil diameter), duration of anesthesia and surgery, degree of surgical stimuli (mean ultrasonographic time and phacoemulsification power), and postoperative values (subjective pain score and time to treatment failure) were compared via the Mann-Whitney U test. Values of P < 0.05 were considered significant.

**Results**

Before the sub-Tenon injections of the assigned solutions, the eyes of all dogs were positioned in a ventromedial or ventral direction. At the beginning of the surgery, all eyes in both groups were centrally positioned. Chemosis and mild subconjunctival hemorrhage were detected in 6 of 14 and 8 of 14 eyes, respectively. Swelling of the conjunctiva did not impede surgical procedures, including making the corneal incision and suturing. In all eyes, the degree of subconjunctival hemorrhage was limited and did not require hemostasis. Akinesia was maintained throughout the surgery (Figure 2). Phacoemulsification was completed successfully without surgical or anesthetic complications in all eyes.

Heart rate, MAP at each point during the surgery, mean ± SD duration of anesthesia (54.1 ± 3.6 minutes), and mean duration of surgery (14.4 ± 3.2 minutes) were not significantly different between the 2 groups. Mean ultrasonographic time and phacoemulsification power were 3.0 ± 1.3 minutes and 19.6 ± 1.9%, respectively, for the control group and were 2.6 ± 0.8 minutes and 19.3 ± 3.0%, respectively, for the lidocaine group. There was no significant difference in ultrasonographic time and phacoemulsification power between the groups. Mean pupil diameter immediately before corneal incision was significantly (P = 0.007) greater for the lidocaine group (13.7 ± 0.7 mm), compared with the value for the control group (12.2 ± 0.8 mm; Figure 2).

Mean end-tidal isoflurane concentrations at each surgical stimulus were calculated (Figure 3). Isoflurane concentration during the surgery were compared for each surgical procedure and mean end-tidal isoflurane concentration during the surgery were compared between the groups.

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rane requirements were significantly lower for the lidocaine group than for the control group at the start of irrigation and aspiration \((P = 0.007)\), corneal suturing \((P = 0.001)\), and conjunctival suturing \((P = 0.007)\).

Mean end-tidal isoflurane concentration during the surgical procedures was significantly \((P = 0.007)\) lower for the lidocaine group (1.02%) than for the control group (1.18%). Moreover, anesthesia was maintained throughout the surgery with a MAC \(\leq 1.0\) for 5 of 7 dogs in the lidocaine group, whereas anesthesia was maintained with a MAC \(\leq 1.0\) for only 2 of 7 dogs in the control group.

The subjective pain score before dogs were premedicated and during the postoperative period were not significantly different between the groups at any time points (Figure 4). Rescue analgesia was required by 2 dogs in the control group (mean \(\pm\) SD, 22.5 \(\pm\) 10.6 minutes after extubation) and 1 dog in the lidocaine group (15 minutes after extubation); time to treatment failure did not differ significantly between the 2 groups.

**Discussion**

The study reported here was performed to evaluate the feasibility of administration of a local anesthetic via sub-Tenon injection to provide regional anesthesia and akinesia of extraocular muscles during phacoemulsification in dogs. Results of this study indicated that sub-Tenon injection of a local anesthetic could provide intraoperative analgesia, akinesia of extraocular muscles, and additional mydriasis during phacoemulsification. Although we hypothesized that the lidocaine group would have lower subjective pain scores during the postoperative period than the control group, there was no significant difference in the values between the 2 groups.

The space beneath Tenon’s capsule is a potential cavity between Tenon’s capsule and the sclera. Because extraocular muscles and sensory and autonomic nerve fibers in the retrobulbar space penetrate Tenon’s capsule to infiltrate the sclera, anesthetic solution administered via sub-Tenon injection anesthetizes the insertion portion of the extraocular muscles and nerve fibers surrounded by Tenon’s capsule. Then, the solution penetrates Tenon’s capsule and spreads into the retrobulbar space, where extraocular muscle cone and sensory or motor nerves exist. This accounts for development of sensory block, akinesia, and pupil dilation.

Administration of anesthetic via sub-Tenon injection is widely used in humans during intraocular surgery for intraoperative and postoperative analgesia. In 1 study in humans, 99.1% of patients undergoing various intraocular surgeries, including cataract removal, trabeculectomy, and vitrectomy, with anesthesia provided by administration of a local anesthetic via sub-Tenon injection, reported no pain during the surgery. The present study revealed that administration of a local anesthetic via sub-Tenon injection could provide excellent intraoperative analgesia during phacoemulsification in dogs because 5 of 7 dogs in the lidocaine group required a low isoflurane requirement (MAC \(\leq 1.0\)) during the surgery. Moreover, sub-Tenon injection of lidocaine reduced the mean end-tidal isoflurane concentration during surgery by 15.7%, compared with the concentration for the control group (1.02% vs 1.18%, respectively). These results suggested that phacoemulsification could be performed more safely in high-risk surgical patients (eg, geriatric animals) with sub-Tenon injection of a local anesthetic. Other general anesthetic regimens (eg, ketamine combined with xylazine and diazepam) that cause less cardiovascular and respiratory suppression could also be combined with...
sub-Tenon injection of a local anesthetic for phacoemulsification in geriatric patients.

In a study\(^8\) in humans, 90% of patients undergoing vitreoretinal surgery after sub-Tenon injection of a local anesthetic did not require postoperative analgesia. However, we did not observe any differences in subjective pain scores between the 2 groups of dogs in the present study. According to studies\(^2,17\) of dogs undergoing phacoemulsification with anesthesia provided via systemic and intracameral injection of lidocaine, time to treatment failure was significantly longer in the lidocaine injection group than the control group. Moreover, the prevalence of treatment failure in the control group in that study ranged from 83.3% to 100%, which was markedly higher than the proportion of dogs with treatment failure in the present study (3/14). Although the pain score system used in the present study was appropriate for assessment of postoperative pain following phacoemulsification in another study,\(^7\) the system could not reflect the exact degree of pain in the present study because pain assessment in animals is highly subjective.\(^2\) Subjective pain scores did not differ significantly between the 2 groups at any time point, and atacurium does not have analgesic or sedative effects.\(^7,16\) Therefore, the results did not appear to be attributable to the observer’s underestimation of the pain score or to atacurium administration. Theoretically, a shorter surgical time could induce less surgical stimuli and pain perception, and it is possible that a shorter duration of the surgery time in the present study (mean ± SD, 14.4 ± 3.2 minutes), compared with that in other studies (mean ± SD, 20.0 ± 4.5 minutes\(^5\); range, 55 to 75 minutes\(^2\)), might have contributed to the results. Additionally, subconjunctival injection of triamcinolone would reduce postoperative pain because anti-inflammatory properties of corticosteroids can contribute to relief of pain.\(^21\)

Although the degree of akinesia is more variable than is the analgesic effect in humans,\(^9,11,22\) akinesia was achieved within 10 minutes after sub-Tenon injection of lidocaine and was maintained throughout the surgery in all eyes in the lidocaine group for the dogs of the present study. This result corresponds with results of a previous study\(^8\) in dogs in which investigators found that akinesia was induced in a mean ± SD of 6.5 ± 9.9 minutes and maintained for 88.5 ± 17.2 minutes after sub-Tenon injection of lidocaine. The difference in the ability to induce akinesia between humans and dogs is presumably attributable to a smaller orbital volume in dogs, compared with that in humans, that contributes to distribution of anesthetic agents.\(^9\) Moreover, in contrast to the procedures in humans, cataract surgery and sub-Tenon injection of a local anesthetic are performed in anesthetized dogs, which prevents conscious movement of the eye during the surgery. Therefore, sub-Tenon injection of a local anesthetic in domestic animals can be a useful alternative to systemic administration of neuromuscular blocking agents that cause respiratory muscle paralysis.\(^8\)

There are only a few reports\(^8,11,22\) of studies in which the mydriatic effects of sub-Tenon injection of a local anesthetic in humans and other animals have been investigated because pupil dilation for intraocular surgery is generally achieved by topical administration of anticholinergic agents such as tropicamide. However, the topical mydriatic agents have a slow onset of mydriatic effects, which delays the time until start of surgery, and these effects typically will disappear during the surgery. Moreover, mydriasis can be insufficient, especially in patients with preexisting uveitis, which is commonly accompanied by hypermature cataracts.\(^11,12\) Sub-Tenon injection of a local anesthetic can be used to overcome these disadvantages of topically applied mydriatic agents. Investigators of another study\(^13\) indicated that they favored sub-Tenon injection of a local anesthetic in cases of insufficient pupil dilation before cataract surgery. In another study\(^9\) in dogs, investigators found that mydriasis was induced a mean ± SD of 4.2 ± 4.3 minutes after the injection and was maintained for 82.9 ± 13.6 minutes. Mean pupil diameter 10 minutes after the sub-Tenon injection in the present study was significantly greater for the lidocaine group than for the control group, which indicated there was an additional mydriatic effect, even after mydriasis had been induced by topical administration of anticholinergic and sympathomimetic agents. Therefore, sub-Tenon injection of a local anesthetic can contribute to maximal dilation of the pupil and access to the lens during phacoemulsification.

Chemosis and subconjunctival hemorrhage are common complications after sub-Tenon injection of a local anesthetic.\(^8,14,15\) Chemosis is caused by rostral migration of solution administered via sub-Tenon injection. The incidence of chemosis is 39.4% to 53.3%; however, it usually does not impede access to the surgical field.\(^11\) In the present study, chemosis was evident in 6 of 14 eyes at the beginning of the surgery but did not impair surgical procedures in any of the affected eyes. Subconjunctival hemorrhage was detected in 32% to 56% of humans in a study.\(^14\) Hemorrhage was limited and did not cause inconvenience during the surgical procedures in the dogs of the present study. Topical application of a vasoconstrictive agent (eg, phenylephrine) or cauterization of conjunctival vessels could reduce hemorrhage in hyperemic eyes.\(^15\) Although blinking ability was not evaluated postoperatively in the present study, akinesia of the eyelids as a result of diffusion of anesthetic solution has been reported in humans.\(^23\) Therefore, close monitoring of eyelid function or topical application of ophthalmic lubricants should be considered after surgery to avoid the risk of corneal ulcers.

Analysis of the results of the present study indicated that sub-Tenon injection of a local anesthetic could be an effective method for providing intraoperative analgesia, akinesia of extraocular muscles, and pupil dilation for phacoemulsification in dogs. Sub-Tenon injection of a local anesthetic would enable cataract surgery without systemic administration of neuromuscular blocking agents, which cause respiratory muscle paralysis. In addition, sub-Tenon injection of a local anesthetic results in the need for only a low isoflurane concentration to maintain anesthesia during surgery, which could be an important factor in high-risk surgical patients. Furthermore, additional mydriatic effects could improve exposure of the surgical field and visibility of the lens during phacoemulsification.
References


Appendix appears on the next page
### Appendix

Subjective pain scoring system for evaluation of postoperative analgesic effects after injection of a local anesthetic or saline (9% NaCl) solution beneath the bulbar sheath (vagina bulb; commonly known as Tenon’s capsule) of the left eye of 14 clinically normal Beagles undergoing phacoeulamulsification.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfort</td>
<td>0</td>
<td>Asleep or calm</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Awake and interested in surroundings</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Mild agitation or depressed and uninterested in surroundings</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Moderate agitation, restless, and uncomfortable</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Extremely agitated or thrashing</td>
</tr>
<tr>
<td>Movement</td>
<td>0</td>
<td>Quiet</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1–2 position changes/min</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3–6 position changes/min</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Continuous position changes</td>
</tr>
<tr>
<td>Appearance of treated eye</td>
<td>0</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Mild changes (affected eye partially closed)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Moderate changes (blinking or third-eyelid protrusion of affected eye)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Severe changes (affected eye continuously closed or pawing at eye)</td>
</tr>
<tr>
<td>Behavior (unprovoked)</td>
<td>0</td>
<td>Too sedate to evaluate</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Minor changes</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Moderately abnormal (less mobile or alert than normal, unaware of surroundings, or restless)</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Markedly abnormal (very restless, vocalizing, self-mutilating, grunting, or facing back of cage)</td>
</tr>
<tr>
<td>Interactive behaviors</td>
<td>0</td>
<td>Too sedate to evaluate</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Pulls away or blepharospasm when surgical site touched; mobile</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Vocalizes when wound touched and reluctant to move but will when coaxed</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Violent reaction to touching of surgical site, snapping, growling when approached, or failing to move when coaxed</td>
</tr>
<tr>
<td>Vocalization</td>
<td>0</td>
<td>Quiet</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Crying but responds to quiet voice and stroking</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Intermittent crying, with no response to quiet voice and stroking</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Constant crying (unusual for this particular dog, with no response to stroking or voice)</td>
</tr>
</tbody>
</table>