DOI: 10.1111/vop.12554

ORIGINAL ARTICLE

WILEY

Sub-Tenon's anesthesia for canine cataract surgery

Kellam D. Bayley | **R. A. Read**

Veterinary Ophthalmic Referrals, Plympton, SA, Australia

Correspondence
K. D. Bayley
Email: kellam.bayley@gmail.com

Abstract

Objective: To test a sub-Tenon's anesthesia technique in dogs as an alternative to systemic neuromuscular blockade to aid in canine cataract surgery under general anesthesia.

Procedures: A prospective controlled clinical study was performed involving 12 dogs undergoing bilateral cataract surgery under general anesthesia. One eye was randomly assigned to have phacoemulsification and prosthetic lens implantation performed with sub-Tenon's anesthesia (STA), and the control eye had surgery performed with systemic neuromuscular blockade (NMB). Intraocular pressure (IOP) was measured immediately before and after STA administration. Globe position, globe rotation, pupillary dilation, and vitreal expansion were assessed for both STA and NMB eyes during surgery.

Results: Sub-Tenon's anesthesia produced a globe position suitable for cataract surgery with the degree of vitreal expansion not significantly different to control NMB eyes. STA produced greater anterior globe displacement than NMB in all cases. STA had no significant effect on IOP.

Conclusion: Sub-Tenon's anesthesia was an effective alternative to systemic neuromuscular blockade for canine cataract surgery and may be beneficial for surgical exposure in deep orbited breeds.

KEYWORDS
canine cataract surgery, globe akinesia, mydriasis, neuromuscular blockade, retrobulbar anesthesia, sub-Tenon's anesthesia

1 | INTRODUCTION

Phacoemulsification and intraocular lens implantation is a highly successful procedure to restore vision in dogs with cataracts.[1,2] Success rates rely on optimizing intraoperative conditions for ease of surgery. These include maximizing surgical exposure of the globe and lens and minimizing extraocular muscle tension which can compromise globe position and/or lead to vitreal expansion.[1,3] These conditions have commonly been achieved with systemic neuromuscular blockade (NMB) using nondepolarizing neuromuscular junction blockers as an adjunct to general anesthesia.[1,2,4,5] These drugs prevent extraocular muscular contraction by temporarily and reversibly occupying postsynaptic acetylcholine receptors within the neuromuscular junction.[6] This NMB-induced extraocular muscle akinesia produces a relaxed centrally located globe and reduces the risk for vitreal expansion.[1,2,5,7,8] The major disadvantage of these systemic drugs is that their effect is not isolated to the extraocular muscles. The effect on respiratory musculature is significant and at standard doses dogs require mechanical ventilation throughout the surgical procedure.[5,9] Some NMB drugs can be used at low doses so the effect on respiration is minimized; however, ventilatory support may still be required.[7,9]

Sub-Tenon's anesthesia (STA) is a regional anesthesia technique which, as an adjunct to general anesthesia, has the potential to achieve the required operating conditions for canine cataract surgery without inducing undesired systemic effects. Through its effects on orbital motor nerves and extraocular muscles, STA produces extraocular muscle akinesia. STA also produces additional benefits for cataract surgery including pupil dilation and regional globe anesthesia (sensory blockade to cornea, sclera, and bulbar conjunctiva) through its localized effect on sensory nerves. STA has been used widely for these effects in humans undergoing cataract surgery for several years.[10-15] The low complication rate with STA in humans has resulted in a shift away from sharp needle retrobulbar and peribulbar injections in many centers.[16] To date, there has only been 1 group which has published on experimental usage of STA in dogs. Ahn et al showed that STA tested in ophthalmologically normal beagles produced extraocular muscle akinesia judged by globe centralization and mydriasis which was at least the equivalent of systemic atracurium NMB or retrobulbar local anesthetic injection. In addition, Ahn et al showed that STA could be used to facilitate phacoemulsification in 7 ophthalmologically normal beagles.[17-19] The study reported here sought to determine whether a specific sub-Tenon's anesthesia technique could provide equivalent or better intraoperative conditions for clinical canine cataract surgery under general anesthesia compared to a commonly used low-dose NMB protocol.

2 | MATERIALS AND METHODS

2.1 | Study design

A prospective, nonmasked, randomized controlled study was performed. Approval was provided by the Massey University animal ethics committee, and the clinical study was carried out accordingly. Informed consent was attained for each case admitted into the study.

2.2 | Reference population

The study population consisted of client-owned dogs that presented to the Veterinary Ophthalmic Referrals clinic (Adelaide, Australia) for bilateral cataract surgery over a fixed period during 2015. Phacoemulsification and foldable acrylic intraocular lens placement was performed in all cases, as is described in standard veterinary ophthalmic textbooks.[2,4] The bilateral cataract surgery cases were managed as matched pairs with one eye being operated on under STA and the remaining eye operated on under NMB. The eye receiving STA was randomly designated by a coin toss but was always operated on first, prior to any NMB being administered for the second (control) eye. This ordering was performed to avoid any confounding effects due to residual NMB used for surgery on the control eye.

NMB is currently considered standard practice for canine cataract surgery,[1,4,9] and was achieved with a low-dose systemic pancuronium protocol used successfully by one author (RAR) since 2007, based on an unpublished but widely used protocol commonly used in canine cataract surgery (Dr Seth Koch, personal communication).

2.3 | Analytical methods

2.3.1 | General anesthetic technique

The anesthesia technique was standardized across all cases in the study. Premedication with acepromazine (0.01-0.025 mg/kg SC, A.C.P 2; Delvet, Seven Hills, Australia) and buprenorphine (0.01 mg/kg SC, Temgesic; Reckitt Benckiser, West Ryde, Australia) was followed by induction with propofol (2.5-4 mg/kg IV, Fresofol 1%; Fresenius Kabi, Pymble, Australia) and maintenance on an inhalational anesthetic circuit with isoflurane (dosed to effect, Isoflurane; Ceva, Glenorie, Australia) in 100% oxygen. The morning of surgery dogs was administered topical tropicamide (Minims tropicamide 1%, Chauvin, Macquarie Park, NSW, Australia) for mydriasis along with topical ketorolac (Acular, ketorolac trometamol 5 mg/mL; Allergan, Gordon, NSW, Australia). The treatment eyes received STA with either 0.25% or 0.5% bupivacaine (Marcaine; AstraZeneca, North Ryde, Australia) at a predetermined dose and volume according to the dog's weight (Table 1). Bupivacaine was chosen over lidocaine due to its longer duration of action which would maximize the length of STA motor blockade.[20] The STA doses were calculated to be below the maximal recommended systemic dose of 2 mg/kg, and the volume used was based on the estimated orbital volume of the patient.[21,22] All STA was placed by the first author (KDB). The control eyes had systemic pancuronium (0.01 mg/kg IV, Pancuronium bromide BP; AstraZeneca) administered immediately prior to beginning surgery on the control (second) eye. Surgeries were performed by one of two authors (KDB and RAR). At the time of extubation, animals received subcutaneous carprofen (2 mg/kg, Rimadyl; Pfizer, West Ryde, Australia) and intravenous acepromazine (0.01 mg/kg) to facilitate a smooth recovery by reducing the risk of emergence dysphoria. All animals received supportive intravenous isotonic crystalloid fluids at 10 mL/kg/h during anesthesia and standard maintenance rates for a few hours after extubation. Anesthetic parameters were recorded at 5-minute intervals throughout surgery, including heart rate, respiratory rate, systolic and mean blood pressure (petMAP graphic; Ramsey medical Inc., Tampa, USA), isoflurane vaporizer setting (Isotec-5; Datex-Ohmeda, Steeton, UK), pulse oximetry, and capnography (CO_2SMO monitor; Respironics, CA, USA).

TABLE 1 Dosing schedule for bupivacaine in this STA study

Weight range	Volume and bupivacaine concentration
<5 kg	2 mL 0.25% bupivacaine
5-9.9 kg	3 mL 0.25% bupivacaine
>9.9 kg	3 mL 0.5% bupivacaine

2.3.2 | Sub-Tenon's anesthesia technique

A basic set of surgical instrumentation was used including an eyelid speculum, curved mosquito hemostat, 0.5 mm rat tooth thumb forceps, and curved Westcott conjunctival scissors. Once the dog was anesthetized, the cilia were clipped and the adnexa surgically prepared (0.05% chlorhexidine solution [Chlorhex-C; Jurox, Rutherford, Australia]) and topical proxymetacaine (0.5% proxymetacaine, Alcaine; Alcon, Frenchs Forest, NSW, Australia) was dropped onto the dorsolateral bulbar conjunctiva and cornea. In lateral recumbency, the head was propped up with a positioning pillow to facilitate exposure. The eyelid speculum was placed and a mosquito hemostat was clamped on the perilimbal dorsolateral conjunctiva in a region between the presumed insertion sites of lateral and dorsal recti muscles, with the globe fixed in a ventromedially rotated position. A 4- to 5-mm snip incision was made with the conjunctival scissors in the bulbar conjunctiva 3-5 mm posterior to the limbus dorsolaterally (Figure 1). The exposed tenons capsule was hydrated with 0.1 mL of the anesthetic solution to assist differentiation of Tenon's capsule from the underlying sclera (Figure 2). Tenon's capsule was grasped with fine rat tooth forceps, and the conjunctival scissors were used to bluntly dissect down through the hydrated Tenon's capsule to reach sclera. The blunt dissection was continued posteriorly staying on the "line of latitude" between the dorsal rectus and lateral rectus extraocular muscles, immediately exterior to the sclera, which corresponded to sub-Tenon's space (Figure 3). A sub-Tenon's tunnel was created to just beyond the globe equator. The sub-Tenon's cannula (19G 1″, Sterimedix, Redditch, UK) was then introduced, taking care to remain within the sub-Tenon's tunnel and not veer intra-Tenon's (Figure 4). Once the cannula tip was beyond the globe equator, local anesthetic infusion began while rotating the cannula tip to maximize coverage of the intraconal region. Following STA infusion, the conjunctival incision was not sutured and allowed to heal by second intention. STA placement took a total of approximately 3 minutes per eye. Successful block placement was indicated if the eye rotated into a central location (Figure 5). This often occurred within 30 seconds, but could take up to 15 minutes. The variable onset of action was still sufficiently rapid for the STA to have taken effect by the time the patient was transferred to surgical theater, positioned, draped, and instrument packs opened.

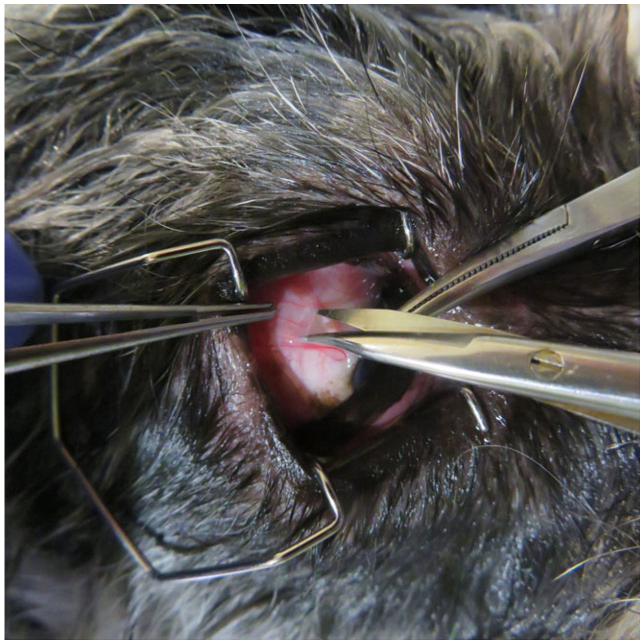

FIGURE 1 Conjunctival snip incision 3-5 mm posterior to the dorsolateral limbus

2.3.3 | Intraocular pressure measurement

Intraocular pressure (IOP) was measured in all eyes as IOP elevation was deemed a potential complication following STA administration. Following general anesthesia and endotracheal intubation, the dog was positioned in sternal recumbency and the chin was supported with a bean bag to elevate the head slightly for tonometry. Care was taken to avoid tension around the neck which can artificially raise IOP.[2] IOP was measured with a rebound tonometer (Tonovet Tonometer; Tiolat Oy, Helsinki, Finland) immediately before and after STA placement in both the STA and control eyes.

2.3.4 | Intraoperative assessment parameters

Specific parameters were directly observed and subjectively assessed before and during surgery to estimate the impact of the STA compared to control eyes receiving NMB. These parameters were assessed by the senior specialist ophthalmologist (RAR) and included globe rotation, anterior–posterior globe position within the orbit, pupil dilation, anterior chamber depth, and vitreal expansion. Globe rotation was assessed as either central or not central depending on if the visual axis was in a neutral forward-facing position or rotated away from that orientation. Anterior–posterior globe position within the orbit was assessed according

FIGURE 2 Hydration of Tenon's capsule with 0.1 mL of local anesthetic solution via the sub-Tenon's cannula

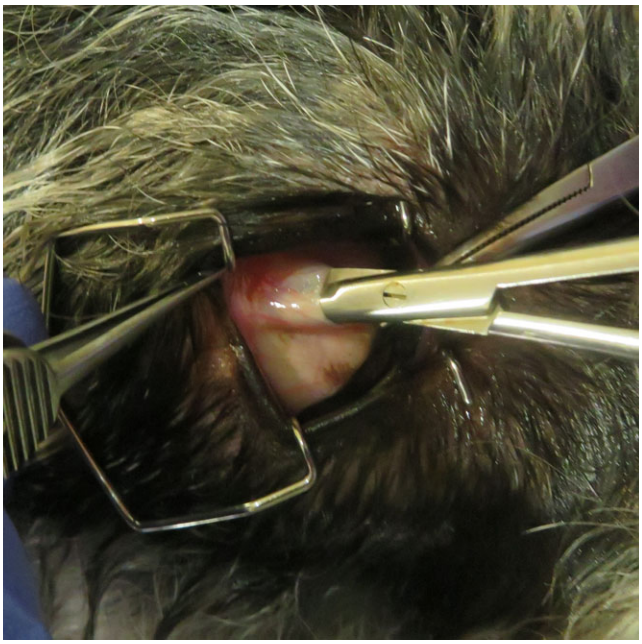

FIGURE 3 Blunt dissection in dorsolateral sub-Tenon's space to create a tunnel to beyond the globe equator

FIGURE 4 Infusion of the local anesthetic solution via a sub-Tenon's cannula in the previously created tunnel

FIGURE 5 STA produces intraconal local anesthesia with resultant extraocular muscle akinesia and a central globe location. Note the presence of chemosis which was often seen following STA

to the central corneal position in relation to the eyelid margins. This was judged as either anterior to, level with, or posterior to the eyelid margins and compared to the control eye. These assessments were made immediately before starting surgery, approximately 20 minutes after STA placement. Pupil dilation was assessed as being either adequately dilated or not adequately dilated for cataract surgery. A pupil was deemed to be adequately dilated if the pupillary diameter was at least 75% of the corneal diameter, sufficient to perform cataract surgery. If the pupil was not adequately dilated, 1:10 000 diluted adrenaline (Adrenaline-Link. Adrenaline 1 mg/mL, 1 in 1000; LinkPharma, Warriewood, NSW, Australia) was instilled intracamerally to improve dilation for cataract surgery. Anterior chamber depth and vitreal expansion were assessed according to the tendency of the iris and posterior lens capsule to protrude anteriorly during surgery. Anterior chamber depth and vitreal expansion were assessed between the STA and control eyes in a comparative manner. The anterior chamber depth in the STA eye was judged to be "shallower than," "equal to," or "deeper than" the anterior chamber depth in the control eye. The vitreal expansion in the STA eye was judged to be either "greater than," "equal to," or "less than" the vitreal expansion experienced in the control eye. These parameters were therefore assessed subjectively in a directly comparative binomial manner within an individual dog.

2.3.5 | Post-operative follow-up

Post-operative complications and outcomes were recorded for 14 days after surgery.

2.4 | Statistical analysis

Statistical software was used to analyze the data (R v 3.1.0; R development core team, 2012; R foundation for statistical computing, Vienna, Austria). Significance was inferred at $P \leq .05$. The 2-tailed Wilcoxon signed-rank test was used to test for differences in the mean general anesthetic parameters and to test for IOP differences pre-STA and post-STA in both the STA-treated and control eyes. An exact binomial test was used to assess whether the anterior chamber was significantly shallower in the treatment group than the control group (there were no treatment group cases where it was deeper), and whether the vitreal expansion was significantly greater in the treatment group than the control group (there were no treatment group cases where it was less).

3 | RESULTS

3.1 | Study population

A total of 12 dogs were enrolled in this study. The mean age of the dogs was 9.9 years (range = 7.5-13 years). The mean bodyweight was 11 kg (range = 5.2-35 kg). The sex distribution was 5 neutered females, 5 neutered males, and 2 entire males. There were 9 breeds represented in the study population, with the most common being Maltese cross (n = 3) followed by Jack Russell terrier (n = 2) while other breeds were represented by a single dog. STA was administered to the right eye for 8 cases and to the left eye for 4 cases, with NMB used in the contralateral control eyes.

3.2 | Intraocular pressure assessment

The mean intraocular pressure measurements for both STA and control groups are presented in Table 2. There was no significant difference in IOP before and after STA placement within both the STA-treated group and the control group (P = .928 and P = .055, respectively). There was also no significant difference in the level of IOP change pre-STA and post-STA placement between the STA and control eyes (P = .084).

TABLE 2 Mean IOP values in STA and control eyes measured before and after STA administration in the treated eye

Treatment group	Pre-STA IOP (mean ± SD) mm Hg	Post-STA IOP (mean ± SD) mm Hg	Change in IOP (mean ± SD) mm Hg
STA-treated eye	12.67 ± 2.64	12.58 ± 3.20	−0.08 ± 3.02
Control eye	13.42 ± 5.53	11.75 ± 4.35	−1.67 ± 2.57

3.3 | Assessment of regional orbital anesthesia

Globe rotation was assessed to be central in all STA-treated eyes. In contrast, only 2 of 12 control eyes were central when assessed at the start of surgery before NMB was administered.

Pupillary dilation (mydriasis) was recorded as either fully dilated or not fully dilated. All eyes had a degree of pupil dilation due to the preoperatively administered mydriatic. All 12 STA-treated eyes were considered fully dilated; however, 2 of 12 eyes from the control group were not fully dilated and required intracameral adrenaline to improve surgical conditions.

The globe position within the orbit was displaced anteriorly in all STA-treated eyes when compared to the control eyes. Upon completion of surgery, this effect was judged to be beneficial, detrimental, or inconsequential to the performance of cataract surgery. This effect was beneficial in 6 cases (50%), detrimental in 1 case (8%), and inconsequential in 5 cases (42%). The cases which benefited had improved globe exposure, resulting in easier surgical instrument manipulation within the eye. The one case that was affected detrimentally also developed significant vitreal expansion, thought to be due to globe compression against the palpebral fissure.

The degree of vitreal expansion was assessed in a comparative manner between the STA and control NMB eyes. This variable was assessed with two visual parameters, vitreal push on the posterior lens capsule and anterior chamber depth. There was no significant relationship between STA and an increase in vitreal push (P = .15). There was also no significant relationship identified between STA and a shallower anterior chamber (P = .77). Vitreal expansion was deemed to be a true complication in one case, in the STA-treated eye. The level of vitreal expansion encountered (as evidenced by the degree of vitreal push and shallowing of the anterior chamber) increased the difficulty in placing an intraocular lens implant, but did not prevent successful completion of the surgery.

3.4 | Assessment anesthesia monitoring parameters

The intraoperative anesthetic parameters assessed and the mean values recorded are presented in Table 3. There were statistically significant differences between the STA and control eyes for systolic blood pressure, mean blood pressure, and $ETCO_2$, all of which were lower for the STA eyes.

3.5 | Complications

Recording and reporting of complications were important aspects of testing the clinical applications of this new technique. They were assessed immediately after STA placement, intraoperatively and post-operatively. Complications were infrequently encountered and relatively mild in severity. The complications are summarized in Table 4. It is worth noting that none of the dogs that received STA lost a palpebral reflex in the post-operative period. Two small dogs weighing 7.2 and 9.4 kg showed a transient upper eyelid ptosis, which self-resolved at 90 and 240 minutes after extubation. While visual performance was not specifically tested in this study, vision returned (positive menace response) to the NMB eye once the dog sufficiently recovered from general anesthesia and to the STA eye within 5 hours of STA placement.

4 | DISCUSSION

This study facilitated a direct comparison between STA and a commonly used NMB protocol for their ability to produce the desired surgical conditions for canine cataract surgery. Bilateral surgical cases were managed as matched pairs, with one eye being operated on under STA, and the remaining eye operated on under NMB. This directly comparative design was used to overcome the considerable individual variation typically seen in the assessment parameters and to increase the sensitivity for detecting differences between the two techniques, particularly for the subjectively assessed parameters. STA is a regional technique with no likely effects on the contralateral eye. In contrast, NMB is a systemic therapy with likely effects on the contralateral eye that may interfere with parameter testing on that eye. For these reasons, STA was always used for the first eye, prior to NMB being administered for the second eye. This approach may confound the assessments due to the nonrandom ordering and the lack of blinding of the surgeon to the treatment group, but the authors felt that these detrimental confounding effects were far outweighed by the improved isolation of effects of individual treatments. Using NMB-treated eyes as a control group, the clinical and practical application of STA for canine cataract surgery could be tested without compromising the operating conditions for the control eye. Prior publications clearly show that STA causes extraocular muscle akinesia, centrally rotated globe position, and mydriasis.[17,19] The objective of this study was to compare the efficacy of STA to a standard NMB protocol to trial the application of STA as an alternative to NMB for clinical canine cataract surgery.

Bupivacaine was chosen as a sole agent to test this STA technique due to its long duration of action. The literature reports various durations of action for lidocaine and bupivacaine with 40-220 minutes for lidocaine and 360-600 minutes for bupivacaine.[20,23] The authors elected to use the agent with the longest duration to ensure the STA would remain effective throughout surgery. The onset of action of bupivacaine is variably reported in the literature

TABLE 3 Comparison of mean intraoperative general anesthesia monitoring parameters for STA and control eyes

	Mean value		Standard deviation			
GA parameter	Control	STA	Control	STA	Wilcox. *P* value[a]	Wilcox. *W* value[b]
Iso %	2.3	2.32	0.48	0.4	0.968	38.5
HR	101.97	98.53	21.09	19.67	0.523	31
BPsys	119.24	112.17	13.97	15.22	0.019	9
BPmean	76.94	72.78	8.91	8.78	0.019	9
RR	17.45	18.91	10.45	10.69	0.529	31
$ETCO_2$	51.55	48.58	5.49	5.89	0.016	6

Iso %, isoflurane vaporizer setting; HR, heart rate (beats/min); BPsys, systolic blood pressure (mm Hg); BPmean, mean blood pressure (mm Hg); RR, respiratory rate (breaths/min); $ETCO_2$, end-tidal carbon dioxide (mm Hg).

[a]The *P* value was calculated from Wilcoxon *z* value.

[b]Both the *P* value and *w* value are presented due to the relatively low population size (n = 12). With a significance level at $P \leq .05$, the critical *W* value is <13.

TABLE 4 Complications associated with STA and their outcomes

Complication	Number of cases	Outcome
Subconjunctival hemorrhage	1	Mild, no impact on surgery
Chemosis	8	One required radial conjunctival "relaxing" incisions, others had no impact on surgery
Vitreal expansion	1	Difficulty in placing intraocular lens, surgery performed successfully
Post-operative corneal ulceration	1	Healed with medical therapy within 7 days
Post-operative intraocular inflammation	2	Both had bilateral involvement, therefore not STA related, resolved with medication
Post-operative intraocular pressure elevation	1	Control eye affected only, therefore not STA related, resolved medically
Euthanasia 3 days post-operatively	1	Diabetic, presumed severe pancreatitis, deemed unrelated to STA

to be between 2.5 and 30 minutes.[20,23] In one study, the reported onset of action of akinesia following a lidocaine STA in dogs was 3.8 ± 5.8 minutes with a range of 1-20 minutes.[17] This is comparable to the onset of action reported in this study which used bupivacaine. Mixtures of bupivacaine, lidocaine, and hyaluronidase are often used in human ophthalmology to minimize the time to onset.[24-26] While this is very important for rapid case flow through busy human surgical theaters, the time to onset of action of STA is not a rate-limiting step in canine cataract surgery. Using a longer duration local anesthetic agent for STA will result in effects lasting longer into the post-surgery period. While this may be beneficial for post-operative pain management, it also temporarily impairs optic nerve function and vision. Time to return of vision following STA was not specifically assessed in this study given the associated difficulties with only one eye from each bilateral procedure receiving STA, the variable recovery rate from general anesthesia, and the marked post-operative miosis due to postsurgery intracameral carbachol (Miostat. Carbachol 0.01%, Alcon). Following completion of this study, assessment of bilateral STA-treated cataract surgery cases showed that vision returned within 5 hours following STA administration in most dogs. (K.D. Bayley, unpublished data) This occurred during the recovery period from anesthesia while patients were still sedated from the effects of the various sedative and anesthetic agents administered. The temporary lack of vision during this period did not cause distress in any case. As most cataract surgery patients had little or no vision in operated eyes prior to STA and surgery, this temporary effect could not be considered a source of significant distress to the patient. Injection of a solution into the orbit can cause some retrobulbar pressure on the globe and result in an elevation in IOP.[27-30] Elevations in IOP can cause damage to sensitive ocular structures including the optic nerve.[2] Increased IOP was also considered a potential indicator of globe compression, increasing the risk of vitreal expansion. Measuring IOP before and immediately after STA placement should highlight the maximal IOP elevation, as the IOP tends to decrease with time following STA.[29,31] A previous STA canine study reported that there was no significant increase in IOP following a 2 mL lidocaine STA placement.[17] There was no statistically significant difference in IOP in the STA or control eyes in our study. There was no appreciable increase in IOP in the STA-treated eyes; however, there was an appreciable reduction in IOP in the control eyes. This reduction in IOP was likely due to the cumulative effect of the inhalational anesthetic agent or a reduction in effect of propofol as it is metabolized through time.[32-35] The different levels of IOP reduction between the STA- and control-treated eyes may indicate a relative IOP increase effect of STA administration; however, changes of this magnitude are unlikely to be clinically significant. In addition, there was no association found between this mild elevation of IOP and the presence of vitreal expansion.

The intraoperative parameters of globe position, pupil dilation, and vitreal expansion were assessed to measure the effect of STA on the surgical conditions. Any deviation from the desired cataract surgery operating conditions (a relaxed centrally rotated globe with good exposure, good pupil dilation, and minimal vitreal expansion) could compromise the surgery and affect outcomes. These parameters for STA eyes were assessed using an ordinal scale and compared to the same parameters in control NMB-treated eyes. Previous studies have used more objective measures to test some of these parameters[1,19,36]; however, as the objective of this study was to test the effect of STA compared to NMB, a subjective directly comparative approach was utilized.

The impact of STA on two aspects of globe positioning was assessed: globe centralization and the anterior–posterior position of the globe within the orbit. The globe position was assessed at the time of surgery (around 20 minutes following STA placement) which provided adequate time for the bupivacaine to take full effect on the extraocular muscles and motor nerves.[20,23] STA usage was strongly associated with globe centralization. The effect of STA could not be totally isolated from the effect of general anesthesia on globe rotation as STA was used as an adjunct to general anesthesia. However, as only 2 of 12 control eyes were central before NMB administration, STA administration significantly contributed to the occurrence of globe centralization. STA caused the globe to displace anteriorly in all cases compared to the NMB globe. Relative protrusion of the globe can facilitate cataract surgery by improving exposure of globe and lens. In deep-set eyes, the dorsal orbital rim can interfere with corneal incisions and instrument manipulation within the eye, increasing the difficulty of surgery. Stay sutures can be used to improve globe position for surgery but excessive tension may increase the risk for vitreal expansion. The beneficial effect of forward movement of the globe is most significant in dolichocephalic and mesaticephalic dogs where it significantly improves surgical exposure of the globe. This parameter was assessed in a subjective comparative manner as there is no established technique for objective assessment and there is marked variation in orbital depth between different dog breeds.[2] STA shifted all globes anteriorly compared to control eyes, which resulted in an improved globe exposure and simplification of surgery in 6 of 12 cases. This study has shown that STA has beneficial effects on globe positioning for canine cataract surgery by creating a centrally rotated eye and anterior globe displacement, both of which facilitate good surgical exposure.

Mydriasis is very important for cataract surgery and is routinely achieved with preoperative topical mydriatic drops. A widely dilated pupil allows better visualization of the peripheral lens during surgery and reduces the risk of intraoperative iris trauma.[1,2] As all cases in this study were preoperatively treated with a mydriatic, isolated assessment of the effect of STA on the pupil was not possible. However, 2 of 12 NMB control eyes required intraoperative intracameral adrenaline due to inadequate mydriasis, compared to 0 of 12 STA eyes. This superior mydriatic effect of STA compared to NMB is supported with findings from a previous study which assessed this variable without pre-STA application of topical mydriatic drops.[19]

Vitreal expansion refers to vitreous body behavior in some patients during cataract surgery and is most common in brachycephalic breeds. This expansion is thought to be largely due to extraocular muscle tension and a positive vitreal pressure, causing a forward protrusion of the posterior lens capsule which can significantly increase the difficulty of cataract surgery.[1,3,37] It also shallows the anterior chamber, complicates placement of a prosthetic lens implant, and increases the risk for iris prolapse through the corneal incision. As such, it needs to be avoided or at least minimized as much as possible. Vitreal expansion risk is reduced by avoiding external pressure and tension on the globe and inducing extraocular muscle paralysis.[4] Vitreal expansion was subjectively assessed in the STA-treated eye as being either greater than or equivalent to the control NMB eye. Conversion of this parameter into binomial comparative data allowed detection of subtle differences between eyes and compensated for individual variation between patients. This allowed direct comparison of the effects of STA to NMB within an individual. However, as an ordinal scale was not used in this study, it is difficult to compare the results from this STA study to previous work assessing vitreal expansion between individuals where ordinal scales have been used.[5] Some STA eyes had an increased level of vitreal expansion when compared to the NMB eye; however, this difference did not reach statistical significance. Vitreal expansion caused a significant clinical effect in just one case and is discussed below as an intraoperative complication. Clinically and statistically, there was no significant difference in the vitreal expansion between the STA and NMB eyes, and STA appears comparable to NMB for preventing vitreal expansion during cataract surgery.

NMB has dose-dependent effects on all skeletal muscles including those involved in respiration which can cause respiratory depression, reduction in tidal volume, hypercapnia, respiratory acidosis, and hypoxia.[5,9,38] These effects are the primary challenge when managing general anesthesia in dogs receiving NMB for cataract surgery. Respiratory function was primarily assessed with a capnograph measuring end-tidal CO_2 ($ETCO_2$) throughout both the STA and NMB phases of general anesthesia. This study utilized a commonly used low-dose pancuronium NMB protocol to achieve extraocular muscle akinesia only, having minimal impact on respiratory function and not requiring routine mechanical ventilation. The capnography results showed that $ETCO_2$ was significantly higher in the NMB phase; however, the $ETCO_2$ levels in both groups were higher than ideal under general anesthesia.[6,39] It is fair to assume that if a higher dose NMB agent was used, there would be a greater difference in either the capnography results or the requirement for routine mechanical ventilation in NMB-treated eyes compared to the STA eyes. Factors other than the direct effect of NMB on respiratory function could also account for an elevated $ETCO_2$ in the NMB eye group. As the NMB eye was always the second eye operated on, the measurements were taken after a period of general anesthesia for surgery on the first eye and after the patient has been repositioned for surgery on the second eye. This combination of affects may result in ventilation–perfusion mismatch due to atelectasis in the previously dependent lung lobe.[6,40] This could theoretically affect $ETCO_2$, although this may be more important in breeds larger than the dogs in this study.[6,41,42] Differences seen in the levels of

$ETCO_2$, systolic, and mean blood pressure between STA and control eyes were not considered to impact the study group mean or standard deviation to a level which could be detrimental to the patient. Study groups with larger numbers would be required to investigate whether these changes are consistent in future studies. This study has shown that STA can achieve the desired extraocular muscle paralysis without impacting respiratory function and therefore provides a useful option for canine cataract surgery without the respiratory support that may be required for NMB.

Complication identification was an important aspect of this study. As STA is a new technique for canine cataract surgery, accurate reporting of complications is required to provide ophthalmic surgeons and anesthetists with a complete picture of the impact of this technique. Complications were assessed at 3 stages: STA placement, intraoperatively, and post-operatively. Minor subconjunctival hemorrhage occurred in 1 case at the time of STA placement. In human studies, minor hemorrhage occurs in 7%-46% of cases, with 0.1% having significant hemorrhage which impacts surgery.[13] Subconjunctival hemorrhage was commonly encountered in a previous canine STA paper where it occurred in 15 of 30 dogs,[18] whereas the STA technique described in our study appears to result in a lower risk for hemorrhage. Chemosis can occur when local anesthetic solution diffuses under the conjunctiva after STA. This is a common occurrence with STA in humans, with a reported occurrence of mild chemosis between 5.6% and 40%.[10,13,25,43] It is important to recognize that this rarely affects surgery, with only 0.06% patients having a more difficult surgery due to chemosis.[10] Marked chemosis was reported in 16 of 30 dogs in a previous canine STA study.[18] Mild chemosis occurred intraoperatively in 58% of cases in this study, and one case developed moderate chemosis which required two perilimbal radial conjunctival “relaxing” incisions to resolve visual obstruction caused by edematous bulbar conjunctiva overriding the planned corneal incision site. As chemosis only slightly affected surgery in 1 dog, its occurrence was not a major concern. The technique described in this study may reduce the risk of marked chemosis development compared to the previously described technique used in dogs. Vitreal expansion is a major intraoperative complication affecting canine cataract surgery. In this study, marked vitreal expansion was only encountered in one STA-treated eye. This was suspected to be caused by anterior movement of the globe due to volume displacement from the STA, resulting in globe compression against the eyelids.[37] This patient, a 5 kg Australian Terrier, had a tight eyelid conformation which likely contributed to the problem. Post-operative complications occurred in five cases within 14 days of surgery. The single patient with post-operative corneal ulceration in the STA-treated eye was the most concerning complication. STA may increase the risk for corneal exposure and associated ulceration via two mechanisms: prolonged corneal desensitization after surgery reducing the stimuli for lacrimation and blinking, and reduced corneal coverage by the eyelids due to forward movement of the globe. None of the dogs in this study lost the ability to blink; therefore, the ulceration was not caused by eyelid akinesia. Overall STA was associated with a low rate of complications, and minor protocol alterations have prevented recurrence of the more serious complications.

This study has shown that STA is a useful alternative to NMB as an adjunct to general anesthesia for canine cataract surgery. The main benefits from STA appear to be anterior globe displacement in deep orbited breeds improving surgical exposure, no deleterious effect on respiratory function, superior pupil dilation, and a long length of action which may improve post-operative analgesia. The main inconveniences associated with this technique involve the increased time to place the STA block (around 5 minutes) compared to intravenous injection of NMB, the tendency for slightly higher levels of vitreal expansion and the delayed onset of vision in dogs during recovery from general anesthesia while bupivacaine wears off (within 5 hours following STA). Simple modifications to the STA technique are likely to reduce the risk of the complications reported. Accurate dissection and cannula placement beyond the globe equator should prevent block failure and reduce the risk of chemosis.[25] For eyes with engorged

TABLE 5 Proposed bupivacaine dosing schedule for STA following outcome of the study

	Bupivacaine concentration and volume	
Dog weight	**Unilateral cataract surgeries**	**Bilateral cataract surgeries**
2.5-5 kg	1 mL 0.5% solution	1 mL 0.25% solution per eye
5.1-10 kg	2 mL 0.5% solution	2 mL 0.25% solution per eye
10.1-15 kg	2 mL 0.5% solution	2 mL 0.5% solution per eye
15.1-25 kg	3 mL 0.5% solution	3 mL 0.5% solution per eye
25 kg+[a]	5 mL + 0.5% solution	5 mL + 0.5% solution per eye

[a]The volume used in deep orbited breeds is varied so the globe is approximately level with the orbital rim to optimize surgical exposure.

episcleral blood vessels, extra care should be taken during dissection to prevent hemorrhage from occurring. A lower volume STA particularly in small and/or brachycephalic breeds should further reduce any IOP elevation post-block, reduce the risk of chemosis, help prevent vitreal expansion, and minimize corneal exposure from relative exophthalmos.[29,31] Use of lubricating ointments or a lateral temporary tarsorrhaphy after STA may also prevent corneal desiccation and ulceration, particularly in shallow orbited breeds that are at higher risk of corneal exposure. Alterations to the dose and volume of bupivacaine have been made subsequent to gathering the data for this study, with the primary goal to reduce any tendency toward excessive anterior globe movement and/or vitreal expansion. The dosing schedule we now use in clinic is presented in Table 5. The dose alterations were developed with consideration of orbital intraconal volumes in different dog breeds, the desire to push the globe anteriorly in deep orbited breeds but not in small brachycephalic breeds, and maintaining a systemic bupivacaine dose under 2 mg/kg.[21,22,44] The author (KDB) has noted that as more experience is gained with the STA technique, the rate of complications encountered reduces. Future study investigating STA across a variety of animal species and surgeries will significantly contribute to our understanding of the uses of this new veterinary technique. In summary, STA was an effective technique for achieving suitable operating conditions for canine cataract surgery under general anesthesia.

ACKNOWLEDGMENTS

The authors would like to thank Dr Hiroki Sano, Dr Helen Long, Dr Jonathon Tuke, Dr Nick Cave, Dr Craig Johnson, and Gemma Brown for their contributions to the study design, data assessment, and manuscript preparation. The authors did not receive financial support for the study and do not have any financial interest in the tested technique or material presented. This data was included in a poster presentation at the 2017 ECVO conference in Estoril, Portugal.

REFERENCES

1. Nasisse MP, Davidson MG, Jamieson VE, English RV, Olivero DK. Phacoemulsification and intraocular lens implantation: a study of technique in 182 dogs. *Prog Vet Comp Ophthalmol*. 1991;1:225-232.
2. Wilkie DA, Colitz CMH. Surgery of the lens. In: Gelatt KN, ed. *Veterinary Ophthalmology*, 5th edn. Ames, IA: Wiley-Blackwell; 2013:1234-1286.
3. Chronopoulos A, Thumann G, Schutz J. Positive vitreous pressure: pathophysiology, complications, prevention and management. *Surv Ophthalmol*. 2016;62:127-133.
4. Gelatt KN, Gelatt JP. *Veterinary Ophthalmic Surgery*. Oxford, UK: Elsevier/Saunders; 2011:400.
5. Sullivan TC, Hellyer PW, Lee DD, Davidson MG. Respiratory function and extraocular muscle paralysis following administration of pancuronium bromide in dogs. *Vet Ophthalmol*. 1998;1:125-128.
6. Thurman J, Tranquilli W, Benson G. Swine. In: Thurman J, Tranquilli W, Benson G, eds. *Lumb and Jones Veterinary Anaesthesia*, 3rd edn. Baltimore, MD: Williams and Wilkins; 1996:627-644.
7. Auer U, Mosing M, Moens Y. The effect of low dose rocuronium on globe position, muscle relaxation and ventilation in dogs: a clinical study. *Vet Ophthalmol*. 2007;10:295-298.
8. Oliver J, Clark L, Corletto F, Gould D. A comparison of anesthetic complications between diabetic and nondiabetic dogs undergoing phacoemulsification cataract surgery: a retrospective study. *Vet Ophthalmol*. 2010;13:244-250.
9. Lee DD, Meyer RE, Sullivan TC, Davidson MG, Swanson CR, Hellyer PW. Respiratory depressant and skeletal muscle relaxant effects of low-dose pancuronium bromide in spontaneously breathing, isoflurane-anesthetized dogs. *Vet Surg*. 1998;27:473-479.
10. Guise PA. Sub-Tenon anesthesia: a prospective study of 6,000 blocks. *Anesthesiology*. 2003;98:964-968.
11. Stevens JD. A new local-anesthesia technique for cataract-extraction by one quadrant sub-Tenons infiltration. *Br J Ophthalmol*. 1992;76:670-674.
12. Nouvellon E, L'Hermite J, Chaumeron A, et al. Ophthalmic regional anesthesia - Medial canthus episcleral (sub-tenon) single injection block. *Anesthesiology*. 2004;100:370-374.
13. Verghese I, Sivaraj R, Lai YK. The effectiveness of sub-Tenon's infiltration of local anaesthesia for cataract surgery. *Aust N Z J Ophthalmol*. 1996;24:117-120.
14. El-Hindy N, Johnston RL, Jaycock P, et al. The Cataract National Dataset Electronic Multicentre Audit of 55 567 operations: anaesthetic techniques and complications. *Eye (Lond)*. 2009;23:50-55.
15. Ripart J, Lefrant JY, Vivien B, et al. Ophthalmic regional anesthesia: medial canthus episcleral (sub-tenon) anesthesia is more efficient than peribulbar anesthesia: a double-blind randomized study. *Anesthesiology*. 2000;92:1278-1285.
16. Eke T, Thompson JR. Serious complications of local anaesthesia for cataract surgery: a 1 year national survey in the United Kingdom. *Br J Ophthalmol*. 2007;91:470-475.
17. Ahn J, Jeong M, Park Y, et al. Comparison of systemic atracurium, retrobulbar lidocaine, and sub-Tenon's lidocaine injections in akinesia and mydriasis in dogs. *Vet Ophthalmol*. 2013;16:440-445.
18. Ahn J, Jeong M, Park Y, et al. A sub-Tenon's capsule injection of lidocaine induces extraocular muscle akinesia and mydriasis in dogs. *Vet J*. 2013;196:103-108.
19. Ahn J, Jeong M, Lee E, et al. 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. *Am J Vet Res*. 2013;74:1126-1132.
20. Aksu R, Bicer C, Ozkiris A, Akin A, Bayram A, Boyaci A. Comparison of 0.5% levobupivacaine, 0.5% bupivacaine, and 2% lidocaine for retrobulbar anesthesia in vitreoretinal surgery. *Eur J Ophthalmol*. 2009;19:280-284.

21. Munger RJ, Ackerman N. Retrobulbar injections in dog - comparison of 3 techniques. *J Am Anim Hosp Assoc*. 1978;14:490-498.
22. Ramsey I. *Small Animal Formulary*, 7th edn. Gloucester, UK: British Small Animal Veterinary Association; 2011. xiv, 434 p.
23. Mauger T, Craig E. *Havener's Ocular Pharmacology*, 6th edn. St Louis, MO: Mosby; 1994.
24. Aslam S, Sarker SJ, Tran-Dang M, et al. Effect of hyaluronidase on ocular motility and eyelid function in sub-Tenon's anaesthesia: randomised controlled trial. *Eye (Lond)*. 2006;20:579-582.
25. Canavan KS, Dark A, Garrioch MA. Sub-Tenon's administration of local anaesthetic: a review of the technique. *Br J Anaesth*. 2003;90:787.
26. Guise P. Sub-Tenon's anesthesia: an update. *Local Reg Anesth*. 2012;5:35-46.
27. Stevens J, Giubilei M, Lanigan L, Hykin P. Sub-Tenon, retrobulbar and peribulbar local anaesthesia: the effect upon intraocular pressure. *Eur J Implant Refract Surg*. 1993;5:25-28.
28. Patton N, Malik TY, Aslam TM, Vallance JH. Effect of volume used in sub-Tenon's anaesthesia on efficacy and intraocular pressure: a randomized clinical trial of 3 mL versus 5 mL. *Clin Exp Ophthalmol*. 2004;32:488-491.
29. Sohn HJ, Moon HS, Nam DH, Paik HJ. Effect of volume used in sub-Tenon's anesthesia on efficacy and intraocular pressure in vitreoretinal surgery. *Ophthalmologica*. 2008;222:414-421.
30. Shilo-Benjamini Y, Pascoe PJ, Maggs DJ, et al. Comparison of peribulbar and retrobulbar regional anesthesia with bupivacaine in cats. *Am J Vet Res*. 2014;75:1029-1039.
31. Alwitry A, Koshy Z, Browning AC, Kiel W, Holden R. The effect of sub-Tenon's anaesthesia on intraocular pressure. *Eye (Lond)*. 2001;15:733-735.
32. Blumberg D, Congdon N, Jampel H, Gilber D. The effects of sevoflurane and ketamine on intraocular pressure in children during examination under anesthesia. *Am J Ophthalmol*. 2007;143:494-499.
33. Sator-Katzenschlager S, Deusch E, Dolezal S, et al. Sevoflurane and propofol decrease intraocular pressure equally during non-ophthalmic surgery and recovery. *Br J Anaesth*. 2002;89:764-766.
34. Hofmeister EH, Williams CO, Braun C, Moore PA. Propofol versus thiopental: effects on peri-induction intraocular pressures in normal dogs. *Vet Anaesth Analg*. 2008;35:275-281.
35. Hofmeister EH, Weinstein WL, Burger D, Brainard BM, Accola PJ, Moore PA. Effects of graded doses of propofol for anesthesia induction on cardiovascular parameters and intraocular pressures in normal dogs. *Vet Anaesth Analg*. 2009;36:442-448.
36. Wilkie D, Latimer C. Effects of topical administration of timolol maleate on intraocular pressure and pupil size in dogs. *Am J Vet Res*. 1991;52:432-435.
37. Schutz JS, Mavrakanas NA. What degree of anaesthesia is necessary for intraocular surgery? It depends on whether surgery is "open" or "closed". *Br J Ophthalmol*. 2010;94:1400-1413.
38. Cullen L. *Muscle Relaxants and Neuromuscular Block*, 3rd edn. Baltimore, MD: Williams and Wilkins; 1996.
39. Redondo JI, Rubio M, Soler G, Serra I, Soler C, Gómez-Villamandos RJ. Normal values and incidence of cardiorespiratory complications in dogs during general anaesthesia. A review of 1281 cases. *J Vet Med A Physiol Pathol Clin Med*. 2007;54:470-477.
40. Barletta M, Almondia D, Williams J, Crochik S, Hofmeister E. Radiographic evaluation of positional atelectasis in sedated dogs breathing room air versus 100% oxygen. *Can Vet J*. 2014;55:985.
41. Schliewert E-C, Lascola KM, O'Brien RT, et al. Comparison of radiographic and computed tomographic images of the lungs in healthy neonatal foals. *Am J Vet Res*. 2015;76:42-52.
42. Gasthuys F, de Moor A, Parmentier D. Haemodynamic effects of change in position and respiration mode during a standard halothane anaesthesia in ponies. *J Vet Med Ser A*. 1991;38:203-211.
43. Kumar CM, Eid H, Dodds C. Sub-Tenon's anaesthesia: complications and their prevention. *Eye (Lond)*. 2011;25:694-703.
44. Accola PJ, Bentley E, Smith LJ, Forrest LJ, Baumel CA, Murphy CJ. Development of a retrobulbar injection technique for ocular surgery and analgesia in dogs. *J Am Vet Med Assoc*. 2006;229:220-225.

How to cite this article: Bayley KD, Read RA. Sub-Tenon's anesthesia for canine cataract surgery. *Vet Ophthalmol*. 2018;21:601-611. https://doi.org/10.1111/vop.12554