RESEARCH PAPER

A computed tomography–based method for the assessment of canine retrobulbar cone volume for ophthalmic anaesthesia

Adelaide Greco[a,b], Dario Costanza[a], Andrea Senatore[c], Dario Bruzzese[d], Fabiana Micieli[b], Ludovica Chiavaccini[e], Mauro Di Giancamillo[f], Giovanni Della Valle[b], Giancarlo Vesce[b], Arturo Brunetti[g,1] & Leonardo Meomartino[a,b,1]

[a]Centro Interdipartimentale di Radiologia Veterinaria, Università di Napoli 'Federico II', Naples, Italy
[b]Dipartimento di Medicina Veterinaria e Produzioni animali, Università di Napoli 'Federico II', Naples, Italy
[c]Centro Intedipartimentale di Ricerca sui Biomateriali, Università degli Studi di Napoli 'Federico II', Naples, Italy
[d]Dipartimento di Sanità Pubblica, Università di Napoli 'Federico II', Naples, Italy
[e]Department of Molecular and Biomedical Sciences, College of Veterinary Medicine, North Carolina State University, Raleigh, NC, USA
[f]Dipartimento di Medicina Veterinaria, Università degli Studi di Milano, Milan, Italy
[g]Dipartimento di Scienze Biomediche Avanzate, Università di Napoli 'Federico II', Naples, Italy

Correspondence: Adelaide Greco, Centro Interdipartimentale di Radiologia Veterinaria, Università di Napoli 'Federico II', via F. Delpino 1, 80137, Naples, Italy. E-mail: adegreco@unina.it

[1] Both authors contributed equally to this work.

Abstract

Objective To develop a comprehensive formula for calculating the volume of local anaesthetic solution used for retrobulbar anaesthesia in dogs with different skull morphologies.

Study design Retrospective cohort imaging study.

Animals Skull computed tomography (CT) images of 188 dogs of different breeds collected between January 2009 and December 2017.

Methods Anatomical integrity of the orbit and adjacent structures, presenting complaint, clinical signs and CT findings were verified to exclude ocular abnormalities. The volume of the retrobulbar cone of 376 eyes was calculated using CT scans of the dogs' skulls. Additional data recorded included morphology of the skull, body weight, sex and size of the dogs, all of which were matched for possible association to the retrobulbar cone volume through univariable and multivariable linear regression models. Results of linear regression models were expressed as estimated beta coefficients with the corresponding 95% confidence intervals (95% CIs).

Results Using univariate analysis, the retrobulbar cone volume was positively associated with weight and male sex. In addition, brachycephalic and dolichocephalic dogs showed a larger retrobulbar cone volume than mesocephalic dogs, while sex was no longer significantly associated with the retrobulbar cone volume. In multivariate analysis, when considering all variables in the model, weight emerged as the strongest predictor (beta coefficient: 0.062 mL kg^{-1}, 95% CI: 0.056–0.067 mL kg^{-1}, $p <$ 0.001).

Conclusions and clinical relevance In the veterinary literature, there is no agreement on the precise volume of local anaesthetic solution that should be used to achieve intraconal retrobulbar anaesthesia in dogs. Here we suggest a formula to calculate the retrobulbar cone volume and, accordingly, the injection volume of local anaesthetic solution for effective retrobulbar anaesthesia.

Keywords CT, dog, eye, local anaesthetics, ophthalmic surgery.

Introduction

Among multimodal analgesia techniques, the analgesic efficacy of regional anaesthesia is unrivalled (Mathews et al. 2014; Shilo-Benjamini et al. 2019). Locoregional anaesthesia of the eye anaesthetizes the sensory, motor and autonomic innervation of the globe and its adnexa, sparing general anaesthesia requirement, decreasing the need for systemic analgesia and avoiding the use of neuromuscular blocking agents (Accola et al. 2006; Ahn et al. 2013; Palte 2015).

One of the most well-documented regional anaesthesia techniques for ophthalmic surgery is retrobulbar anaesthesia.

Please cite this article as: Greco A, Costanza D, Senatore A et al. A computed tomography–based method for the assessment of canine retrobulbar cone volume for ophthalmic anaesthesia, Veterinary Anaesthesia and Analgesia, https://doi.org/10.1016/j.vaa.2021.03.015

It consists of the injection of local anaesthetic caudal to the globe in close proximity to the optic foramen and orbital fissure. The optic (II), oculomotor (III), trochlear (IV), abducens (VI), and ophthalmic and maxillary branches of the trigeminal (V) cranial nerves emerge from this fissure. These nerves are in close proximity to the rostral alar foramen carrying the zygomatic nerve and to the ethmoidal foramen allowing passage of the ethmoidal nerve. Retrobulbar anaesthesia allows eye akinesia, exerts effective sparing effects on perioperative anaesthetic and analgesic treatments (Myrna et al. 2010; Ploog et al. 2014; Zibura et al. 2020), and inhibits the oculocardiac reflex (Oel et al. 2014; Vézina-Audette et al. 2019).

Despite the widespread use of retrobulbar anaesthesia, there is currently no agreement on the volume of anaesthetic required to obtain good clinical efficacy. Nor is there agreement on a formula to easily calculate that volume for daily use. Shilo-Benjamini (2019) reviewed different retrobulbar anaesthetic techniques in dogs, remarking that most of the authors reported a different volume of local anaesthetic solution for injection. This was mostly calculated empirically and based solely on the dog's body weight. However, studies compared by Shilo-Benjamini (2019) lacked homogeneous morphometry of the subjects.

Dogs are the most morphologically variable land mammals on earth (Shearin & Ostrander 2010). Within the considerable variation in their size and morphology, the cranial index has been used to categorize approximately 400 dog breeds into three broad classes: dolichocephalic, mesocephalic and brachycephalic (Schoenebeck & Ostrander 2013). Within these categories, there exists a wide variation in the ocular anatomy, which means that the practitioners must consider several variables when they perform retrobulbar anaesthesia. One of these variables is the volume of local anaesthetic solution for injection. Underestimating this volume can result in an ineffective block. An overestimation of this volume can cause severe undesirable effects including toxicity, proptosis and increased intraocular pressure (Giuliano 2008).

Since mixed breed dogs represent a large part of the canine population, cranial index categorization has been hindered by an absence of clearly defined craniofacial margins (Drake & Klingenberg 2010; Schoenebeck & Ostrander 2013). As a consequence, dogs with similar body weight but with a differing skull morphology might display different retrobulbar cone volumes and shapes. Therefore, the volume of anaesthetic solution required for retrobulbar anaesthesia should be calculated accordingly. Klaumann et al. (2018) were the first authors to consider a dog's skull morphology, as distinct from their body weight, to calculate the required injection volume. However, a limited number of subjects were enrolled in that study. To the authors' knowledge, there are currently no studies assessing the differences in the retrobulbar cone volume between dolichocephalic, mesocephalic, and brachycephalic dogs via computed tomography (CT) examination.

The objective of our study was to develop a comprehensive formula for calculating the volume of the retrobulbar cone in dogs with different skull morphologies. For this purpose, our retrospective study evaluated the retrobulbar cone volume variations between dolichocephalic, mesocephalic and brachycephalic dogs in a large population. Using morphometric data of canine skulls acquired by CT, we describe a comprehensive formula for estimating the actual volume to be injected (VTBI) for retrobulbar anaesthesia in dogs. We hypothesized that not only bodyweight but also skull morphology would affect the retrobulbar cone volume in dogs of different breeds.

Materials and methods

The protocol received full approval by the ethical committee for animal use at the Animal Welfare Committee of the University of Naples Federico II (PG/2020/0043383). All canine head CT studies performed during general anaesthesia for different clinical reasons, between January 2009 and December 2017 at the Interdepartmental Center of Veterinary Radiology, University of Naples Federico II, were retrospectively evaluated. Due to the retrospective nature of the study, anaesthetic protocols were not standardized. Inclusion criteria were complete visualization of the globes. Exclusion criteria included the presence of ocular, retrobulbar and/or orbital diseases. All CT studies were performed using a slice thickness of 1.5−2.5 mm and were then post-processed using 'standard' and 'bone' convolution filters. Images were evaluated through a soft tissue window (window width 350 HU and window level, 40 HU) using a DICOM viewer software (Horos Version 3.0.1; The Horos Project, MD USA).

For measurement of the retrobulbar cone volume, all CT examinations were processed through a multiplanar reformation technique along the axial, sagittal and dorsal planes. The lateral and medial ocular rectus muscles and the orbital canal were chosen as the anatomical landmarks for retrobulbar cone volume measurements because they were easily identified.

The axial plane was positioned at the level of the eye lenses and oriented until a symmetrical image of both eyes was obtained. The sagittal plane was placed in the centre of the globe and then the dorsal plane was tilted until the optic canal and retrobulbar cone were entirely visible (Fig. 1). After obtaining the images, the cone base diameter and its height were traced. The diameter of the retrobulbar cone base was measured between the insertion points of the lateral and medial rectus muscles on the globe. The height of the cone was then measured as the line running from the centre of the traced cone base diameter to the optic foramen (Fig. 2). For each eye, the retrobulbar cone volume (expressed in mL) was calculated according to the formula:

Please cite this article as: Greco A, Costanza D, Senatore A et al. A computed tomography−based method for the assessment of canine retrobulbar cone volume for ophthalmic anaesthesia, Veterinary Anaesthesia and Analgesia, https://doi.org/10.1016/j.vaa.2021.03.015

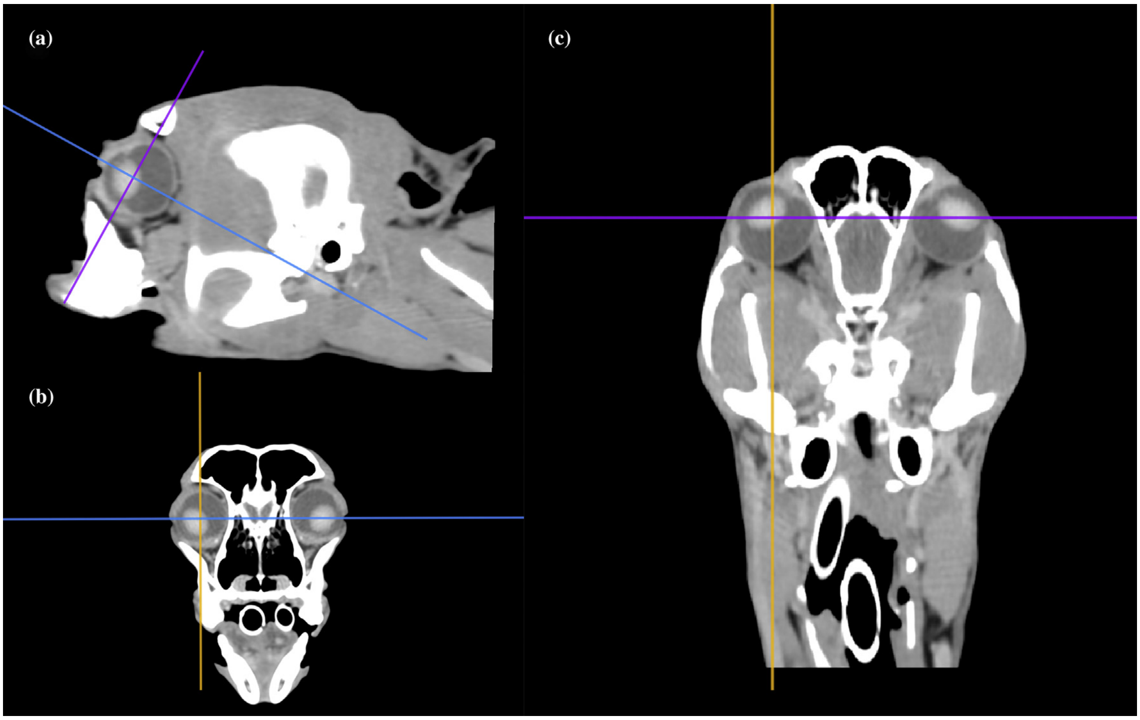

Figure 1 Multiplanar reconstruction of a dolichocephalic dog skull; (a) sagittal, (b) axial and (c) dorsal planes are displayed. The yellow line represents the sagittal plane, the violet line the axial plane and the blue line the dorsal plane. Images show the centring of the sagittal and the axial planes on the right globe, and the tilting of the dorsal plane to fully expose the retrobulbar cone and optic foramen. Note: please view the online version for full colour figure.

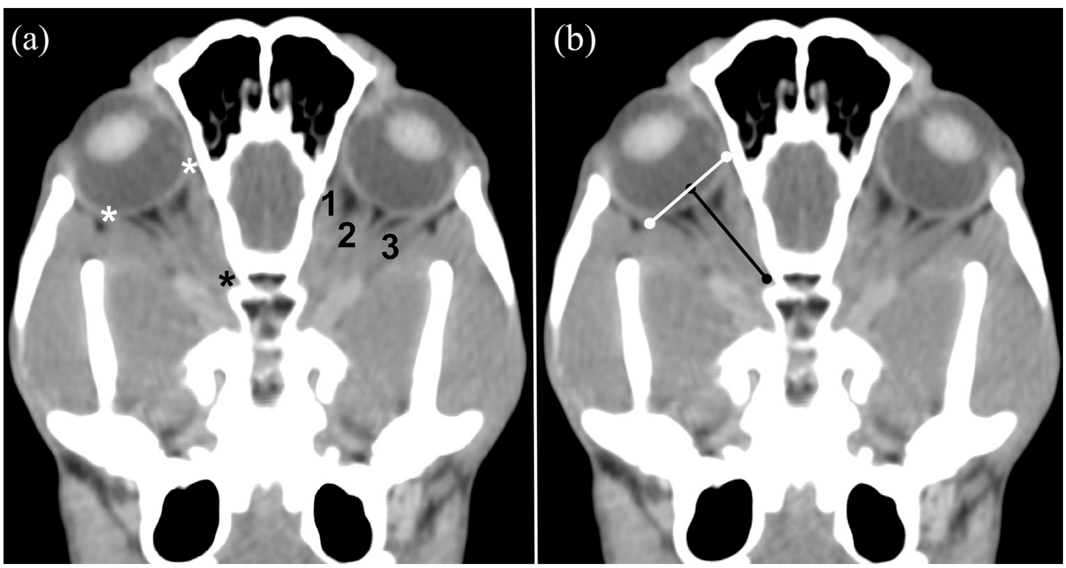

Figure 2 A representative example of the retrobulbar cone volume measurements in a dolichocephalic dog skull, made in the dorsal plane. (a) The anatomical landmarks used to trace the cone base diameter and the cone height are displayed: insertion points of medial and lateral rectus muscles (white asterisks); optic canal (black asterisk); 1 = medial rectus muscle; 2 = optic nerve; 3 = lateral rectus muscle. (b) The measurements of retrobulbar cone base diameter (white line) and retrobulbar cone height (black line).

Please cite this article as: Greco A, Costanza D, Senatore A et al. A computed tomography–based method for the assessment of canine retrobulbar cone volume for ophthalmic anaesthesia, Veterinary Anaesthesia and Analgesia, https://doi.org/10.1016/j.vaa.2021.03.015

$(\pi \cdot r\hat{2} \cdot h) / 3$

where π was pi, r was the cone base radius expressed in centimetres (one half of the cone base diameter) and h was the cone height expressed in centimetres. All CT measurements were made by a radiologist with 10 years experience.

In addition, the sex, body weight (expressed in kg), skull morphology and the size of each animal were recorded as possible variables affecting the retrobulbar cone volume. Canine skulls were classified based on the cranial index (skull width × 100/skull length) as dolichocephalic (cranial index approximately 39), mesocephalic (cranial index approximately 52) and brachycephalic dogs (cranial index approximately 81 or greater) (Evans & De Lahunta 2013). Based on body weight, the size of the dogs was classified as small (≤ 8 kg), medium (> 8 but ≤ 22 kg) and large (> 22 kg).

Statistical analysis

We used the statistical platform R (Version 3.5.1, R Foundation for Statistical Computing, Austria, https://www.R-project.org/) for data manipulation, descriptive analysis and linear regression. Standard descriptive statistics were used to describe the characteristics of the sample, and data are reported as mean ± standard deviation (SD) or frequencies (percentages). Potential violations from normality were visually checked using boxplots. Univariate comparisons between groups were based on one-way analysis of variance (ANOVA) test, followed by Tukey's honest significant difference *post-hoc* tests. Pearson correlation coefficients were used to assess the collinearity between continuous variables. Multivariate linear regression was used to derive the best equation for predicting retrobulbar cone volume according to the selected predictors. Variable selection was guided by recognition of the importance of the variables in the literature and no automatic procedure was undertaken. All clinically relevant interactions terms were tested. The prediction sum of squares (Allen 1974) was used to select the best model. Results of the final model were expressed as estimated beta coefficients with the corresponding 95% confidence intervals (95% CIs). All analyses were conducted at an alpha level of 0.05.

Results

The initial sample included 213 skull CT scans. A total of 25 dogs were excluded from the study because they had presented with lesions of the eyes, of the ocular annexes and/or of the retrobulbar space, orbital or periorbital bones. Therefore, the final number of dogs enrolled in the study was 188 and 376 eyes. There were 83 (44.1%) female (32 ovariohysterectomized) and 105 (55.9%) male (11 castrated) dogs. According to the cranial index categorization of the skulls, 22 (11.7%) were brachycephalic, 153 (81.4%) were mesocephalic and 13 (6.9%) were dolichocephalic. Representative 3D volume rendering CT images are reported in Fig. 3. The mean ± SD body weight was 18.8 ± 13.4 kg, and the mean ± SD age was 6.8 ± 4.0 years.

According to the ANOVA test, the cone volume was significantly larger in the large dogs (2.8 ± 0.77 mL) than in medium (1.88 ± 0.63 mL, $p < 0.001$) and small dogs (0.94 ± 0.31 mL, $p < 0.001$) (Fig. 4a). Sex also affected the retrobulbar cone volume, being larger in male dogs than in female dogs with the same skull morphology (2.19 ± 1.09 mL *versus* 1.6 ± 0.84 mL; $p < 0.001$), while no significant differences were found between castrated male and ovariohysterectomized female dogs.

Significant skull morphology—linked retrobulbar cone volume differences were found (Fig. 4b). Mesocephalic dogs displayed a smaller volume (1.82 ± 0.91 mL) than brachycephalic (2.45 ± 1.36 mL, $p = 0.012$) and dolichocephalic dogs (2.46 ± 0.69 mL, $p = 0.037$).

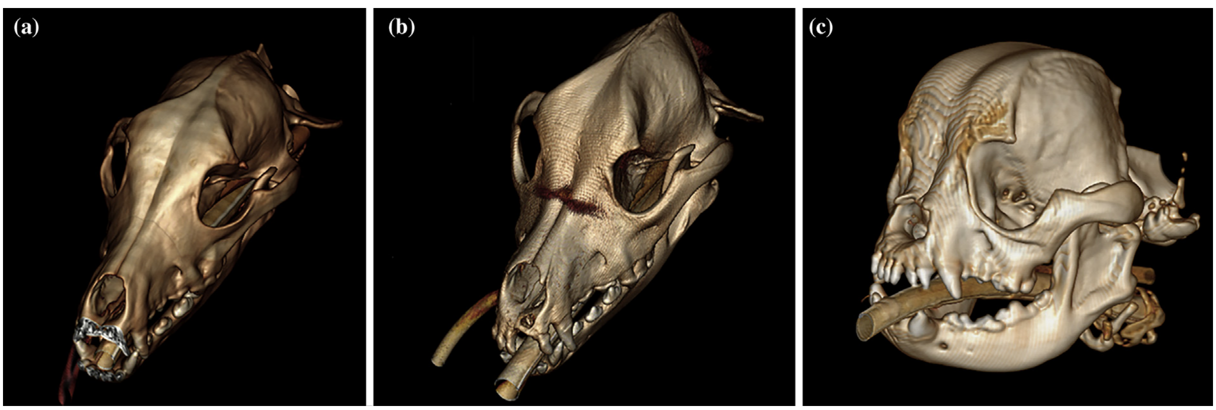

Figure 3 Computed tomography 3D volume rendering images of the morphology groups of three dogs' skulls: (a) dolichocephalic, (b) mesocephalic and (c) brachycephalic.

Please cite this article as: Greco A, Costanza D, Senatore A et al. A computed tomography—based method for the assessment of canine retrobulbar cone volume for ophthalmic anaesthesia, Veterinary Anaesthesia and Analgesia, https://doi.org/10.1016/j.vaa.2021.03.015

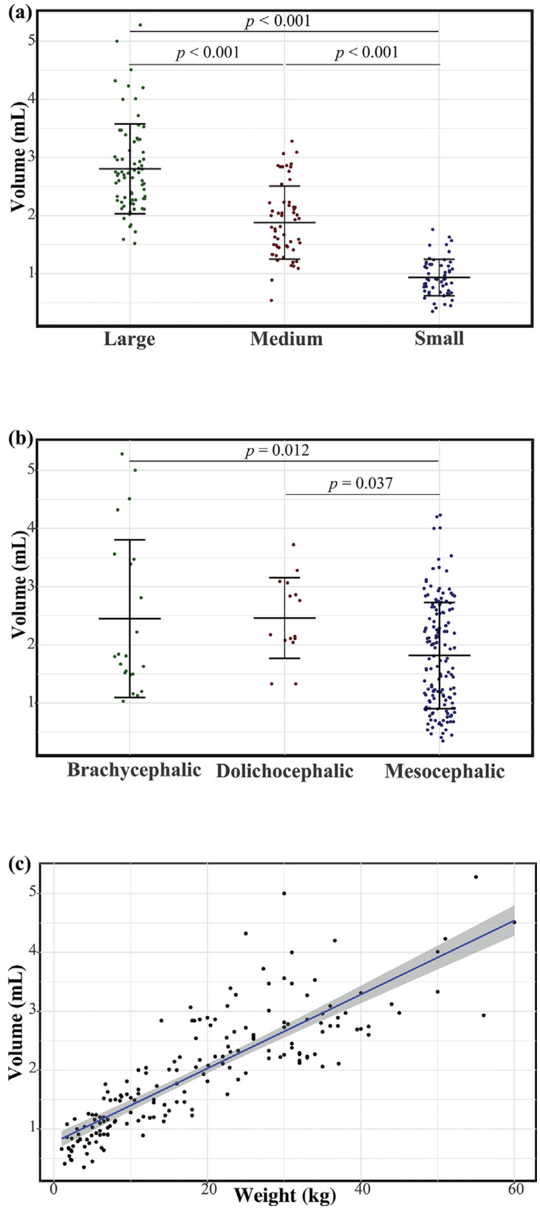

Figure 4 Retrobulbar cone volume grouped by size and by skull morphology. (a) The distribution of retrobulbar cone volume grouped by skull size (large, medium and small). The horizontal lines refers, for each group, to the mean ± standard deviation; *p* values were obtained using *post-hoc* Tukey's honest significant difference (HSD) test. (b) The distribution of retrobulbar cone volume grouped by skull morphology (brachycephalic, dolichocephalic and mesocephalic). The horizontal lines refers, for each group, to the mean ± standard deviation; *p* values were obtained using *post-hoc* Tukey's HSD test. (c) The scatter plot shows the correlation between the dog's body weight (kg) and retrobulbar cone volume (mL). The straight blue line represents the regression line obtained using the least squares method, and the grey area shows the confidence band, setting confidence level at 95%. Note: please view the online version for full colour figure.

Finally, a positive correlation between retrobulbar cone volume and animal body weight was also found (Pearson $r = 0.84$; $p < 0.001$; Fig. 4c).

In the multivariate analysis, because there was a strong correlation between size and body weight, only the latter was used. When all the variables were considered, weight persisted as the strongest retrobulbar cone volume predictor, with a significant difference between skull morphologies. When accounting for all the variables in the model, sex was no longer significantly associated with retrobulbar cone volume, thus it was excluded.

To assess the relative value of each predictor, we built several nested models by starting with the simplest one, in which only body weight was used. The predictive accuracy of the different models is displayed in Fig. 5. By adding the skull morphology to the weight, a relevant reduction in the prediction error was gained while the inclusion of the first-order interaction between morphology and weight, although significant, did not account for a further decrease in the prediction error.

Therefore, body weight and skull morphology were the only variables retained in the final model, accounting for 75% of the whole variability of the cone volume ($R^2 = 0.75$). The model was overall significant ($p < 0.001$). When accounting for all the variables in the model, for each kg increase in body weight, the retrobulbar cone volume increased by 0.06 mL (95% CI: 0.06−0.07 mL kg^{-1}; $p < 0.001$). In addition, in brachycephalic and dolichocephalic dogs, the retrobulbar cone volume was larger than in mesocephalic dogs (difference: + 0.57 mL, 95% CI 0.34-0.80 mL, $p < 0.001$ and + 0.37 mL, 95% CI 0.11-0.64 mL, $p < 0.001$, respectively)

Based on our model, the retrobulbar cone volume can be estimated in dogs based on their morphology and body weight using the following formulae, where coefficients are reported up to the fifth decimal digit to improve accuracy:

Retrobulbar cone volume (mL)

1) 0.69238 + 0.06177 × BW in kg for mesocephalic skull morphology dogs.
2) 0.69238 + 0.06177 × BW in kg + 0.57034 for brachycephalic skull morphology dogs.
3) 0.69238 + 0.06177 × BW in kg + 0.37414 for dolichocephalic skull morphology dogs.

Discussion

In this study we were able to develop a formula to predict the volume of the intraconal space, as defined by the periorbita, using the dog's body weight and conformation.

We found a positive association between the retrobulbar cone volume and dog's body weight, size, skull morphology and sex. In particular, using univariate analysis, the dog's size

Please cite this article as: Greco A, Costanza D, Senatore A et al. A computed tomography−based method for the assessment of canine retrobulbar cone volume for ophthalmic anaesthesia, Veterinary Anaesthesia and Analgesia, https://doi.org/10.1016/j.vaa.2021.03.015

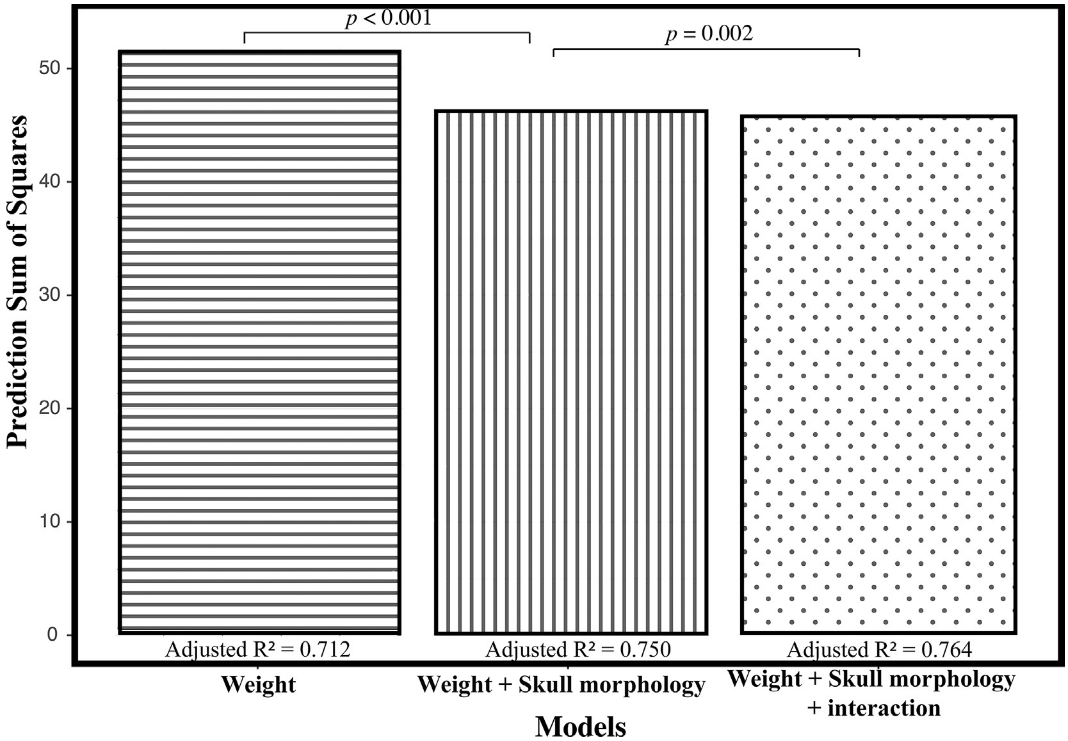

Figure 5 Graphical representation of the prediction sum of squares associated with estimated nested model; *p* values refer to the analysis of variance comparison between models.

showed a positive linear association with cone volume, where larger sized dogs displayed significantly larger retrobulbar cone volumes than medium and small sized dogs. Sex also showed a significant association with retrobulbar cone volume, being larger in male dogs than in female dogs of the same skull morphology group. Such sexual dimorphism was not observed between the castrated or ovariohysterectomized dogs of either sex. As expected, skull morphology showed a significant association with retrobulbar cone volume, being larger in dolichocephalic and brachycephalic dogs than in mesocephalic dogs.

Based on our findings, we were able to easily calculate the retrobulbar cone volume. For each of the three skull morphologies, an estimated coefficient was proposed to multiply by the dog's body weight (in kg). The numerical value, expressed in mL eye^{-1}, resulting from this mathematical calculation, theoretically corresponds to the VTBI required for intraconal retrobulbar anaesthesia. For the intraconal retrobulbar anaesthesia technique, a smaller volume of local anaesthetic solution is used to achieve anaesthesia and akinesia of the eye, compared with that needed for extraconal or periorbital infiltration techniques. Previously, different retrobulbar anaesthesia techniques and different injection volumes have been reported in dogs (Shilo-Benjamini 2019). Accola et al. (2006) injected 2 mL (0.2 mL kg^{-1}) of a 2% lidocaine solution through an inferior-temporal-palpebral approach in 10 kg Beagle dogs. They obtained adequate analgesia and a suitable distribution of the injectate within the retrobulbar cone. More recently, Chiavaccini et al. (2017) reported a novel supratemporal approach for intraconal retrobulbar anaesthesia in canine cadavers. They suggested that an injection volume of only 0.1 mL kg^{-1} of local anaesthetic solution *versus* 2 mL was needed for the inferior-temporal-palpebral approach. In their study, a 1:1 mixture of 0.5% bupivacaine with a contrast agent was deemed sufficient for intraconal retrobulbar anaesthesia in dogs, essentially filling 60% of the extraocular muscle cone. Klaumann et al. (2018) used dogs' morphometric features, in addition to body weight, to estimate the ideal injection volume for retrobulbar anaesthesia. Given that the dog's splanchnocranium is less variable than the neurocranium, those authors correlated cranial length with periorbital length and suggested an injection volume of 0.1 mL of anaesthetic solution for each cm of cranial length. Based on the author's experience, an ultrasound-guided supratemporal approach for intraconal injection facilitates retrobulbar block in dogs, using volumes as small as 0.1 mL kg^{-1}. The advantages derived from injecting a smaller volume within the extraocular muscle cone include a reduced risk of local anaesthetic toxicity avoiding proptosis and also an associated increase in the intraocular pressure. Under these circumstances, the availability of a mathematical

Please cite this article as: Greco A, Costanza D, Senatore A et al. A computed tomography–based method for the assessment of canine retrobulbar cone volume for ophthalmic anaesthesia, Veterinary Anaesthesia and Analgesia, https://doi.org/10.1016/j.vaa.2021.03.015

formula to calculate the VTBI for intraconal retrobulbar anaesthesia could be a valuable aid for ophthalmic surgery (Lin et al. 2007). The intraconal volume of 0.06 mL kg^{-1} resulting from our calculation allows plenty of freedom for possible drug dilution and the use of drug combinations. Our data increase the practitioners' awareness of the high variability in the retrobulbar cone volume between dogs of differing breeds and of the need to adjust this volume according to a dog's size and skull morphology.

The main limitation of the present study was the relatively small number of dolichocephalic dogs in the analysed sample, probably owing to their low presence in the south of Italy. Moreover, the derived model should be validated using an independent external cohort in order to correct for over-optimism of the estimated prediction sum of squares. Further multicentre imaging studies will be needed to expand our statistical findings; additionally, several clinical intraconal retrobulbar anaesthesia studies will be required to test the effectiveness of the VTBI calculated using our formula.

Conclusions

Based on our data, body weight and skull morphology are the main variables required to calculate the retrobulbar cone volume in dogs. Thereby, the volume of anaesthetic solution to be injected for an effective intraconal retrobulbar anaesthesia can be determined. A mathematical formula to calculate retrobulbar cone volume for each of the three canine skull morphologies is proposed. Further studies are needed to confirm the clinical effectiveness of the VTBI calculated when the proposed formula is used.

Acknowledgements

This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

Authors' contributions

AG: manuscript preparation and design. DC: data management. AS: data interpretation. DB: statistical analysis. FM: data revision. LC: data revision. MDG: data collection. GDV: data review. GV: manuscript preparation. AB: manuscript revision. LM: manuscript design and manuscript preparation.

Conflict of interest statement

LC is an Associate Editor for *Veterinary Anaesthesia and Analgesia*. The other authors declare no conflict of interest.

Ethical statement

This was a retrospective cohort study conducted at the Interdepartmental Center of Veterinary Radiology, University of Naples Federico II. The protocol received the ethical clearance by the Institutional Ethics Committee for Animal Use (PG/2020/0043383), and written consent from the owners was obtained for each animal before its inclusion in the study.

References

Accola PJ, Bentley E, Smith LJ et al. (2006) Development of a retrobulbar injection technique for ocular surgery and analgesia in dogs. J Am Vet Med Assoc 229, 220–225.

Ahn J, Jeong M, Park Y et al. (2013) Comparison of systemic atracurium, retrobulbar lidocaine, and sub-Tenon's lidocaine injections in akinesia and mydriasis in dogs. Vet Opht 16, 440–445.

Allen DM (1974) The relationship between variable selection and data agumentation and a method for prediction. Technometrics 16, 125–127.

Chiavaccini L, Micieli F, Meomartino L et al. (2017) A novel supratemporal approach to retrobulbar anaesthesia in dogs: Preliminary study in cadavers. Vet J 223, 68–70.

Drake AG, Klingenberg CP (2010) Large scale diversification of skull shape in domestic dogs: disparity and modularity. Am Nat 175, 289–301.

Evans HE, De Lahunta A (2013) The skeleton. In: Miller's Anatomy of the Dog (4 edn). Evans HE, De Lahunta A (eds). Elsevier, USA. pp. 80–157.

Giuliano EA (2008) Regional anesthesia as an adjunct for eyelid surgery in dogs. Top Companion Anim Med 23, 51–56.

Klaumann PR, Moreno JCD, Montiani-Ferreira F (2018) A morphometric study of the canine skull and periorbita and its implications for regional ocular anesthesia. Vet Ophthalmol 21, 19–26.

Lin CT, Hu CK, Liu CH, Yeh LS (2007) Surgical outcome and ocular complications of evisceration and intraocular prosthesis implantation in dogs with end stage glaucoma: a review of 20 cases. J Vet Med Sci 69, 847–850.

Mathews K, Kronen PW, Lascelles D et al. (2014) Guidelines for recognition, assessment and treatment of pain: WSAVA Global Pain Council members and co-authors of this document. J Small Anim Pract 55, E10–E68.

Myrna KE, Bentley E, Smith LJ (2010) Effectiveness of injection of local anesthetic into the retrobulbar space for postoperative analgesia following eye enucleation in dogs. J Am Vet Med Assoc 237, 174–177.

Oel C, Gerhards H, Gehlen H (2014) Effect of retrobulbar nerve block on heart rate variability during enucleation in horses under general anesthesia. Vet Ophthalm 17, 170–174.

Palte HD (2015) Ophthalmic regional blocks: management, challenges, and solutions. Local Reg Anesth 8, 57–70.

Ploog CL, Swinger RL, Spade J et al. (2014) Use of lidocaine-bupivacaine–infused absorbable gelatin hemostatic sponges versus lidocaine-bupivacaine retrobulbar injections for postoperative analgesia following eye enucleation in dogs. J Am Vet Med Assoc 244, 57–62.

Shearin AL, Ostrander EA (2010) Canine morphology: hunting for genes and tracking mutations. PLoS Biol 8, e1000310.

Schoenebeck JJ, Ostrander EA (2013) The genetics of canine skull shape variation. Genetics 193, 317–325.

Please cite this article as: Greco A, Costanza D, Senatore A et al. A computed tomography–based method for the assessment of canine retrobulbar cone volume for ophthalmic anaesthesia, Veterinary Anaesthesia and Analgesia, https://doi.org/10.1016/j.vaa.2021.03.015

Shilo-Benjamini Y (2019) A review of ophthalmic local and regional anesthesia in dogs and cats. Vet Anaesth Analg 46, 14–27.

Shilo-Benjamini Y, Pascoe PJ, Maggs DJ et al. (2019) Retrobulbar vs peribulbar regional anesthesia techniques using bupivacaine in dogs. Vet Ophthalmol 22, 183–191.

Vézina-Audette R, Steagall PVM, Gianotti G (2019) Prevalence of and covariates associated with the oculocardiac reflex occurring in dogs during enucleation. J Am Vet Med Assoc 255, 454–458.

Zibura AE, Posner LP, Ru H, Westermeyer HD (2020) A preoperative bupivacaine retrobulbar block offers superior antinociception compared with an intraoperative splash block in dogs undergoing enucleation. Vet Ophthalmol 23, 225–233.

Received 22 July 2020; accepted 12 March 2021.

Available online xxx

Please cite this article as: Greco A, Costanza D, Senatore A et al. A computed tomography–based method for the assessment of canine retrobulbar cone volume for ophthalmic anaesthesia, Veterinary Anaesthesia and Analgesia, https://doi.org/10.1016/j.vaa.2021.03.015