Gonioscopic findings in 69 Leonberger dogs in Switzerland from 2019 to 2023

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Gonioskopische Befunde bei 69 Leonberger-Hunden in der Schweiz von 2019 bis 2023

Die Studie zeigt einen Überblick über die gonioskopischen Befunde bei Leonberger-Hunden in der Schweiz und beschreibt Glaukomfälle in dieser Population.

Reinrassige Leonberger Hunde nahmen an dieser prospektiven, multizentrischen Querschnittsstudie teil. Bei allen Hunden wurde eine vollständige Untersuchung auf hereditäre Augenkrankheiten (HED) einschliesslich Gonioskopie durchgeführt. Die Morphologie des *Ligamentum pectinatum* und die Breite des iridokornealen Winkels (ICA-Weite) wurden notiert und in die Grade 0–3 bzw. 0–2 eingeteilt.

Neunundsechzig Hunde (137 Augen) mit einem medianen Alter von 2 Jahren und 8 Monaten wurden in die Studie aufgenommen.

Abnormalität des *Ligamentum pectinatum* (PLA) und die Breite des iridokornealen Winkels (ICA-width) wurden zu einem Endwert der Abnormalität des iridokornealen Winkels (ICA-abnormality) zusammengefasst. Zwanzig Prozent (14/69) aller Augen wiesen eine hochgradige ICA-Abnormalität (ICA-Abnormalität-Grad 3), 36 % (25/69) eine mittelgradige ICA-Abnormalität (ICA-Abnormalität-Grad 2) und 31 % (21/69) eine leichtgradige Abnormalität (ICA-Abnormalität-Grad 1) auf. Mit anderen Worten: 87 % der Leonberger in dieser Studie wiesen irgendeine Form von Abnormalität des iridokornealen Winkels auf. Vier Prozent (6/137) aller Augen, d. h. 6 % der Hunde (4/69), entwickelten im Alter von 5,5–6 Jahren ein Glaukom. Alle diese Augen wiesen hochgradige Veränderungen des ICA auf (ICA-Abnormalität Grad 3).

Eine signifikante Anzahl von Leonberger-Hunden in der Schweiz ist von ICA-Abnormalität betroffen und hat ein erhöhtes Risiko, ein primäres Winkelverschlussglaukom zu entwickeln. Leonberger-Züchter sollten ermutigt werden, bei allen potenziellen Zuchttieren eine Gonioskopie gemäss den Richtlinien des European College of Veterinary Opht-

Abstract

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The present study provides an overview of gonioscopic findings in Leonberger dogs in Switzerland and describes glaucoma cases within this sample population.

Purebred Leonberger dogs participated in this prospective, multicenter, cross-sectional study. A full hereditary eye disease (HED) examination including gonioscopy was performed in all dogs according to the European College of Veterinary Ophthalmologists (ECVO) HED scheme. The morphology of the pectinate ligament and the width of the iridocorneal angle (ICA-width) were noted and categorized into grades 0–3 and 0–2, respectively.

Sixty-nine dogs (137 eyes) with a median age of 2 years and 8 months were included in the study. Pectinate ligament abnormality (PLA) and iridocorneal angle width (ICA-width) were combined to final scores of iridocorneal angle abnormality (ICA-abnormality). Twenty percent (14/69) of all eyes displayed severely affected iridocorneal angles (ICA-abnormality grade 3), 36 % (25/69) moderately affected (ICA-abnormality grade 2) and 31 % (21/69) mildly affected (ICA-abnormality grade 1). Overall, 87 % of the Leonbergers in this study showed some form of iridocorneal angle abnormality. Four percent (6/137) of all eyes, corresponding to 6 % (4/69) of dogs, developed glaucoma between the ages of 5,5–6 years. All of these eyes displayed severely affected ICAs (ICA-abnormality grade 3).

A significant number of Leonberger dogs in Switzerland demonstrate iridocorneal angle abnormalities and are at an increased risk for developing primary angle closure glaucoma. Leonberger breeders should be encouraged to have gonioscopy performed on all potential breeding animals, as per the ECVO HED guidelines.

Keywords: Canine primary angle-closure glaucoma, Leonberger, iridocorneal angle abnormality, goniodysgenesis

halmologists (ECVO) für hereditäre Augenkrankheiten durchführen zu lassen.

Schlüsselwörter: Primäres Winkelverschlussglaukom beim Hund, Leonberger, *Ligamentum pectinatum*-Abnormalität, Goniodysgenesie, iridokornealer Winkel

Introduction

Glaucoma, including primary- or primary angle-closure glaucoma (PACG) in canines, is a progressive optic neuropathy characterized by degeneration of the optic nerve head (ONH), loss of retinal ganglion cells, and consequent irreversible vision loss.[32]

The underlying pathophysiology of pectinate ligament abnormalities (PLA), especially pectinate ligament dysplasia (PLD) remains an area of ongoing debate in veterinary ophthalmology. Historically, PLD has been described as a congenital failure of embryologic rarefaction, resulting in persistent mesodermal or embryonic tissue spanning the iridocorneal angle.[16] This interpretation aligns with the traditional use of the term goniodysgenesis, referring to incomplete transformation of the primordial angle tissue into discrete, fenestrated pectinate ligaments. However, accumulating evidence indicates that PLD may also exhibit postnatal progression in certain breeds, such as the Basset Hound and Flat-Coated Retriever.[28,31] Because pectinate ligament architecture is considered fully developed by approximately 8 weeks of age,[35] later changes are unlikely to reflect developmental failure alone. Pearl et al.[31] described several postnatal features – including increased trabecular cellularity, progressive envelopment of the collagenous core by thickening Descemet's membrane, and deposition of periodic acid-Schiff (PAS)-positive, basal lamina-like material – that support a model of progressive thickening or remodeling of established pectinate ligament structures.[31] Histopathologic findings in multiple breeds, including the Bouvier des Flandres, further demonstrate associations between PLD, narrowing of the iridocorneal angle, and extracellular matrix accumulation within the trabecular meshwork.[38]

Taken together, these observations suggest that PLA/PLD likely represents a spectrum of developmental and post-developmental processes rather than a single etiologic mechanism. While incomplete embryologic remodeling may contribute to the formation of broad sheets of tissue in some individuals, secondary thickening, extracellular matrix deposition, and chronic low-grade inflammation may also play important roles in the evolution and severity of PLD across breeds. The long-standing debate between these two conceptual frameworks – strictly developmental versus progressive remodeling – may therefore reflect an oversimplification of a multifactorial condition, with the true pathogenesis involving contributions from both mechanisms to varying degrees.

All these mentioned morphological alterations may obstruct aqueous humor outflow, thereby precipitating an elevation in IOP. Sustained elevation of IOP induces progressive damage to the ONH and retinal ganglion cells, ultimately culminating in permanent blindness.

Certain dog breeds are disproportionately more affected by PACG than others. For many of these breeds, a genetic predisposition to developing PACG is either suspected or confirmed.[2,3, 6,10,11,16,17,18,22,24,28,29,30,33] Consequently, the European College of Veterinary Ophthalmologists (ECVO) advises using gonioscopy as a screening method to assess the ICA in all prospective breeding animals of these breeds. Both the ECVO and the American College of Veterinary Ophthalmologists (ACVO) recommend against the breeding of dogs with overt clinical signs of PACG. And yet, despite the high prevalence of PACG in certain dog breeds (0,71–5,25 % depending on the breed),[16] a specific genetic basis for primary glaucoma was identified only for a small number of breeds.[1,2,3,14,20,23,33]

By March 2020, 905 Leonbergers were registered in Switzerland's dog registry (AMICUS ID national dog registration data base – Identitas AG, Bern). From 2019 to 2021 an increasing number of PACG cases was identified in Leonbergers in Switzerland, which prompted the Ophthalmology Section at the Vetsuisse Faculty, University of Zurich, and the Swiss Leonberger Club (SLC – the national Leonberger dog breeding association) to conduct a study identifying the prevalence and severity of ICA-abnormality in Leonbergers in Switzerland. Despite the fact that the SLC has actively promoted pre-breeding ophthalmologic examinations, gonioscopy is not a mandatory pre-breeding test for Leonbergers in Switzerland. Gonioscopy should allow identification of the relative ICA-abnormality burden within a breed and allow breeding clubs to direct their pre-breeding testing and breeding requirements towards a decreased glaucoma risk, thus improving the ocular health of the breed.[36] According to Holz et al.,[19] examiners using the 2022 ECVO Hereditary Eye Disease (HED) gonioscopy grading scheme provided consistent breeding recommendations.

The purpose of this study was therefore to use the 2022 ECVO-HED gonioscopy grading scheme to describe and summarize ICA-abnormality among Leonbergers in Switzerland and to document clinical glaucoma cases encountered in the dogs included in the study.

Material and methods

In this observational cross-sectional study, Leonbergers were presented for mandatory pre-breeding ECVO-HED[11] examinations to different veterinary hospitals and private practices across Switzerland.[11] The eye examinations were conducted by ECVO or ACVO board-certified veterinary ophthalmologists between January 2019 and November 2023. The study was conducted in close collaboration with the SLC.

The gonioscopy examinations were performed and ICA abnormalities graded according to the ECVO gonioscopy scheme 2022.[11] These guidelines are openly accessible online under www.ecvo.eu/hereditary-eye-diseases/ecvo-manual. Included were purebred Leonberger dogs that were older than six months and were living in Switzerland. Owners were made aware of the study by written contact through the SLC, but also through several private clinics and social media. Therefore, we consider our method of sampling as convenience sampling, an epidemiological term referring to the inclusion of cases based on their ready availability to the investigators. Written consent was obtained from all owners prior to the ophthalmic examination.

The following data were collected from all participants: signalment (age, gender) and results from a full ophthalmic examination for hereditary eye diseases, which was performed on both eyes in every individual. Ophthalmic examination included slit lamp biomicroscopy (Kowa SL-17, Kowa Co Ltd, Nagoya, Japan) and indirect ophthalmoscopy following pupillary dilation (Tropicamide 0,5 %, Théa Pharma SA, Schaffhausen, Switzerland) using binocular headsets (Heine Omega 500 binocular ophthalmoscope, Heine Optotechnik, Gilching, Germany) and 28D and 2.2D condensing lenses (Volk Optical Inc., Mentor, USA). In some cases, tonometry (TonoVet tonometer, iCare®, Helsinki, Finland) values were noted (tonometry is optional for ECVO-HED examinations). Prior to pupil dilation and following the application of a local anesthetic (oxybuprocaine – Novesine, Merck-Sharp & Dohme-Chibret, Paris, France or oxybuprocaine Gtt Opht 0,4 %, Théa PHARMA SA, Schaffhausen, Switzerland), gonioscopy was performed by gently applying an 18 or 19 mm Koeppe gonioscopy lens (Ocular Instruments, Redmond, USA) with a cohesive viscoelastic contact gel (an-bfh 1,8 %, an-vision GmbH, Hennigsdorf, Germany or hypromellose Methocel 2 %, OmniVision, Neuhausen, Switzerland) to the cornea and evaluating the ICA with a slit lamp (Kowa SL-17, Kowa Co Ltd, Nagoya, Japan) set on 10x magnification. All dogs were awake and unsedated during the ophthalmic examination. Dogs that would have required sedation for the exam were excluded from the study.

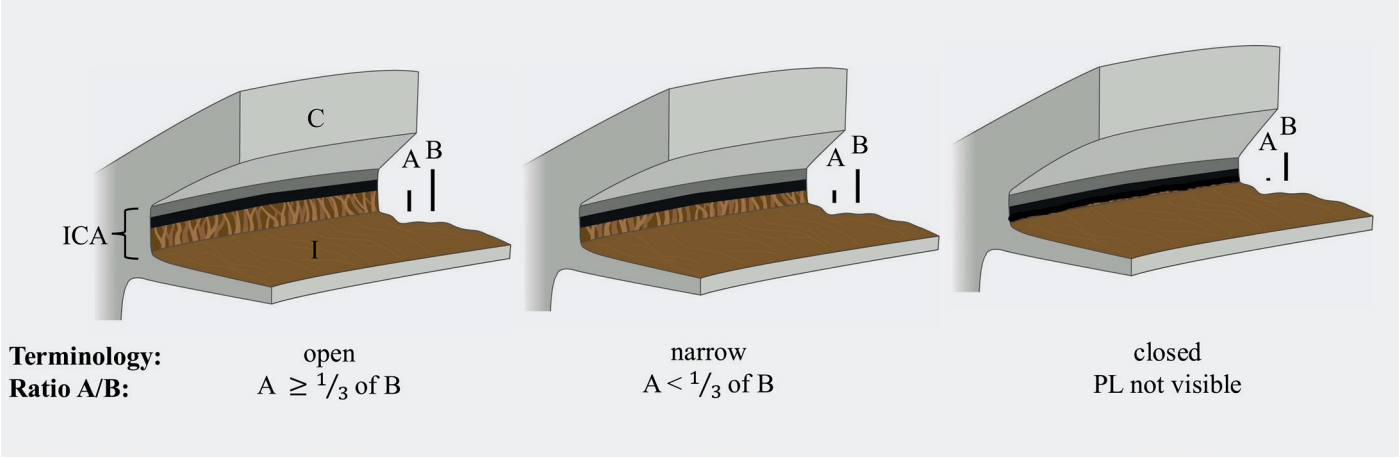
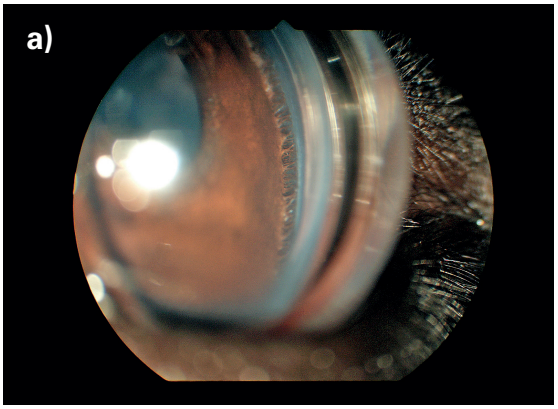


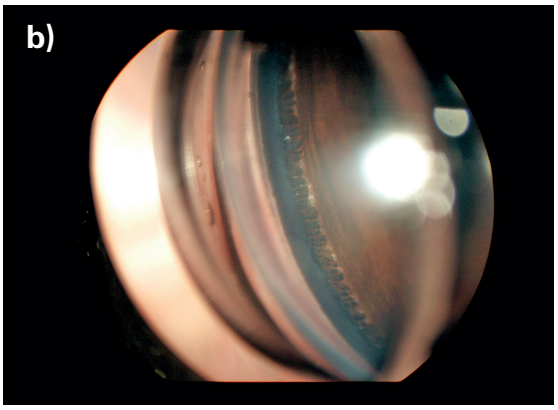
Figure 1: Iridocorneal angle width (ICA-width) grading system (ECVO HED manual – guidelines11 and Ekesten et al 199112).
PL = pectinate ligament, A = length of PL, B = distance from the origin of the PL to the anterior surface of the cornea at the transection area, C = Cornea, ICA = Iridocorneal angle, I = Iris

The 2022 ECVO-HED gonioscopy grading scheme [11] was followed to categorize the ICA. Also, a numeric score for each grading was needed to perform statistical analyses. These numeric scores are provided between brackets. The complete ICA (360°) was examined, noting the grading for PLA and ICA-width for each eye. According to the gonioscopy scheme, a pectinate ligament with 0–50 % fibrae latae is judged as unaffected (grade 0); 50–100 % fibrae latae and/or <25 % laminae as mildly affected (grade 1); 25–50 % laminae as moderately affected (grade 2) and >50 % laminae as severely affected (grade 3). Relating to the ICA-width (Figure 1), a normal open angle is considered when the PL-length (A) is equal or greater than 1/3 of the distance from the origin of the PL at the base of the iris to the anterior surface of the cornea at the transection area (B) (grade 0); if the PL-length is smaller than 1/3 of B, the ICA is considered narrow/moderately affected (PLA grade 1); if the PL is not visible, the ICA is considered closed/severely affected (ICA-width grade 2).[11]

When combining the two ICA characteristics (PLA and ICA-width), a final iridocorneal angle abnormality score is reached, which determines the individual breeding recommendation: normal/unaffected (grade 0, breeding allowed), mildly affected (grade 1, breeding optional), moderately affected (grade 2, breeding optional) and severely affected (grade 3, breeding not recommended).[11]

Cases that developed glaucoma during the period of the study were included and their clinical course including histopathological description was documented. After enucleation, three globes Case A1, Case A2, Case B) were fixed in 4 % buffered formalin for 2–3 days, sagittally sectioned and routinely paraffin-embedded. Three micrometer thick sections were produced, demonstrating an anterior to posterior section of the globe, including cornea, anterior chamber, iris, ciliary body, posterior chamber, lens, vitreous, retina, optic cup, optic nerve, choroid and sclera. Sections were deparaffinized, routinely Hematoxylin-Eosin and PAS/Al-





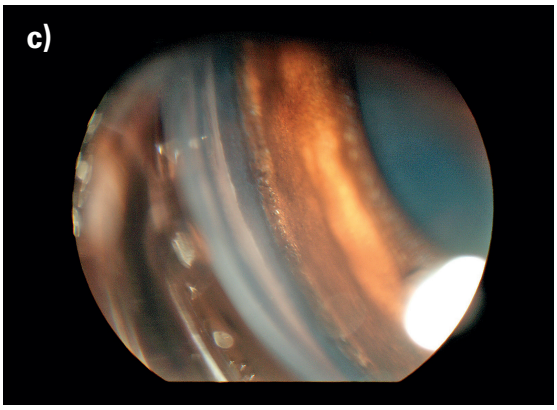


Figure 2: Gonioscopic photographs of three young Leonberger dogs with mild to moderate Iridocorneal angle7 – abnormality. Pectinate ligament abnormality (PLA) and ICA-width grades determination is described in material and methods.

a & b: Gonioscopic view of an 8 months old Leonberger dog with PLA grade 1; open angle (ICA-width grade 0)

c: Gonioscopic view of a 19 months old dog with a narrow angle (ICA-width grade 1); displayed is an area of sheething (laminae) with flow holes. If all 360 degrees of the ICA of this dog would appear like on this image, the eye would be graded as PLA grade 3, severely affected. Since less than 50 % of all 360 degrees of the ICA of this dog displayed laminae like on this image, this eye was graded as PLA grade 2, moderately affected.

d & e: Gonioscopic view of a 9 months old dog with PLA grade 2; displayed are areas of sheething (laminae) and fibrae latae; open angle (ICA-width grade 0)

cian Blue stained, and photographed under a Nikon Eclipse N*i* microscope, with NIS-Elements Advanced Research software (Version 43002).

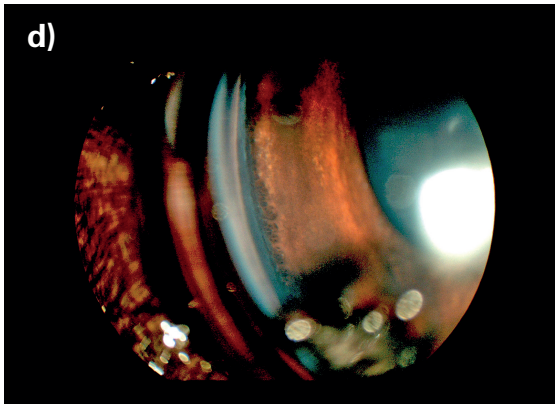
For this study, we applied statistics for which we used R studio (version 4.0.5) with ggplot2 and dplyr packages. The initial sample size was calculated based on the findings of Fricker et al., who found that 9 % of UK Leonbergers had PLA rated as moderately (4 %) and severely (5 %) affected during ophthalmic examination.[15] For the calculation, we used a sample size calculator to estimate the apparent prevalence of the condition in the population (905 Leonbergers registered in Switzerland at the time the study was planned (AMICUS ID national dog registration data base – Identitas AG, Bern), with 5 % precision (epitools.ausvet.com.au). Animal welfare statement:

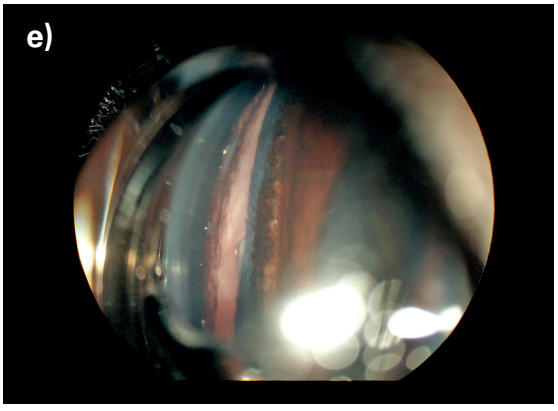
This study did not require approval by the Cantonal Animal Experimentation Committee, as all ophthalmic examinations were conducted at the request of the owners, and in the interest of the individual animals' health. Gonioscopy is a routine component of the ophthalmic examination and is performed in many clinical patients. The purpose of the examinations was to assess the presence of anatomical risk factors associated with glaucoma, enabling early identification of predisposed dogs and the implementation of appropriate prophylactic measures when indicated.

Results

Sixty-nine dogs (37 female and 32 male dogs, 137 eyes) were examined by six ECVO or ACVO board-certified veterinary ophthalmologists between January 2019 and November 2023. The age range at examination ranged from 7 months to 10 years and 4 months, with a median age of 2 years and 8 months (Table 1). The age of the dogs in the sampled population was categorized into four groups. The results of the gonioscopic abnormality grading is presented in Table 1 and photographs representative of PLA severity grades 1 and 2 are displayed in Figure 2 a-e. Fourteen percent (19/137) of eyes were not PLA affected, 36 % (49/137) mildly PLA affected (grade 1), 31 % (42/137) moderately PLA affected (grade 2) and 20 % (27/137) severely PLA affected (grade 3) (Figure 3). Iridocorneal angle width was assessed as open in 64 % (87/137) of eyes in the study population, 30 % (41/137) showed a narrow angle and in 6 % (9/137) of eyes the angle was closed (Figure 4). The final ICA-abnormality (PLA and ICA-width combined) results for this study population amount to 31 % (42/137) mildly affected (ICA-abnormality grade 1), 36 % (50/137) moderately affected (ICA-abnormality grade 2), 20 % (27/137) severely affected (ICA-abnormality grade 3) (Figure 5). Overall, 87 % of the Leonberger eyes in this study showed some form of iridocorneal angle abnormality.

In most dogs (68/69), both eyes were examined; one dog had previously undergone enucleation of one eye for uncontrolled PACG. Its remaining eye showed severe PLA and developed glaucoma within 12 months despite prophylactic brinzolamide (Azopt, Novartis AG, Basel, Switzerland) therapy, ultimately requiring enucleation. Another dog presented as an emergency case with unilateral glaucoma and was enrolled at that time; both eyes showed severe PLA, and both ultimately required enucleation within three months despite medical therapy. A third dog with severe PLA developed glaucoma in one eye three weeks after examination and required enucleation following treatment failure. The fellow eye required escalating medical therapy (Cosopt, Santen Pharmaceutical Co., Ltd., Osaka, Japan; Travatan, Novartis AG, Basel, Switzerland) and eventually endoscopic cyclophotocoagulation combined with Ahmed valve





(Ahmed Glaucoma Valve VFP7, New World Medical, Rancho Cucamonga, USA) implantation, allowing it to remain visual for two years until the dog was euthanised for an unrelated condition.

Of the 4 dogs that presented with clinical glaucoma during this study, three dogs were male, one was female.

The male to female ratio in the study population was 0,86:1 (32:37). Our data suggest no predisposition or association between PLA or ICA-width severity grades and sex. (Figure 2 & 3)

A summary of other ocular anomalies that were noted during the ophthalmic examination is listed in Table 2 (other ocular findings).

Histopathological examination was performed on three enucleated eyes (two from the same dog) (Figure 6). Across all cases, varying degrees of terminal Descemet's membrane fraying were observed, ranging from mild (Case A1) to moderate (Case A2) and severe (Case B). Each eye showed broad sheets or segments of iris-like tissue extending into the iridocorneal angle, sometimes overlapping or integrating with the pectinate ligament. All specimens demonstrated physiologic pigmentation of the uveal tract along with glaucoma-associated pigment dispersion within the corneoscleral and uveoscleral trabecular meshwork. Additionally, mild to moderate ciliary body atrophy and lymphocytic infiltration were present in all cases.

Table 1: The analyzed sample population of 69 Leonberger dogs and pectinate ligament abnormalities (PLA), iridocorneal angle width (ICAW) and abnormality (ICAA) grades

	Age											Total		
	0,5 to 2,5y			2,51 to 4y			4,1 to 10y			>10,1 y				
	Eyes		*Dogs*	Eyes		*Dogs*	Eyes		*Dogs*	Eyes		*Dogs*	Eyes		*Dogs*
	n (%)	95 %CI	*n**	n (%)	95 %CI	*n**	n (%)	95 %CI	*n**	n (%)	95 %CI	*n**	N# (%)	95 %CI	*N**
Sex															
Female	34 (55)	42–67	*17*	24 (67)	50–78	*12*	12 (36)	22–53	*6*	4 (67)	30–90	*2*	74 (54)	46–62	*37*
Male	28 (45)	34–57	*14*	12 (33)	20–50	*6*	21 (64)	47–78	*11*	2 (33)	10–70	*1*	63 (46)	38–54	*32*
PLA															
Grade 0	7 (11)	6–21	*14*	4 (11)	4–25	*2*	8 (24)	13–41	*5*	0	0–39	*0*	19 (14)	9–21	*10*
Grade 1	33 (53)	41–65	*17*	10 (28)	16–44	*8*	6 (18)	9–34	*3*	0	0–39	*0*	49 (36)	28–44	*25*
Grade 2	16 (26)	17–38	*8*	18 (50)	34–67	*11*	4 (12)	5–27	*2*	4 (67)	30–90	*2*	42 (31)	24–39	*21*
Grade 3	6 (10)	5–20	*3*	4 (11)	4–25	*2*	15 (46)	30–62	*8*	2 (33)	10–70	*1*	27 (20)	14–27	*14*
ICAW															
Open	50 (81)	69–89	*25*	20 (56)	40–70	*10*	17 (52)	35–67	*9*	0	0–39	*0*	87 (64)	54–73	*44*
Narrow	12 (19)	11–31	*6*	14 (39)	25–55	*7*	9 (27)	15–44	*5*	6(100)	61–100	*3*	41 (30)	22–39	*21*
Closed	0	0–6	*0*	2 (5)	1–18	*1*	7 (21)	11–38	*3*	0	0–39	*0*	9 (6)	2–12	*5*
ICAA															
Grade 0	6 (9)	4–19	*3*	4 (11)	4–25	*2*	8 (24)	12–41	*4*	0	0–39	*0*	18 (13)	8–20	*9*
Grade 1	30 (48)	36–60	*15*	8 (22)	11–38	*4*	4 (12)	5–27	*2*	0	0–39	*0*	42 (31)	23–39	*21*
Grade 2	20 (32)	22–44	*10*	20 (56)	39–70	*10*	6 (18)	8–34	*3*	4 (67)	30–90	*2*	50 (36)	29–45	*25*
Grade 3	6 (9)	4–19	*3*	4 (11)	4–25	*2*	15 (46)	30–62	*8*	2 (33)	10–70	*1*	27 (20)	14–27	*14*
Total	62	–	*31*	36	–	*18*	33	–	*17*	6	–	*3*	137	–	***69****

Legend: n- number of eyes or dogs in one of the categories. N- the total number of eyes or dogs
*As an individual dog may have eyes that belong to two different PLA/ICAW grades the total number of dogs in the rows will not equal the 69 dogs.
#One eye that was enucleated is excluded from the above summary.
One can interpret the table by comparing the widths of the confidence intervals within the same row (e.g., within «PLA: Grade 3»). If, when considering the potential risk factor «Age», the CIs of the «Age» categories within the row «PLA: Grade 3» do not overlap, this indicates that the factor «Age» may affect the presence of PLA: Grade 3. In this example the CI's of the age categories «0,5 to 2,4y» and «2,51 to 4y»do not overlap with the CI of the age category «4,1 to 10 y». This indicates that individuals in the age category 4,1 to 10 years have a significantly higher chance of having PLA Grade 3 compared to individuals in the age categories 0,5 to 2,5 years and 2,51 to 4 years.

Discussion

Eighty-seven percent (60/69) of the Leonbergers in this study demonstrated ICA abnormalities, with 20 % (14/69) of dogs being severely affected (ICA abnormality grade 3). Only 13 % of the study population showed a normal iridocorneal angle (ICA abnormality grade 0).

Interestingly, when including eyes affected by all ICA-abnormality grades (1–3), our reported 87 % incidence in Leonbergers is substantially higher than the 18 % published.[15] A possible explanation for this discrepancy is the possible difference in sampling methods and grading scheme (although both used a total of 4 grades) between the studies. Fricker et al [15] examined dogs at breed club events, meaning that the selection bias in our study may be higher, considering the possibility that a larger number of concerned owners of dogs with affected relatives participated.

Our study identified several younger individuals (<2,5 years), which displayed a grade 2–3 PLA; however, in general, older individuals displayed a higher grade of both PLA and ICA-width (Figure 2, 3 & 4).

These findings suggest that PLA and ICA-width abnormalities may progress with age in Leonbergers, which was supported by the results from Fricker et al..[15] Comparable findings have also been reported for other breeds, namely Pearl et al and Oliver et al who conducted serial gonioscopy examinations on Flat Coated Retrievers and Welsh Springer Spaniels (unaffected by glaucoma), respectively, and who observed a significant progression of PLA.[13,21,27,28,29,31] Contrarily, Westermeyer et al could not detect changes in PLA in unilaterally glaucomatous dogs, where the contralateral side was serially examined over a time span of mean 1,1 years.[39] An alternative possibility for ICA-width narrowing with age is that ICA narrowing may be caused by a normal age-related increase in lens size.[4]

Four of 69 dogs (6 %) in the study developed or presented with PACG during the study period. All four dogs had been examined and had an ICA-abnormality grade of 3, severely affected. These affected individuals were all over 5 years of age (range 5–6 years), which may suggest a tendency for middle-aged dogs to develop glaucoma in this breed. Since 55 of the 69 dogs in our study were younger than five years of age, it is possible that additional clinical cases in our study population may present in the coming years. Sex ratio of the dogs affected with PACG was 3:1 male:female, whereas Fricker showed a 1:5 male:female ratio.[15] However, due to the low number of affected dogs in both studies, it was not possible to establish statistical significance of the sex ratio in either study. Tsai et al.[37] presented several hypotheses as possible reasons for an overrepresentation of female dogs with PLA. One hypothesis is that the shorter axial globe length and narrower ICA opening in females may result in a higher susceptibility for IOP to increase.[7,22] Studies showing female gender predisposition were also performed in the American Cocker Spaniel,[25] Welsh Springer Spaniel,[8] and Siberian Husky,[26] with females being more frequently affected. In the English Springer Spaniel,[6] Samoyed[13] and Flat Coated Retriever,[34] no gender difference could be found, like in the study presented here.

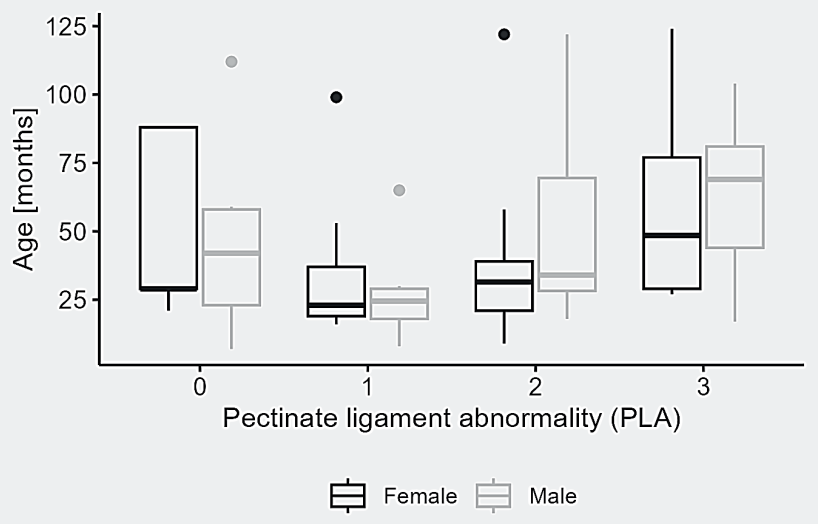


Figure 3: Pectinate ligament abnormality (PLA) grade (0 = normal, 1 = mild, 2 = moderate, 3 = severe) and age in 137 examined eyes in 69 Leonberger dogs

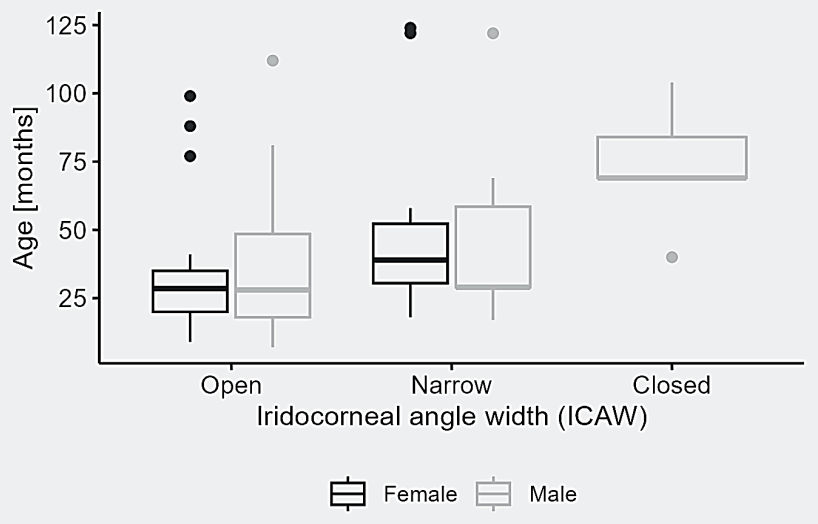


Figure 4: Iridocorneal angle[7] -width and age in 137 examined eyes in 69 Leonberger dogs

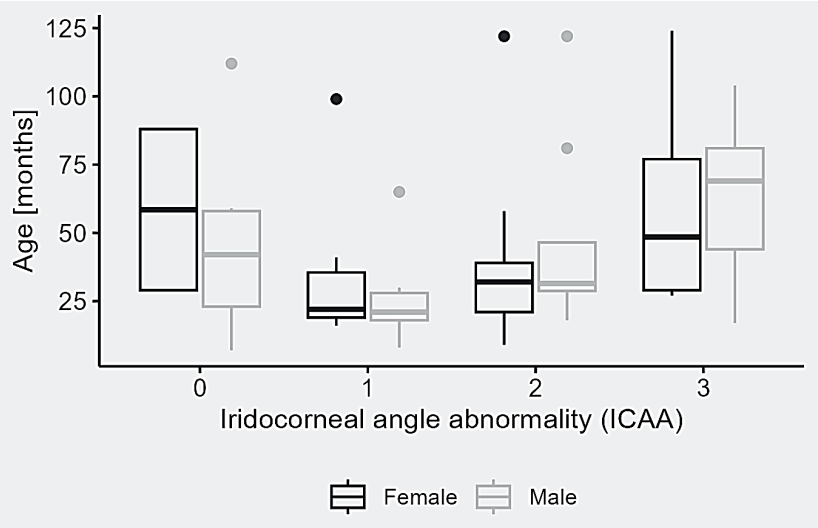


Figure 5: Iridocorneal angle[7] -abnormality grade (0 = normal, 1 = mild, 2 = moderate, 3 = severe) and age in 137 examined eyes in 69 Leonberger dogs.
PLA: pectinate ligament abnormality; ICA: iridocorneal angle; ICA-width: iridocorneal angle width; ICA-abnormality: iridocorneal angle abnormality

Table 2: Other ocular findings in the enrolled population of 69 Leonberger dogs

Affected anatomic structure	Abnormality	Affected eyes		Affected dogs
		n (%)	95 % CI	n
Eyelids	Distichia	2 (1,5)	0,5 – 5	**1**
	Entropion	6 (4)	*2 – 9*	3
	Macroblepharon	19 (12)	8 – 18	10
	Ectropion	4 (3)	1 – 7	2
Conjunctiva	Mild follicular conjunctivitis	2 (1,5)	0,5 – 5	1
Cornea	Incision fibrosis	2 (1,5)	0,5 – 5	1
	Pigment spotted endothelium	1 (1)	0 – 4	1
Iris	PPM Iris-Iris	41 (23)	17 – 30	23
	Naevus	1 (1)	0 – 4	1
	Diffuse melanosis	2 (1,5)	0,5 – 5	1
Lens	Anterior capsular opacities	3 (2,2)	–	2
	Anterior cortical punctate cataract	8 (5,8)	–	5
	Fiberglass nuclear cataract	3 (2,2)	–	2
	Nuclear ring	6 (4,4)	2 – 9	3
	Nuclear cataract	2 (1,5)	0,5 – 5	2
	Nuclear sclerosis	2 (1,5)	0,5 – 5	1
	Visible suture line tips	2 (1,5)	0,5 – 5	1
	Posterior capsular opacities	3 (2,2)	–	2
	Posterior cortical/subcapsular cataract	5 (3,7)	–	3
	Posterior polar cataract	4 (2,9)	1 – 7	2
	Cataract undefined	2 (1,5)	0,5 – 5	1
Vitreus	PHTVL grade 1	1 (1)	0 – 4	1
	PHTVL grade 2	1 (1)	0 – 4	1
	Arteria hyaloidea persistens	1 (1)	0 – 4	1
Fundus	Punctate retinal scar	1 (1)	0 – 4	1
Total		137	–	69

PPM = persistent pupillary membranes; PHTVL = persistent hyperplastic tunica vascularis lentis

The trigger for the sudden onset of glaucoma in dogs affected by PLA and/or a narrowed ICA is still unknown. In addition to age as a positive risk factor,[27,28,31] low grade ocular inflammation might also play a part in the development of glaucoma, by obstruction of flow through the trabecular meshwork by small macromolecules.[6,9]

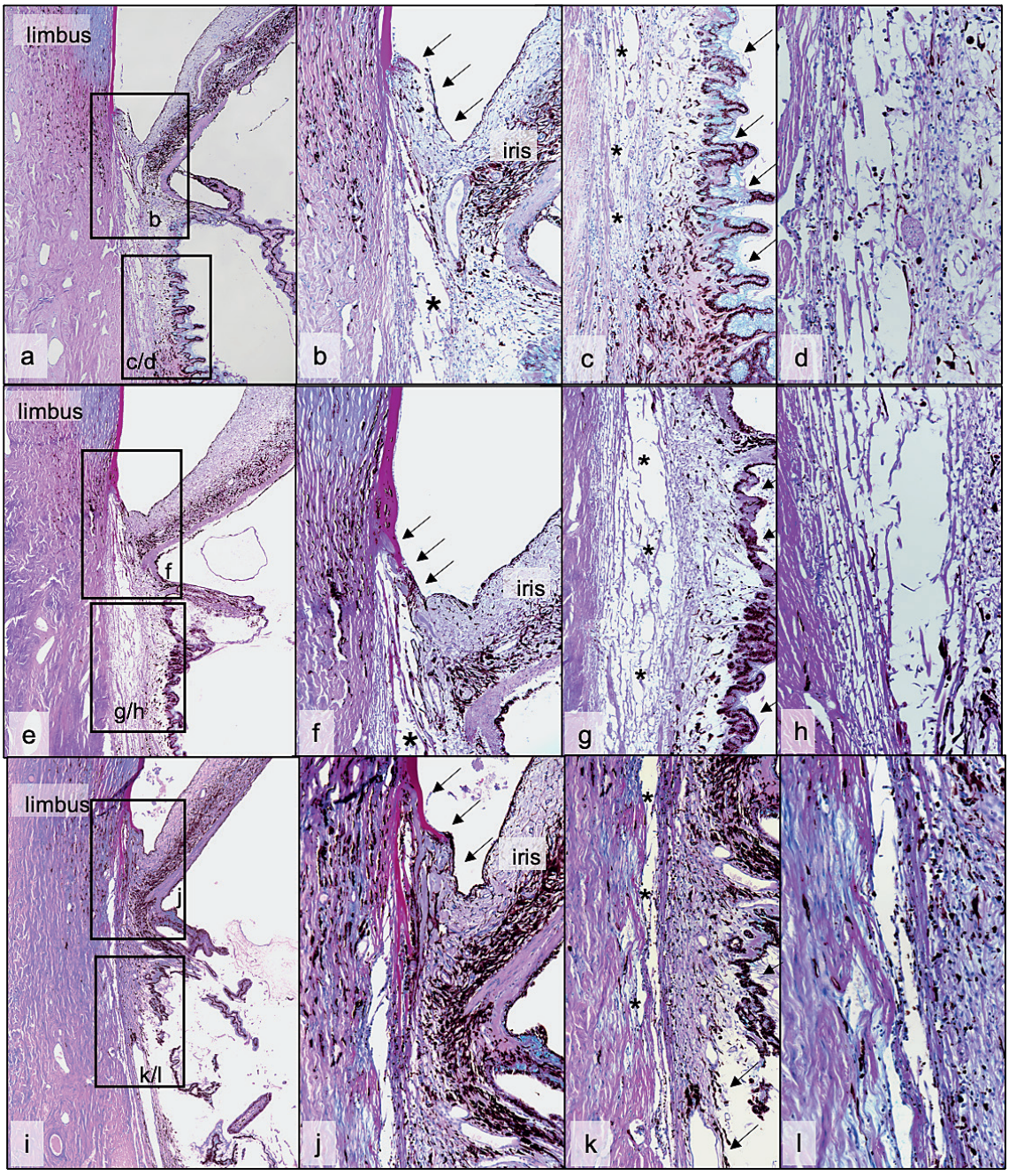


Figure 6: Histopathologic description of the iridocorneal angle7 in enucleated eyes in Leonberger dogs
a-d: Case A1, e-h: Case A2, i-l: Case B
a, e, i: Overview of the ICA, corneoscleral and uveoscleral trabecular meshwork.
b, f, j: Ligamentum pectinatum (arrows), corneoscleral trabecular meshwork and uveoscleral trabecular meshwork (asterisk). Severe sclerosis of the Ligamentum pectinatum (arrows) and mild compression and sclerosis of uveoscleral meshwork (asterisk).
c, g, k: Posterior uveoscleral trabecular meshwork with mild compression and sclerosis (asterisks) and moderate (c) and complete (g) atrophy of the ciliary body processes (arrows).
d, h, l: Uveoscleral trabecular meshwork with atrophy of trabecular cells.
PAS-/Alcian Blue stain, 10x (a, d), 20x (b, c, f, g), 40x (d, h)

Histopathology results enhance the quality of information, but a histologic diagnosis of PLA does not necessarily correspond to the clinical diagnosis, which is why pathologists rely on gonioscopy information provided by the treating clinician when establishing a diagnosis of primary angle closure glaucoma.[4] Observed histomorphological changes of the ICA in glaucomatous eyes are numerous and can be breed-related.[5] Histologic findings can include: sheets of iris-like uveal tissue extending from the iris base to the terminus of Descemet's membrane,[4] a frayed terminal DM at the PL insertion, DM extension into the ciliary cleft along trabecular beams, extension of pigmented spindle cells into the deep corneal stroma adjacent to DM, an abnormal PL with variation in length and thickness, fibrovascular membrane formation, inflammation in the anterior uveal stroma, ICA structures, ciliary cleft and anterior chamber, lymphocytic infiltration, loss of trabecular meshwork arrangement or thickening of trabecular meshwork beams, and posterior iris epithelium loss.[4,5]

In our study, the DM was frayed and extended towards the corneoscleral trabecular meshwork, the PL appeared broad and/or incorporated into a sheet of iris-like tissue. The corneoscleral and uveoscleral trabecular meshwork were compressed and atrophied and contained a variable amount of glaucoma associated dispersed pigment cells, and the ciliary body showed lymphocytic infiltration and atrophy.

One of the study limitations is the lower than calculated number (n = 182) of study participants. This observational cross-sectional study was originally planned as a prevalence study. Due to the ongoing COVID-19 pandemic, large examination events were not possible, which is why the study ended up depending on individual client visits at the participating clinics. These clinics had varying rules and measures concerning patient and owner contact, which we suspect may have discouraged a significant number of dog owners to participate (oral communication with owners and the SLC), resulting in a smaller than expected number of dogs enrolling into the study during a two-year timeline. Given the high incidence of iridocorneal angle abnormalities observed in our study population, we deemed it essential to publish our findings promptly rather than wait for further data collection, which would have taken several additional years due to the current slow enrollment rate. Our goal was to provide the Swiss Leonberger breeding community with timely information to enable them to adjust breeding criteria promptly, thereby helping to mitigate the propagation of this condition in Switzerland. Additionally, we aimed to raise awareness within the veterinary community regarding the potential for ICA abnormalities in Leonberger dogs.

One potential limitation of our study was reliance on voluntary participation of Leonberger dog owners and breeders. Speculatively, discovering – or even suspicion – for a potentially heritable health problem in a breed could result in discouraging certain breeders from participating in such a study, leading to selection bias. On the other hand, a selection bias can also present itself in the opposite way, by increased participation of owners concerned about their dog's health. For one dog, a selection bias was clearly present, given that the animal entered the study following presentation as a clinical glaucoma case.

Future directives of the current study include ongoing examination and enrolment of Leonbergers to evaluate the prevalence and the potential heritability of ICA abnormalities, with the goal of establishing genetic testing for prospective breeding animals and improving ocular health in the Leonberger breed.

Conclusion

In Switzerland, a substantial proportion of Leonbergers exhibit iridocorneal angle abnormalities, with many cases presenting moderate to severe grades. Notably, individuals with severe abnormalities appear to have an elevated risk of developing glaucoma. Therefore, we advised the Swiss breeding club to add gonioscopy to the mandatory pre-breeding HED examination for Leonbergers. Including dogs in the breeding program who are free from ICA abnormalities or including only those who are affected to a lower degree (mild/moderate), could lower the risk for the development of primary glaucoma in this breed. In addition, as changes affecting the ICA may progress with age, we suggest performing gonioscopic examinations of Leonbergers every three years.

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Conflict of Interest

The authors have no conflict of interest to declare.

Résultats gonioscopiques chez 69 chiens Leonberger en Suisse entre 2019 et 2023

La présente étude fournit un aperçu des résultats gonioscopiques chez les chiens Leonberger en Suisse et décrit les cas de glaucome au sein de cet échantillon de population.

Des chiens Leonberger de race pure ont participé à cette étude prospective, multicentrique et transversale. Un examen complet des maladies oculaires héréditaires (HED), incluant une gonioscopie, a été réalisé chez tous les chiens conformément au programme HED de l'European College of Veterinary Ophthalmologists (ECVO). La morphologie du ligament pectiné et la largeur de l'angle irido-cornéen (largeur ICA) ont été notées et classées respectivement en grades 0–3 et 0-2.

Soixante-neuf chiens (137 yeux) d'un âge médian de 2 ans et 8 mois ont été inclus dans l'étude. L'anomalie du ligament pectiné (PLA) et la largeur de l'angle irido-cornéen (largeur ICA) ont été combinées pour obtenir les scores finaux de l'anomalie de l'angle irido-cornéen (anomalie ICA). Vingt pour cent (14/69) de tous les yeux présentaient des angles irido-cornéens gravement affectés (anomalie ICA de grade 3), 36 % (25/69) modérément affectés (anomalie ICA de grade 2) et 31 % (21/69) légèrement affectés (anomalie ICA de grade 1). Dans l'ensemble, 87 % des Leonbergers participant à cette étude présentaient une forme d'anomalie de l'angle irido-cornéen. Quatre pour cent (6/137) de tous les yeux, correspondant à 6 % (4/69) des chiens, ont développé un glaucome entre l'âge de 5,5 et 6 ans. Tous ces yeux présentaient des ICA gravement touchés (anomalie ICA de grade 3).

Un nombre important de chiens Leonberg en Suisse présentent des anomalies de l'angle irido-cornéen et courent un risque accru de développer un glaucome primaire à angle fermé. Les éleveurs de Leonberg devraient être encouragés à faire réaliser une gonioscopie sur tous les animaux reproducteurs potentiels, conformément aux directives HED de l'ECVO.

Mots clés: Glaucome primaire à angle fermé chez le chien, Leonberg, anomalie de l'angle irido-cornéen, goniodysgénésie

Reperti gonioscopici in 69 cani di razza Leonberger in Svizzera dal 2019 al 2023

Il presente studio fornisce una panoramica dei reperti gonioscopici nei cani di razza Leonberger in Svizzera e descrive i casi di glaucoma osservati in questa popolazione.

Dei cani Leonberger di pura razza hanno partecipato a questo studio prospettico, multicentrico e trasversale. Tutti i soggetti sono stati sottoposti a un esame completo delle malattie oculari ereditarie (HED), comprensivo di gonioscopia. La morfologia del *legamento pettinato dell'iride* e l'ampiezza dell'angolo iridocorneale (ICA-width) sono state registrate e classificate rispettivamente in gradi da 0 a 3 e da 0 a 2.

Sono stati inclusi nello studio 69 cani (137 occhi), con un'età mediana di 2 anni e 8 mesi. Le anomalie del *legamento pettinato dell'iride* (PLA) e l'ampiezza dell'angolo iridocorneale (ICA-width) sono state combinate per ottenere un punteggio finale di anomalia dell'angolo iridocorneale (ICA-abnormality). Il 20 % (14/69) degli occhi ha mostrato un'alterazione grave dell'angolo iridocorneale (ICA-abnormality grado 3), il 36 % (25/69) un'alterazione moderata (ICA-abnormality grado 2) e il 31 % (21/69) un'alterazione lieve (ICA-abnormality grado 1). Complessivamente, l'87 % dei Leonberger inclusi nello studio presentava una qualche forma di anomalia dell'angolo iridocorneale. Il 4 % (6/137) degli occhi, corrispondente al 6 % (4/69) dei cani, ha sviluppato glaucoma tra i 5,5 e i 6 anni di età. Tutti questi occhi presentavano un'alterazione grave dell'angolo iridocorneale (ICA-abnormality grado 3).

Un numero significativo di cani Leonberger in Svizzera presenta anomalie dell'angolo iridocorneale ed è pertanto a maggior rischio di sviluppare glaucoma primario ad angolo chiuso. Gli allevatori di Leonberger dovrebbero essere incoraggiati a sottoporre tutti i potenziali riproduttori a esame gonioscopico, in conformità alle linee guida dell'European College of Veterinary Ophthalmologists (ECVO) per le malattie oculari ereditarie.

Parole chiave: glaucoma primario ad angolo chiuso nel cane, Leonberger, anomalia del legamento pettinato dell'iride, goniodisgenesia, angolo iridocorneale

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