



A Retrospective Study of Canine Primary Glaucoma (2011-2020)

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Abstract To determine the prevalence of breed, age, and sex of canine primary glaucoma by comparing previous reports in Korea. We included the medical records of dogs diagnosed with primary glaucoma who visited the veterinary medical teaching hospital of Seoul National University (SNU) from January 2011 to December 2020 and investigated their breed, age, and sex. All the patients underwent a full ophthalmic examination. We analyzed the results using a binary logistic regression analysis based on the Jindo dog, which was close to the mean value of the primary glaucoma incidence rate. Of the 14,587 dogs treated at the veterinary medical teaching hospital of SNU, 107 (0.73%) were diagnosed with primary glaucoma. Glaucoma occurred in 14 breeds, including the American Cocker Spaniel, Shih Tzu, Maltese, Pomeranian, Jindo dog, Mixed Breed, Pekinese, Toy Poodle, Samoyed, Shiba Inu, Miniature Pinscher, Boston Terrier, Labrador retriever, and Yorkshire Terrier. The mean age of onset of primary glaucoma was 7.8 ± 2.3 years. Primary glaucoma was observed in 53 spayed females, 11 females, 38 castrated males, and five males. Regardless of neutralization, the ratio of females to males was 1.5:1. This study showed that primary glaucoma was significantly higher in American Cocker Spaniels and higher in Shih Tzus than other breeds in Korea; they had the highest incidence of primary glaucoma at 7 and 8 years of age, respectively. Therefore, the two breeds should be carefully monitored for the occurrence of primary glaucoma when they approach 7 years of age.

Key words American Cocker Spaniel, dog, primary glaucoma, Shih Tzu.

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Introduction

Glaucoma is a painful, progressive, and leading cause of irreversible blindness in humans and dogs (4,14). In glaucoma, necrosis of retinal ganglion cells and axons results from heterogeneous causes, such as inhibition of aqueous humor drainage, leading to an increase in intraocular pressure (IOP) (major risk factor) (24). Congenital glaucoma (characterized by goniodysgenesis [GD] with iridocorneal angle [ICA] abnormalities) occurs at a relatively early age (<1 year of age) and has a low occurrence in dogs (24). In addition, congenital glaucoma has been reported at the age of 21 days in the breed Dogue de Bordeaux, 28 days in Jack Russell Terrier, 35 days in German Hunting Terrier, and 6.5 months in Kooikerhondje in Switzerland (24). Unlike secondary glaucoma, primary glaucoma develops because of primary abnormalities rather than other ocular diseases. It occurs bilaterally, and breed predisposition has been reported (18). Although the exact mechanism of primary glaucoma is still unknown, genes that develop glaucoma have been documented (17). Primary glaucoma is divided into primary open-angle glaucoma (POAG) and primary angle-closure glaucoma (PACG). In POAG, the ICA is normal at the beginning of the disease, but gradually becomes closed; it has been reported in juvenile beagles or middle-aged-to-older Petit Basset Griffon Vendéens and Norwegian Elkhounds (1,2,12). POAG often has a mutation gene, such as ADAMTS10, that affects trabecular meshwork and raises the IOP (12). It is more common in humans than in dogs (20). However, PACG is characterized by structural abnormalities, such as a narrowed ICA and ciliary cleft. It is also closely associated with pectinate ligament dysplasia (PLD), and high IOP-related clinical signs usually occur in middle-to-old age (19). The breed predispositions for PLD are English Springer Spaniel, Flat-coated retriever, Great Dane, and Samoyed (3,6,26). The prevalence of PACG in primary glaucoma is approximately 26% and 87% in humans and dogs, respectively (5,15). Among congenital, primary, and secondary glaucoma, PACG progresses most rapidly and even causes vision loss with severe pain within a day in dogs (15).

Primary glaucoma has been reported to occur in 42 predisposed breeds (7). The American Cocker Spaniel, Basset Hound, Chow Chow, Shar-Pei, and Boston Terrier in North America; Siberian Husky, mixed breed, Entlebucher Mountain Dog, Vizsla, and Newfoundland in Switzerland; Shiba Inu Dog, Shih Tzu, Mixed breed, American Cocker Spaniels, and Beagle in Japan; and American Cocker Spaniels, Shih Tzu, and mixed breed in Korea, are breeds with a high prevalence of primary glaucoma (7,10,18,24). The prevalence of

primary glaucoma is affected by nation, region, and breed preferences. Primary glaucoma is diagnosed using gonioscopy, ultrasound biomicroscopy (UBM), high-resolution ultrasonography (HRUS), or optical coherence tomography (21). The ICA can be identified as open, narrow, occluded, or GD.

This study investigated the prevalence of breed, age, and sex of canine primary glaucoma by comparing previous reports in Korea.

Materials and Methods

In this study, we included the medical records of dogs diagnosed with primary glaucoma who visited the veterinary medical teaching hospital of Seoul National University (SNU) from January 2011 to December 2020. We investigated breed, age, and sex of patients diagnosed with primary glaucoma.

All patients underwent a full ophthalmic examination. Schirmer tear test-1 (STT-1; Schering-Plough Animal Health, Union, NJ, USA), tonometry (TonoVet, iCare, Helsinki, Finland), fluorescein staining (Flu-Glo[®], Akorn Pharmaceuticals, Decatur, IL, USA), neuro-ophthalmic testing, slit-lamp biomicroscopy (SL-D7, Topcon, Tokyo, Japan), gonioscopy (Volk Optical, Mentor, OH, USA), indirect ophthalmoscopy (Vantage Indirect Ophthalmoscope[®], Keeler, Windsor, UK) with a 30D condensing lens, and b-wave ocular ultrasonography were performed. The ICA and ciliary cleft were identified using gonioscopy and UBM (MD-320W; MEDA Co., Ltd, Tianjin, China).

The diagnostic criteria for primary glaucoma were an IOP of >30 mmHg measured using rebound tonometer and accompanied by clinical signs of glaucoma, including episcleral injection, mydriasis, corneal edema, buphthalmos, optic disc cupping, retinal hyperreflectivity, ocular pain, and reduced or loss of vision. We excluded patients with secondary glaucoma with a history of lens luxation, uveitis, intraocular tumors, ocular trauma, or those who had undergone intraocular surgery, such as phacoemulsification.

The results of this study were compared with those of a previous study on American Cocker Spaniels and Shih Tzus, the breeds with the highest prevalence of primary glaucoma in Korea. We compared and analyzed the data obtained using binary logistic regression analysis based on the results of analysis on the Jindo dog, which were close to the mean value of the primary glaucoma incidence rate.

Results

Of the 14,587 dogs treated at the veterinary medical teach-

ing hospital of SNU in ophthalmic clinic, 107 (0.73%) were diagnosed with primary glaucoma. The number of American Cocker Spaniels and Shih Tzus steadily decreased during this study period (Fig. 1). Glaucoma occurred in 14 breeds, including American Cocker Spaniel, Shih Tzu, Maltese, Pomeranian, Jindo dog, Mixed Breed, Pekinese, Toy Poodle, Samoyed, Shiba Inu, Miniature Pinscher, Boston Terrier, Labrador retriever, and Yorkshire Terrier (Table 1). In this study, we identified nine new breeds, including Pomeranian, Jindo dog, Toy Poodle, Samoyed, Shiba Inu, Miniature Pinscher, Boston Terrier, Labrador retriever, and Yorkshire Terrier, which were not reported in previous domestic studies. Compared with previous studies in Korea, primary glaucoma was also significantly higher in American Cocker Spaniels and Shih Tzus in this study. The mean age of onset of primary glaucoma was 7.8 ± 2.3 years. The top two breeds, American Cocker Span-

iel and Shih Tzu, had a mean age of 7.8 ± 2.6 and 8.1 ± 2.6 years, respectively (Fig. 2). The sexes of primary glaucoma breeds were 53 spayed females, 11 females, 38 castrated males, and five males. Regardless of neutralization, the ratio of females to males was 1.5:1. The ratios of females to males in the American Cocker Spaniel, Shih Tzu, and Maltese breeds were 1.3:1, 1.4:1, and 1.8:1, respectively. The mean IOP was 44.0 ± 21.4 mmHg at the time of hospital visit. The mean IOPs of the American Cocker Spaniel, Shih Tzu, and Maltese breeds were 47.4 ± 25.4 mmHg, 48.4 ± 18.0 mmHg, and 47.6 ± 24.6 mmHg, respectively. Primary glaucoma occurred in 60 right eyes and 47 left eyes.

Discussion

This study investigated breed prevalence, age, and sex, of

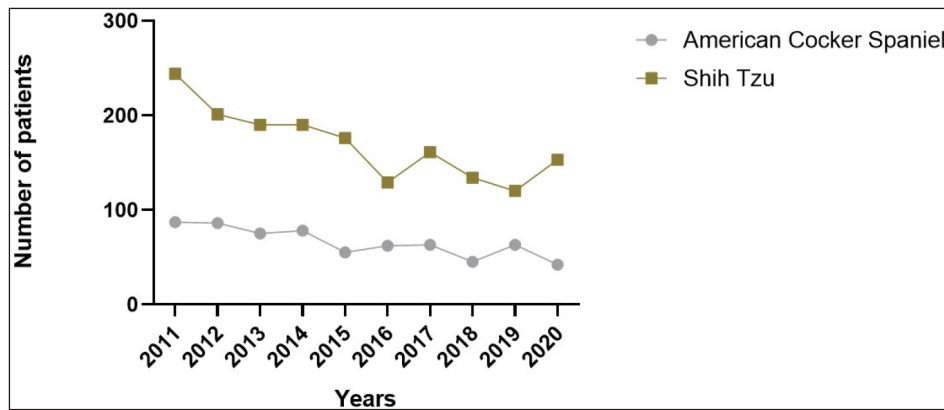


Fig. 1. Presentation number of ocular examinations by years for the American Cocker Spaniel and Shih Tzu.

Table 1. Patients summary with primary glaucoma

No	Breeds	Individual	Primary glaucoma	Incidence rate (%)	Age	Sex (F:M)	Direction (OD/OS)	p value
1	American Cocker Spaniel	656	36	5.5	7.8 ± 2.6	20:16	21:15	0.002
2	Shih Tzu	1,698	39	2.3	8.1 ± 2.6	23:16	20:19	0.057
3	Maltese	2,977	11	0.37	8.9 ± 2.0	7:4	6:5	0.353
4	Pomeranian	930	4	0.43	7.0 ± 2.6	3:1	2:2	0.553
5	Jindo dog	444	3	0.68	5.7 ± 2.5	2:1	2:1	-
6	Mixed Breed	789	2	0.25	7.5 ± 3.5	0:2	2:0	0.282
7	Pekinese	570	2	0.35	11.5 ± 0.7	2:0	0:2	0.472
8	Toy Poodle	1,461	2	0.14	10.0 ± 4.4	1:1	2:0	0.080
9	Samoyed	303	2	0.66	6.0 ± 1.4	2:0	0:2	0.980
10	Shiba Inu dog	313	2	0.64	3.0 ± 2.8	1:1	1:1	0.951
11	Miniature Pinscher	476	1	0.21	6	1:0	1:0	0.311
12	Boston Terrier	309	1	0.32	9	1:0	1:0	0.523
13	Labrador Retriever	582	1	0.17	8	0:1	1:0	0.235
14	Yorkshir Terrier	1,399	1	0.07	11	1:0	1:0	0.051
15	Others	1,680	0	0				
Total		14,587	107	0.73	7.8 ± 2.3	64:43	60:47	

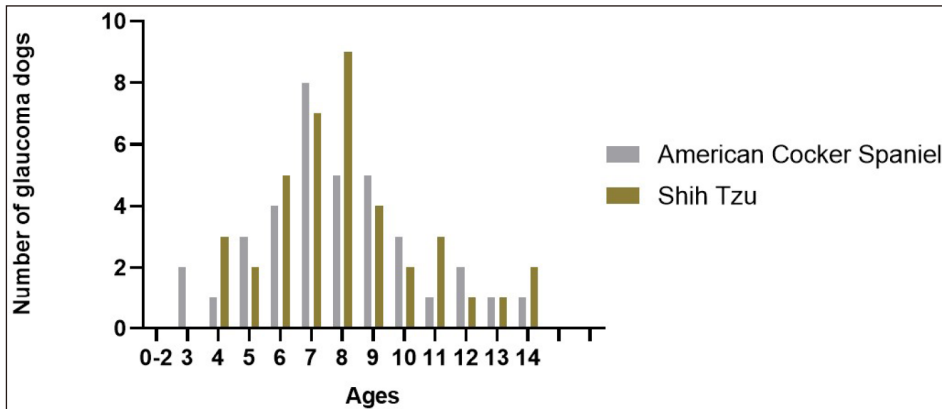


Fig. 2. Presentation number of primary glaucoma by ages for the American Cocker Spaniel and Shih Tzu.

canine primary glaucoma in Korea from 2011 to 2020. The breeds with primary glaucoma vary in different countries and regions and may change with time for numerous reasons. Therefore, the occurrence of primary glaucoma may also change. In this study, primary glaucoma occurred at a high rate in the following order of breeds: American Cocker Spaniel, Shih Tzu, Maltese, and Pomeranian. It did not occur in the Maltese breed at a significantly higher rate, even though it is a very popular breed in Korea. A large number of primary glaucoma cases were confirmed because of the large study population. In the current study, compared with a previous study, we identified nine new breeds, including Pomeranian, Jindo dog, Toy Poodle, Samoyed, Shiba Inu, Miniature Pinscher, Boston Terrier, Labrador retriever, and Yorkshire Terrier. Cases of primary glaucoma in the Pomeranian, Toy Poodle, Samoyed, Shiba Inu dog, Boston Terrier, Labrador retriever, and Yorkshire Terrier breeds have been reported in the United States, Japan, and Switzerland (7,10,24). Among these breeds, Shiba Inus had the highest incidence (3.4%) of glaucoma in Japan, and it is gradually increasing in Korea. Although the incidence rate was low, Jindo dogs had no reports of primary glaucoma in other countries and regions. The reason for this is because the Jindo dog is a preferred breed in Korea, just as the West Highland White Terrier in North America, the Entlebucher Mountain Dog in Switzerland, and the dachshund in Japan. Another reason for this was probably the lack of reports on the prevalence of primary glaucoma in these breeds.

In this study, the prevalence of primary glaucoma was higher (0.73%) than in a previous study in Korea (0.55%). This observation was similar to that in a study on primary glaucoma in North America, which showed a steady increase in over 40 years (1964-73: 0.29%, 1974-1983: 0.46%, 1984-1993: 0.76%, 1994-2002: 0.89%) (7). In Korea, as in North America, the diagnosis of primary glaucoma has increased

with the distribution of ophthalmic equipment, such as tonometers, slit-lamp biomicroscopes, gonioscopes, and the increasing number of private specialty practices.

American Cocker Spaniels and Shih Tzus demonstrated a high prevalence of primary glaucoma, which was similar to results of a previous study in Korea (18). Primary glaucoma in American Cocker Spaniels is characterized by a narrowed ICA and ciliary cleft with PLD (21). This breed has a high prevalence of primary glaucoma worldwide, including in North America, Japan, Switzerland, and South Korea (7,10,18,24). The mean ages of the American Cocker Spaniels at the onset of primary glaucoma in North America, Japan, and the previous domestic study were 6.4 ± 1.3 , 7.4 ± 2.5 , and 6.8 years, respectively (7,10,18), and that of the present study was 7.8 ± 2.6 years. The females to male ratio in North America, Japan, and the previous domestic study was 1.5:1, 1:1, and 2.6:1, respectively, and 1.3:1 in this study. The prevalence of primary glaucoma in the American Cocker Spaniel was as follows: 5,984 (1.39%; 1964-1973); 15,440 (2.07%; 1974-1983); 25,205 (3.95%; 1984-1993); and 10,591 (5.52%; 1994-2002) in North America (7). The number of American Cocker Spaniels increased steadily (1964-1993) and declined sharply in the last period (10,591; 1994-2002). However, the prevalence of primary glaucoma in American Cocker Spaniels increased more in the last period (5.52%; 1994-2002) (7). In this study, the number of American Cocker Spaniels steadily decreased over the past decade (Fig. 1) and is expected to decrease further in the future, similar to that in North America. The preference for the American Cocker Spaniel breed showed a decreasing trend due to various diseases, such as external otitis and intervertebral disc disease, as well as ocular diseases, including cataract and glaucoma in Korea (13,22,23,27).

Primary glaucoma in Shih Tzus is characterized by a closed ICA (18). Previous studies reported that secondary glaucoma associated with hyphema, vitreous degeneration, and retinal

detachment were common in Shih Tzus (10,18). Shih Tzu was the second most common breed with primary glaucoma after American Cocker Spaniels in Japan and Korea. The age of onset of primary glaucoma in this breed was 7.0 ± 1.4 years (1994-2002) and 8.3 ± 2.1 years in the United States and Japan, respectively, and 8.1 ± 2.6 years in this study. The ratio of females to males in the United States, Japan, and our study was 1.2:1, 1.1:1, and 1.4:1, respectively. Similar to the American Cocker Spaniel, the popularity of Shih Tzu has also been decreasing, and its population has steadily decreased over the past 10 years (Fig. 1). However, the incidence rate of primary glaucoma has increased nearly twice as high in this breed compared to the previous domestic study. Shih Tzus are predisposed to many chronic diseases, such as calculus, hyperadrenocorticism, mammary gland tumors, and ocular diseases, including primary glaucoma and corneal disease. (8,9,11,16).

The age of onset of primary glaucoma varies by breed and usually occurs in middle-to-old age. In this study, the mean age of onset of primary glaucoma in canines was 7.8 ± 2.3 years (Fig. 2). A previous study reported that the mean ages of onset of canine primary glaucoma in North America, Switzerland, and Japan were 6.39 ± 1.30 , 7.25 ± 0.70 , and 7.54 ± 1.54 years, respectively (7,10,24). It has been reported that the reason for the occurrence of primary glaucoma in middle age is the position of the lens, which is relatively anterior near the pupil, and prevents the drainage of aqueous humor and increases the length and thickness of the lens axis (10).

Primary glaucoma occurred at a higher rate in females than in males in several studies, including English Cocker Spaniel (7.4:1), Welsh Terrier (2.5:1), Newfoundland (2:1), Vizsla (1.7:1), Basset Hound (1.7:1), and American Cocker Spaniel (1.5:1) (7,24). In the present and Japanese studies, the ratio of females to males with primary glaucoma prevalence showed a similar trend, with a mean of 1.5:1 and 1.3:1, respectively. This tendency is mainly observed in human PACG, especially in Asian people (21). A recent study using HRUS and ultrasound reported a decrease in ICA, small-angle open distances, and angle recess area in female PACG (25).

In conclusion, this study confirmed that primary glaucoma was significantly higher in American Cocker Spaniels ($p < 0.002$) and higher in Shih Tzus than other breeds in Korea. American Cocker Spaniels and Shih Tzus had the highest incidence of primary glaucoma at 7 and 8 years of age, respectively. Therefore, the two breeds should be carefully monitored for the occurrence of primary glaucoma as they approach 7 years of age.

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Conflicts of Interest

The authors have no conflicting interests.

References

- Ahonen SJ, Kaukonen M, Nussdorfer FD, Harman CD, Komáromy AM, Lohi H. A novel missense mutation in ADAMTS10 in Norwegian Elkhound primary glaucoma. *PLoS One* 2014; 9: e111941. Erratum in: *PLoS One* 2015; 10: e0118256.
- Bedford PG. Open-angle glaucoma in the Petit Basset Griffon Vendéen. *Vet Ophthalmol* 2017; 20: 98-102.
- Bjerkås E, Ekesten B, Farstad W. Pectinate ligament dysplasia and narrowing of the iridocorneal angle associated with glaucoma in the English Springer Spaniel. *Vet Ophthalmol* 2002; 5: 49-54.
- Dees DD, Fritz KJ, Maclaren NE, Esson DW, Sheehan Gaerig AM, Atkins RM, et al. Efficacy of prophylactic antiglaucoma and anti-inflammatory medications in canine primary angle-closure glaucoma: a multicenter retrospective study (2004-2012). *Vet Ophthalmol* 2014; 17: 195-200.
- Dubey S, Jain K, Mukherjee S, Sharma N, Pegu J, Gandhi M, et al. Current profile of secondary glaucoma in a Northern India tertiary eye care hospital. *Ophthalmic Epidemiol* 2019; 26: 200-207.
- Ekesten B, Torräng I. Heritability of the depth of the opening of the ciliary cleft in Samoyeds. *Am J Vet Res* 1995; 56: 1138-1143.
- Gelatt KN, MacKay EO. Prevalence of the breed-related glaucomas in pure-bred dogs in North America. *Vet Ophthalmol* 2004; 7: 97-111.
- Heo S, Hwang T, Lee HC. Ultrasonographic evaluation of skin thickness in small breed dogs with hyperadrenocorticism. *J Vet Sci* 2018; 19: 840-845.
- Houston DM, Moore AE. Canine and feline urolithiasis: examination of over 50 000 urolith submissions to the Canadian veterinary urolith centre from 1998 to 2008. *Can Vet J* 2009; 50: 1263-1268.
- Kato K, Sasaki N, Matsunaga S, Nishimura R, Ogawa H. Incidence of canine glaucoma with goniodysplasia in Japan: a retrospective study. *J Vet Med Sci* 2006; 68: 853-858.
- Kim HW, Lim HY, Shin JI, Seung BJ, Ju JH, Sur JH. Breed- and age-related differences in canine mammary tumors. *Can J Vet Res* 2016; 80: 146-155.
- Kuchtey J, Kunkel J, Esson D, Sapienza JS, Ward DA, Plummer

- CE, et al. Screening ADAMTS10 in dog populations supports Gly661Arg as the glaucoma-causing variant in beagles. *Invest Ophthalmol Vis Sci* 2013; 54: 1881-1886.
13. Kunz RE, Rohrbach H, Gorgas D, Gendron K, Henke D, Forterre F. Assessment of intrathecal pressure in chondrodystrophic dogs with acute thoracolumbar disk disease. *Vet Surg* 2015; 44: 687-693.
 14. Medeiros FA, Gracitelli CP, Boer ER, Weinreb RN, Zangwill LM, Rosen PN. Longitudinal changes in quality of life and rates of progressive visual field loss in glaucoma patients. *Ophthalmology* 2015; 122: 293-301.
 15. Miller P. The glaucomas. In: Maggs D, Miller P, Ofri R, editors. *Slatter's fundamentals of veterinary ophthalmology*. 6th ed. St. Louis: Elsevier. 2018: 279-305.
 16. O'Neill DG, Lee MM, Brodbelt DC, Church DB, Sanchez RF. Corneal ulcerative disease in dogs under primary veterinary care in England: epidemiology and clinical management. *Canine Genet Epidemiol* 2017; 4: 5.
 17. Park SA, Sledge D, Monahan C, Bartoe JT, Komáromy AM. Primary angle-closure glaucoma with goniodysgenesis in a Beagle dog. *BMC Vet Res* 2019; 15: 75.
 18. Park YW, Jeong MB, Park SA, Kim WT, Kim SE, Ahn J, et al. A retrospective study of primary glaucoma in dogs: 43 cases (2006-2009). *J Vet Clin* 2012; 29: 38-42.
 19. Pearl R, Gould D, Spiess B. Progression of pectinate ligament dysplasia over time in two populations of Flat-Coated Retrievers. *Vet Ophthalmol* 2015; 18: 6-12.
 20. Plummer CE, Bras D, Grozdanic S, Komáromy AM, McLellan G, Miller P, et al. Prophylactic anti-glaucoma therapy in dogs with primary glaucoma: a practitioner survey of current medical protocols. *Vet Ophthalmol* 2021; 24 Suppl 1: 96-108.
 21. Plummer CE, Komáromy AM, Gelatt KN. The canine glaucomas. In: Gelatt KN, Ben-Shlomo G, Gilger BC, Hendrix DVH, Kern TJ, Plummer CE, editors. *Veterinary ophthalmology*. 6th ed. Ames: Wiley Blackwell. 2021: 1173-1255.
 22. Sapienza JS, van der Woerd A. Combined transscleral diode laser cyclophotocoagulation and Ahmed gonioimplantation in dogs with primary glaucoma: 51 cases (1996-2004). *Vet Ophthalmol* 2005; 8: 121-127.
 23. Scott EM, Esson DW, Fritz KJ, Dubielzig RR. Major breed distribution of canine patients enucleated or eviscerated due to glaucoma following routine cataract surgery as well as common histopathologic findings within enucleated globes. *Vet Ophthalmol* 2013; 16 Suppl 1: 64-72.
 24. Strom AR, Hässig M, Iburg TM, Spiess BM. Epidemiology of canine glaucoma presented to University of Zurich from 1995 to 2009. Part 1: congenital and primary glaucoma (4 and 123 cases). *Vet Ophthalmol* 2011; 14: 121-126.
 25. Tsai S, Bentley E, Miller PE, Gomes FE, Vangyi C, Wiese A, et al. Gender differences in iridocorneal angle morphology: a potential explanation for the female predisposition to primary angle closure glaucoma in dogs. *Vet Ophthalmol* 2012; 15 Suppl 1: 60-63.
 26. Wood JL, Lakhani KH, Mason IK, Barnett KC. Relationship of the degree of goniodysgenesis and other ocular measurements to glaucoma in Great Danes. *Am J Vet Res* 2001; 62: 1493-1499.
 27. Zur G, Lifshitz B, Bdolah-Abram T. The association between the signalment, common causes of canine otitis externa and pathogens. *J Small Anim Pract* 2011; 52: 254-258.