
Devin A. J. Johnsen, BS; David J. Maggs, BVSc, DACVO; Philip H. Kass, DVM, PhD, DACVP

Objective—To determine the immediately antecedent cause of secondary glaucoma and the prevalence of secondary glaucoma with anterior uveitis or lens dislocation in dogs.

Design—Retrospective case series.

Animals—156 dogs with secondary glaucoma.

Procedures—Cause of glaucoma was determined from records. Breed, age, sex, and neuter status of all dogs with secondary glaucoma were compared with the general hospital population. The prevalence of secondary glaucoma in dogs with a primary diagnosis of lens dislocation or anterior uveitis during the same period was determined.

Results—Secondary glaucoma was diagnosed in 156 of 2,257 (6.9%) dogs examined because of ophthalmic disease and was bilateral in 33 (21.2%) of those dogs. In 31 (94%) bilaterally affected dogs, the antecedent cause was the same in both eyes. Common causes of secondary glaucoma were nonsurgical anterior uveitis (44.9%), anterior uveitis associated with prior phacoemulsification (15.8%), and lens dislocation (15.2%). Parson Russell Terriers, Poodles, Boston Terriers, Cocker Spaniels, Rhodesian Ridgebacks, and Australian Cattle Dogs had diagnoses of secondary glaucoma more often than expected, compared with the reference population. Age, sex, neuter status, and laterality were not associated with secondary glaucoma. The prevalence of secondary glaucoma in dogs with lens dislocation or uveitis was 15% or 17%, respectively.

Conclusions and Clinical Relevance—Glaucoma develops secondary to many intraocular diseases, particularly uveitis and lens dislocation. Diagnosis of these diseases should prompt frequent monitoring of intraocular pressure, regardless of signalment. (J Am Vet Med Assoc 2006;229:1270–1274)

Glaucma in dogs is a common, complex, and multifactorial disease in which the flow of aqueous humor in the eye is impeded by a gross or microscopic intraocular abnormality; the IOP increases to values incompatible with normal neural function, and the optic nerve and retina are terminally injured.1,3 Although the terminology for classifying glaucoma in dogs has been confusing, glaucoma may be broadly categorized on an etiologic basis as primary or secondary. By use of a number of published definitions,1,4 primary glaucoma may be defined as a breed-related (presumably inherited) condition in which typically middle-aged dogs develop increased IOP in the absence of other antecedent ophthalmic disease. Affected dogs usually have unilateral disease when first examined, but the second eye subsequently becomes affected. Medical and surgical methods of decreasing IOP remain the mainstay of treatment for all dogs with primary glaucoma; however, these interventions are not entirely satisfactory, and treatment is usually unsuccessful and results in a nonvisual and painful globe. Even with hypotensive treatment, dogs with primary glaucoma are likely to lose vision in the affected eye within 12 months (median, 8 months) of referral to a veterinary ophthalmologist.1 Prophylactic treatment increases the median time to blindness caused by primary glaucoma in the contralateral eye to 31 months,1 but bilateral vision loss is inevitable in most dogs with primary glaucoma1 despite treatment. Affected dogs should be removed from breeding programs.

In contrast, secondary glaucoma has been described15 as developing in dogs in which high IOP can be ascribed to 1 or more identifiable primary intraocular diseases that impede aqueous humor flow within and from the eye. Recognized antecedent diseases include primary lens dislocation (luxation or subluxation),1,2,5,6,12 acute or chronic anterior uveitis,2,5,13-15 intraocular cysts,16,17 intumescent cataract formation (phacomorphic glaucoma),18 hyphema,19 intraocular neoplasia,2,10 and ocular melanosis (pigmentary glaucoma).2,12 Dogs with secondary glaucoma may have unilateral or bilateral glaucoma when examined, depending on the primary cause and, although secondary glaucoma is not inherited, the cause of the glaucoma may be. In contrast to primary glaucoma, secondary glaucoma may be successfully prevented or treated if the primary disease process is detected and treated sufficiently early.15 Importantly, even if secondary glaucoma causes loss of vision in 1 eye, if the primary condition can be prevented from occurring or progressing to cause secondary glaucoma in the contralateral eye, total vision loss can be avoided. Therefore, earlier recognition and more aggressive treatment of diseases that can lead to secondary glaucoma are essential goals in clinical practice.
Despite this, there are few reports regarding the prevalence of secondary glaucoma or the relative contribution of each of the known causes of secondary glaucoma in dogs. In fact, disagreement exists regarding the most common causes of secondary glaucoma. The study reported here was designed to determine the prevalence and immediately antecedent cause of secondary glaucoma in dogs and the characteristics of the affected population at 1 referral institution. An additional objective was to determine the prevalence of glaucoma in dogs with anterior uveitis or lens dislocation, 2 diseases that are known to cause secondary glaucoma.

Criteria for Selection of Cases

The computer database of records for dogs examined by members of the University of California-Davis VMTH ophthalmology service between July 1, 1999, and June 30, 2004, was searched for dogs with a diagnostic code of glaucoma. Medical records for these dogs were individually reviewed for a concurrent clinical diagnosis known to cause secondary glaucoma.

Procedures

For the purposes of the study, ophthalmic diagnoses considered to be potential causes of secondary glaucoma included lens dislocation (luxation or subluxation), anterior uveitis, intraocular cysts, cataract, hyphema, intraocular neoplasia, and ocular melanosis (pigmentary glaucoma). When anterior uveitis was diagnosed, it was further categorized as nonsurgical, associated with prior phacoemulsification for treatment of cataract, or associated with intracapsular lens extraction for lens dislocation. Because of the retrospective nature of the study and differences in the extent of diagnostic testing each dog underwent, the cause of nonsurgical uveitis could not be ascertained in a sufficient number of dogs to permit evaluation. Dogs without a concurrent condition known to cause glaucoma were considered to have primary glaucoma, and those medical records were not reviewed further. Records of dogs with glaucoma and a concurrent disease known to cause secondary glaucoma underwent detailed review. Each medical record was reviewed in its entirety by 2 investigators (DJM and DAJJ). Information collected included age of onset of glaucoma, sex, neuter status, breed, eye affected, and likely primary ophthalmic disease processes. When a single potential primary disease was diagnosed, glaucoma was considered to be secondary to that disease process if the medical record revealed that the disease had been present prior to development of glaucoma. When glaucoma and the potentially primary disease process coexisted at the time of the first examination at the VMTH, glaucoma was considered to be secondary if the putative primary disease was bilateral and the glaucoma was unilateral, if the disease preceded the onset of glaucoma as determined by the owner’s or referring veterinarian’s report, or if glaucoma was less severe or advanced than would have been expected if it had been a primary condition. When glaucoma and > 1 potential primary disease process were detected, the disease considered likely to have most recently preceded the onset of glaucoma (on the basis of the same criteria) was classified as the primary cause. When it was clear that ≥ 1 preexisting ophthalmic disease existed but the ocular disease that developed immediately antecedent to the development of glaucoma could not be determined with adequate certainty, glaucoma was classified as secondary and the cause was categorized as undetermined.

To determine a reference population against which the population of dogs with secondary glaucoma could be compared, information pertaining to the age, sex, neuter status, and breed of all dogs examined at the VMTH during the same period (July 1, 1999, to June 30, 2004) was also retrieved from the computer database. Effects of age at onset of secondary glaucoma, sex, neuter status, laterality, and bilaterality on cause of secondary glaucoma were assessed by use of a χ² test of homogeneity with commercial software. A χ² test of homogeneity was also used to assess age, breed, neuter status, and sex distributions between the reference and study populations. For these analyses, age was considered in 6 ranges as follows: 0 to < 3 years, 3 to < 6 years, 6 to < 9 years, 9 to < 12 years, 12 to < 15 years, and ≥ 15 years. For all analyses, values of P < 0.05 were considered significant. Only breeds in which ≥ 3 cases of secondary glaucoma were identified were used in breed comparisons. Dogs identified as crossed with a single breed (eg, terrier cross) were considered as individual breeds, whereas dogs identified as mixed breed were not included in breed analyses. The SMR was used to compare the most common breeds in the study population with those in the VMTH population. The SMR was calculated by comparing the observed number of dogs of a given breed in the study population with the expected number on the basis of the VMTH reference population.

In the second part of the study, the prevalence of secondary glaucoma was determined in dogs with a primary diagnosis of lens dislocation or anterior uveitis. The computer database of records for the same period studied in part 1 of the study was searched for all dogs with a diagnostic code of lens luxation, lens subluxation, or lens dislocation (collectively termed lens dislocation) or anterior uveitis or iridocyclitis (collectively termed anterior uveitis). For this portion of the study, anterior uveitis was not subcategorized as surgical or nonsurgical as was done in the initial phase of the study. Medical records of dogs with these primary diagnoses were reviewed to determine the prevalence of secondary glaucoma in that population. Dogs with primary glaucoma were excluded, and glaucoma was considered to be secondary to lens dislocation or anterior uveitis according to the guidelines used in the first part of the study.

Results

Members of the VMTH Veterinary Ophthalmology Service examined 2,257 dogs during the 5-year study period. Of those, 156 (6.9%) dogs (158 eyes) had a diagnosis of secondary glaucoma. Secondary glaucoma was diagnosed in dogs from all age ranges but was most common in middle-aged dogs, whereas the VMTH reference population was skewed toward younger animals (Figure 1). Age distributions were significantly (P < 0.001) different between the study population and the reference population. The sex distributions for the study and reference populations, respectively, were

JAVMA, Vol 229, No. 8, October 15, 2006
46.2% and 41.4% spayed females, 36.5% and 35.6% neutered males, 12.2% and 13.6% sexually intact males, and 5.1% and 9.5% sexually intact females; these differences were not significant (P = 0.24). Secondary glaucoma was diagnosed in 45 breeds and 28 breed crosses. The following breeds were represented by ≥ 5 dogs with secondary glaucoma: Parson Russell Terrier (n = 13), Cocker Spaniel (13), Golden Retriever (6), Australian Cattle Dog (5), Labrador Retriever (5), and Terrier cross (5). The number of cases per breed was too small to permit significance testing; therefore, SMR was used to assess the possible effects of breed and was found to be high for Parson Russell Terriers (SMR, 7.1), Poodles (4.7), Boston Terriers (4.1), Cocker Spaniels (3.7), Rhodesian Ridgebacks (4.1), and Australian Cattle Dogs (3.1). The SMR was decreased only in Labrador Retrievers (0.3).

Glucoma was considered to be secondary to nonsurgical anterior uveitis in 71 (44.9%) eyes, anterior uveitis after phacoemulsification in 23 (15.8%) eyes, lens dislocation in 24 (15.2%) eyes, intraocular tumor in 17 (10.8%) eyes, anterior uveitis after intracapsular lens extraction in 6 (3.8%) eyes, hyphema in 5 (3.2%) eyes, and cataract in 4 (2.5%) eyes (Figure 2). A markedly narrowed anterior chamber with presumed pupillary block was recorded for all 4 eyes (3 dogs) in which cataracts were considered to be the primary cause of glaucoma. Although all 4 of those eyes had signs of previous anterior uveitis, signs of active uveitis (aqueous flare) were noted in only 1 of those 4 eyes at the time glaucoma was diagnosed. The immediately antecedent cause of glaucoma could not be adequately determined in 6 (3.8%) eyes with secondary glaucoma. No significant effects of sex and neuter status, age, or laterality on the cause of secondary glaucoma were detected.

The right eye only was affected in 60 (38.3%) dogs, the left eye only was affected in 63 (40.4%) dogs, and both eyes were affected in 33 (21.2%) dogs. No significant difference in sex and neuter status or age was detected between dogs with unilateral secondary glaucoma and those with bilateral disease. No differences were detected between the 2 groups in breeds affected. However, the overall distribution of causes was different between dogs with unilateral or bilateral secondary glaucoma (P = 0.049). This difference was a result of the absence of intraocular tumor or hyphema as a primary diagnosis in any dog with bilateral secondary glaucoma. In 31 of the 33 (94%) dogs with bilateral secondary glaucoma, the same antecedent cause was detected in both eyes. In the remaining 2 dogs, glaucoma was considered to be secondary to lens dislocation in 1 eye and secondary to anterior uveitis associated with intracapsular lens extraction for lens dislocation in the other. In the second part of the study, the prevalences of secondary glaucoma in dogs with a primary diagnosis of lens dislocation or uveitis were 13% and 17%, respectively, during the 5-year period reviewed. However, accurate assessment of how rapidly secondary glaucoma developed in individual dogs was not possible.

Discussion

In the present study, secondary glaucoma was diagnosed in approximately 7% of all dogs examined for ophthalmic disease at this referral institution. These data are similar to those from another report in which glaucoma represented 8.6% of ophthalmic diagnoses. In the study reported here, secondary glaucoma was diagnosed most frequently in either eye of middle-aged to older dogs of either sex and irrespective of neuter status. Overrepresented breeds included the Parson Russell Terrier, Poodle, Boston Terrier, Cocker Spaniel, Rhodesian Ridgeback, and Australian Cattle Dog; however, many breeds and age groups were represented. Of the frequently affected breeds, the Boston Terrier, Cocker Spaniel, and Poodle have all been reported by other authors as being affected by primary glaucoma, and this finding has been supported by histologic or gonioscopic confirmation of goniodysgenesis in Cocker Spaniels. This finding highlights a problem inherent in the assumption that primary and secondary glaucoma are mutually exclusive. Rather, it seems reasonable that an...
eye that is genetically and anatomically predisposed to development of primary glaucoma may also be more likely to develop secondary glaucoma and to do so earlier and with a less severe primary insult than would an eye without the same genetic predisposition. This trend has also been observed in previous studies.\textsuperscript{2,3,12-14}

In contrast, Parson Russell Terriers, Rhodesian Ridgebacks, and Australian Cattle Dogs are not commonly reported to be affected by primary glaucoma.\textsuperscript{15}

Therefore, veterinarians should be suspicious of secondary glaucoma when a known antecedent disease is diagnosed in a dog with any signalment, but particularly those with a genetic predisposition to glaucoma.

The immediately antecedent causes of secondary glaucoma in the present study in order of decreasing frequency were nonsurgical anterior uveitis, anterior uveitis associated with prior phacoemulsification, lens dislocation, intraocular tumor, anterior uveitis associated with prior intracapsular lens extraction, hyphema, and cataract. Together, anterior uveitis and lens dislocation accounted for more than three fourths of all eyes with secondary glaucoma. Consequently, it was not surprising to find that the breeds most predisposed to primary lens dislocation (eg, terrier breeds, Australian Cattle Dogs, and Labrador Retrievers),\textsuperscript{3,11,12} primary uveitis (Golden Retrievers),\textsuperscript{17} or cataracts requiring phacoemulsification (terrier breeds, Cocker Spaniels, Labrador Retrievers)\textsuperscript{17} were represented most frequently in the present study. In contrast, it was reported in a recent study\textsuperscript{18} that secondary glaucoma was most frequently associated with cataract formation. This likely represents differences between the 2 studies in research methods and definitions of conditions. In the present study, we attempted to determine the disease process that resulted directly in development of secondary glaucoma; authors of the previous study,\textsuperscript{18} however, reported ocular diagnoses that are most commonly codiagnosed with glaucoma, and it was not clear how primary and secondary processes were differentiated. Although intumescent cataracts can directly cause glaucoma via lens enlargement and associated pupillary block, with or without iridocorneal angle closure (so-called phacomorphic glaucoma),\textsuperscript{19} this direct association was diagnosed rarely in dogs in our study and accounted for only 2% of dogs with secondary glaucoma. Because cataracts are a common cause of anterior uveitis in dogs, some or all of these 4 eyes (3 dogs) may have developed glaucoma secondary to anterior uveitis rather than, or in addition to, pupillary block and forward displacement of the iris. However, the fact that all 4 eyes had narrowed anterior chambers and only 1 of 4 eyes had clinical evidence of active uveitis at the time secondary glaucoma was diagnosed suggests that iris displacement played an important role in the precipitation of glaucoma in those dogs. More commonly in our study population, anterior uveitis (likely subsequent to development of cataracts or surgery for cataracts in many dogs) was believed to be the immediately antecedent cause of secondary glaucoma. This conclusion was supported by prevalence data from the second part of the study, in which secondary glaucoma was observed to have developed in 17% of dogs with anterior uveitis. In comparison, Gelatt and MacKay\textsuperscript{5} reported that only 7.1% of dogs had anterior uveitis and secondary glaucoma.

Other differences between the 2 studies warrant discussion. Investigators in the earlier study\textsuperscript{7} conducted the record search on the basis of a finite number of diagnostic codes for possible causes of secondary glaucoma (ie, cataract formation, lens luxation, cataract surgery, uveitis of unknown cause, hyphema of unknown cause, and intraocular neoplasia), whereas in the present study, we did not exclude any potential disease processes. Additionally, because of the period of review (39 years) and the multicenter nature of the veterinary medical database from which data were gathered in the earlier study, criteria for each diagnosis, as well as the consistency and training of the practitioners making the diagnoses, likely varied. The study reported here was designed to determine the immediately antecedent cause of secondary glaucoma in dogs at a single referral institution over a more limited interval during which personnel, diagnostic techniques, equipment, criteria, and medical recordkeeping were less likely to vary. Therefore, we selected a period of 3 years during which all diagnoses were made by use of a single style of tonometer used by 3 board-certified veterinary ophthalmologists or 6 residents being trained by those ophthalmologists. Furthermore, in the present study, each medical record was reviewed in its entirety by only 2 investigators, resulting in consistent application of the entry and evaluation criteria.

As is true for all retrospective studies, constructs of the present study reflect some inherent weaknesses. First, dogs included in this study were all examined at a university referral hospital and this population may not accurately represent the population of dogs examined by general practitioners. Secondly, the reliability of data retrieved from medical records is dependent on accurate reporting. In particular, breed definition may have been affected by interpretive change. The most important potential weakness in the present study and others like it may be the difficulty in correctly determining whether glaucoma is primary or secondary in nature and in correctly defining the immediately antecedent cause of secondary glaucoma. Many of the diseases we defined as potential causes of glaucoma can also be caused by glaucoma. Furthermore, many of the primary antecedent diseases are caused by and can cause other antecedent diseases. Therefore, secondary glaucoma may be caused by or cause directly or indirectly many of the diagnoses defined in this study as primary and thereby create a cycle of intraocular pathologic change in which it can be difficult to ascertain the original event.

Although primary glaucoma is a painful and typically blinding disease, secondary glaucoma can sometimes be prevented, especially in the contralateral eye, if the primary disease process is promptly identified and aggressively treated. Differentiation of primary from secondary glaucoma is an essential early step in the clinical approach to these diseases because the distinction is a critically important determinant of treatment, prognosis, and breeding advice. It is therefore imperative that veterinarians are alert to the associa-
tions between secondary glaucoma and the antecedent diseases reported and schedule all dogs with ≥ 1 of these primary diagnoses for serial monitoring of IOP. Dogs with anterior uveitis, regardless of cause, should be especially monitored because that diagnosis accounted for nearly two thirds of all dogs with secondary glaucoma in the first part of the study and because, in the second part of the study, 17% of dogs with uveitis developed secondary glaucoma within 5 years of diagnosis. The absence of association between secondary glaucoma and sex, neuter status, age, or laterality underscores the need to be alert for these primary disease processes and to monitor IOP in all dogs affected with these conditions.

References