Ultrasound biomicroscopy operates at frequencies of 50 to 100 MHz and was developed to evaluate the anterior chamber of the human eye. Ultrasound biomicroscopy has been used prior to and after phacoemulsification in humans to evaluate the ICA and the trabecular iris angle, which is the equivalent of the canine ICA. Structural changes of the anterior chamber have been quantified in humans prior to and after cataract surgery via UBM, with high intraobserver reproducibility.

High-resolution ultrasound operating at frequencies of approximately 20 MHz and UBM have also recently been used to evaluate the ICA of dogs. To our knowledge, there are no reports of imaging studies in dogs in which the structure of the ICA was assessed before and immediately after phacoemulsification and IOL implantation. This information would be useful in evaluation of the morphology of the ICA structures in dogs with POH and would help better elucidate the pathophysiology of POH, which has a reported incidence of 20% to 49% following phacoemulsification and IOL implantation.

In humans, the change of the AOD after cataract surgery may be of clinical use for evaluation and treatment of eyes with angle closure glaucoma or occludable angles. In dogs, this information may also be valuable in the evaluation of diseases of small angles, such as goniodysgenesis, and in the investigation of the pathophysiology of POH. The purpose of the study reported here was to compare the ICA and AOD in dogs with cataractous and noncataractous lenses; evaluate eyes before surgery were at greater risk of developing POH. This information may be useful for future studies to determine whether preventative treatment for POH administered prior to surgery may be beneficial. (Am J Vet Res 2008;69:279–288)

Objective—To compare the iridocorneal angle (ICA) and angle opening distance (AOD) in dogs with cataractous and noncataractous lenses; evaluate cataractous eyes ultrasonographically for association of postoperative ocular hypertension (POH) with the ICA, AOD, and postoperative echogenic anterior chamber debris; and evaluate intraobserver reliability associated with ICA and AOD measurements.

Animals—56 dogs with 102 cataracts, and 23 clinically normal dogs.

Procedures—Ultrasound biomicroscopy was performed on 102 eyes of 56 dogs before and after cataract surgery and on 46 nondilated and dilated eyes of 23 clinically normal dogs. Cataract stage, ICA, AOD, and association with POH were assessed.

Results—Cataract stage and ICA or AOD were not significantly associated; however, ICA and AOD typically decreased with increasing cataract maturity. Before and after pupillary dilation, AODs were significantly smaller in cataractous eyes than in noncataractous eyes. Before surgery, ICA and AOD in eyes without pupillary dilation were significantly associated with POH. At >13°, odds of developing POH increased by 11% for each degree increase in the ICA. Postoperative anterior chamber debris was not associated with POH. Coefficient of variation for repeated measurements was 10% for the ICA and 9.5% for the AOD, suggesting good intraobserver reliability.

Conclusions and Clinical Relevance—In this study, dogs with larger ICA and AOD measurements before surgery were at greater risk of developing POH. This information may be useful for future studies to determine whether preventative treatment for POH administered prior to surgery may be beneficial.
ultrasonographically for association of POH with the ICA, AOD, and postsurgical echogenic anterior chamber debris; and evaluate intraobserver reliability associated with ICA and AOD measurements.

Materials and Methods

Selection of dogs—Dogs that underwent elective cataract surgery at The Ohio State University Veterinary Medical Teaching Hospital between June 2004 and July 2005 were eligible for inclusion in the prospective clinical study. For each dog, informed consent from the owner was obtained prior to inclusion of the dog in the study. This study was approved by the Animal Use and Care Committee of The Ohio State University Veterinary Medical Teaching Hospital. All dogs underwent a complete ophthalmic evaluation prior to UBM, including applanation tonometry, biomicroscopy, indirect ophthalmoscopy, and high-resolution ultrasonography of both eyes. If ocular examinations revealed no abnormalities other than the presence of a cataract in an affected dog, the dog's eyes were included in the study. Dogs with brachycephalic, mesaticephalic, and dolichocephalic skull types were examined. Eyes with congenital ocular diseases or traumatic cataracts, aggressive dogs that did not allow examination of the eye without sedation, dogs with retinal detachments or flat electroretinograms, dogs with microphthalmia or deep orbits that precluded obtaining a diagnostic image because of the large footprint of the ultrasound probe were not included in the study. Eyes of healthy dogs with no abnormal findings via ocular examination were included in the study as noncataractous eyes.

Tonometry—To perform tonometry, 0.5% proparacaine hydrochloride (a topical ophthalmic anesthetic agent) was applied to both of each dog's eyes. Tonometry was performed on all eyes with an applanation tonometer prior to surgery and at 1 and 3 hours after surgery.

Cataract staging—The stage of each cataract was determined on the basis of findings of an ocular examination performed by an ophthalmologist (AGM or DAW). Cataracts were classified as follows: incipient cataract = early focal lens opacity without significant vision change; immature cataract = incomplete marked lens opacity, tapetal reflex still visible, and decreased vision; mature cataract = completely opaque lens, fundus not visible ultrasonoscopically; intumescent cataract = swollen lens; and hypermature cataract = evidence of lens resorption and possibly LIU.

UBM examinations—Examinations were performed by use of a high-definition ultrasound system. In dogs with cataracts, the examinations were performed before surgery without pupillary dilation and 30 minutes after topical administration of tropicamide and then at 1 and 3 hours after phacoemulsification and IOL implantation. In dogs without cataracts, examinations were performed without pupillary dilation and 30 minutes after topical administration of tropicamide. Examinations were performed with a 53-MHz mechanical transducer that allowed tissue penetration of 7 mm. Proparacaine hydrochloride was instilled into each eye to provide local anesthesia. Sterile lubricating gel was used as a coupling medium between the ultrasound transducer and the globe. Dogs were in a sitting position for the ocular imaging. The eyelids were manually held open; the transducer was placed directly over the globe and centered at the dorsal limbus in the sagittal plane. When the ultrasound probe was held perpendicular to the globe, the ICA was at its largest and an image was obtained.

ICA measurement—The apex of the measured ICA was placed at the junction of the iris, trabecular meshwork, and sclera, and the lines were extended from the apex along the inner surface of the sclera and iris to the level of the limbus. An ICA measurement was obtained (Figure 1).

AOD measurement—A 500-μm line was drawn from the apex of the ICA to a point on the inner corneoscleral surface. From this point, a line perpendicular to the first line was drawn to the iris, and the length of this perpendicular line was measured (Figure 1). This measurement is similar to the AOD measurement in a human study.

Images were imported into a computerized imaging program. By use of calipers provided with the software, the described measurements were made. All images had ICA and AOD measurements determined by 1 individual (MDR). Additionally, 24 images of the cataractous eyes obtained without pupillary dilation were measured 3 times by 1 individual (MDR) to evaluate intraobserver reliability. The individual making measurements was unaware of the patient identification, intraocular pressure measurements, and the time point at which the image was obtained.

Evaluation for anterior chamber debris—Images obtained after surgery were evaluated for ultrasonographically evident echogenic anterior chamber debris.

Figure 1—Drawing to illustrate the measurement of the ICA and AOD on a UBM image of a canine eye. The inset image illustrates the anterior and posterior chamber, lens, and ICA; the larger image illustrates a closer view of the ICA.
Results were considered positive if the anterior chamber appeared anechoic prior to surgery and had small suspended hyperechoic particles in it after surgery.

Surgery—Phacoemulsification and artificial lens implantation were performed. The anterior chamber was reinfilled with sodium hyaluronate (a viscoelastic substance). An IOL made of PMMA or acrylic was implanted into the capsular bag. Surgery was performed by 1 of 3 board-certified ophthalmologists (2 of which were investigators in the study [DAW and AGM]). The viscoelastic substance was removed from the anterior chamber via irrigation and aspiration. If POH developed 1 to 5 hours after surgery, the dogs received 1 or more of the following treatments: topical application of a carbonic anhydrase inhibitor, oral administration of a carbonic anhydrase inhibitor, topical application of a parasympathomimetic preparation, IV administration of an osmotic diuretic, or passive ocular centesis.

Statistical analysis—in most of the dogs with cataracts, the elective cataract surgery was performed on both eyes and several repeated measurements were obtained from each eye (measurements with and without pupillary dilation were obtained prior to surgery, and 2 measurements were obtained after surgery). Also, full ocular examinations were performed on both eyes of 23 dogs without cataracts. This correlated data structure needed to be accounted for in the statistical analysis. Therefore, to evaluate whether the ICA and AOD in cataractous and noncataractous eyes were different and whether the ICA or AOD measurements changed over time, a repeated-measures analysis was performed. A compound symmetry covariance structure was used to account for the correlated data (ie, repeated measures from an eye and 2 eyes/dog). Time points at which measurements were obtained and cataract status (yes or no) of the eye were included as explanatory variables in the model. If either of those aforementioned variables was significantly associated with the outcome (ICA or AOD), an interaction term between them was also tested. Inclusion of the interaction term between cataract status and time allowed the comparison of the noncataractous eyes with the cataractous eyes at any time point as well as comparison of each eye before and after pupillary dilation. A Tukey-Kramer procedure was used to adjust for the multiple comparisons. A similar analysis was performed to evaluate whether the stage of cataract, including diabetes-mellitus–related cataracts, was associated with the ICA and AOD values without pupillary dilation and assess the difference in the ICA and AOD among differing stages of cataracts. To evaluate whether occurrence of POH was significantly associated with the ICA or AOD before surgery, the ICA or AOD change from the value before surgery to the value after surgery, or the ultrasonographic detection of anterior chamber debris, generalized estimation equations with logit link and binomial error distribution were used. In the analyses, POH was used as the outcome, and percentage change in the ICA and AOD values from before to after surgery; the actual ICA and AOD values before surgery; and diagnosis of diabetes mellitus, cataract stage, age, and breed of the dog were considered as explanatory variables or potential confounders. Compound symmetry covariance structure was used to account for the correlated data (2 eyes/dog). The change from the baseline value (both before and after pupillary dilation) at 1 and 3 hours after surgery was calculated as follows:

\[ \% \text{change} = \left( \frac{1}{\text{ICA or AOD after surgery} - \text{ICA or AOD at baseline}} \right) \times 100 \]

Intraobserver coefficients of variation (calculated as 100% multiplied by [SD divided by mean value]) were derived by use of the measurements obtained from a subset of dogs generated by 1 observer (MDR). A value of \( P < 0.05 \) was considered significant.

Results

Ultrasound biomicroscopy was performed on 46 noncataractous eyes of 23 dogs for which no abnormal findings were obtained via ocular examination. The mean age of these dogs was 5.0 ± 2.73 years (range, 0.6 to 10 years), and mean weight was 18.7 ± 12.2 kg (range, 4.3 to 41.3 kg). There were 8 male dogs and 15 female dogs.

Ultrasound biomicroscopy was also performed on 102 eyes of 56 dogs undergoing elective cataract surgery. Among these dogs, there were 48 purebred and 8 mixed-breed dogs. The most common breeds represented included the Bichon Frise, Cocker Spaniel, Boston Terrier, Miniature Schnauzer, and mixed. There were 36 males and 20 females, which was similar to the sex distribution within the hospital canine population. Mean age of these dogs was 8.3 ± 2.9 years (range, 0.9 to 14.6 years), and mean weight was 12.2 ± 2.9 kg (range, 4.2 to 44.7 kg). Age or breed of dogs was not associated with the development of POH in the analyses of the study data.

Prior to surgery, 12 dogs with cataractous eyes were excluded for the following reasons: microphthalmia or inability to place the probe on the surface of the eye because of a deep orbit (3 dogs; 6 eyes), flat or decreased corneal thickness (3 dogs; 5 eyes), aggressive behavior (3 dogs; 6 eyes), precluding ocular ultrasonographic examination (1 dog; 1 eye), persistent tunic vasculosa lenta and persistent hyperplastic primary vitreous (2 dogs; 4 eyes), and trauma-induced cataract (1 dog; 1 eye). After surgery, 4 dogs with 8 cataractous eyes were removed from the study for the following reasons: posterior chamber hemorrhage (1 dog), ventricular tachycardia (1 dog), and prolonged anesthetic recovery period during which ultrasonographic images could not be obtained (2 dogs).

Duration of phacoemulsification ranged from 6 seconds to 7 minutes and 18 seconds. Following surgery, most dogs received at least 1 treatment as follows: topical application of a carbonic anhydrase inhibitor, oral administration of a carbonic anhydrase inhibitor, topical application of a parasympathomimetic preparation, IV administration of an osmotic diuretic, or passive ocular centesis. Administration of treatments varied from immediately to 5 hours after surgery; 4 dogs received no treatments, 10 dogs received treatment at 1 time point, 14 dogs received treatments at 2 time points, 2 dogs received treatments at 3 time points.
received treatments at 3 time points, 3 dogs received treatments at 4 time points, 2 dogs received treatments at 5 time points, and 1 dog received treatments at 6 time points.

Reported postoperative complications included lens capsule tears (7 eyes), decentered lens (2), broken haptic (anchoring device of implanted lens; 2), corneal ulcer (1), corneal sloughing (1), bulging vitreous humor (1), lens subluxation (1), and extrusion of vitreous humor into the anterior chamber (1).

**Findings in noncataractous eyes**—In noncataractous eyes, the ICA after pupillary dilation (10.4° ± 5.0°) was significantly (P = 0.01) smaller than the value before pupillary dilation (12.6° ± 5.3°; Table 1). The AOD before (273.4 ± 88.9 µm) and after (275.6 ± 71.1 µm) pupillary dilation were not significantly (P = 0.99) different (Figure 2).

**Findings in cataractous eyes before surgery**—Anatomic features were easily identified in UBM images of cataractous eyes (Figure 3). In cataractous eyes, the ICAs before (13.6° ± 6.4°) and after (12.8° ± 5.8°) pupillary dilation were not significantly (P = 0.47) different. The AODs before (204.4 ± 96.6 µm) and after (192.3 ± 87.7 µm) pupillary dilation were not significantly (P = 0.64) different (Table 1). Images of the noncataractous eyes before and after pupillary dilation were compared with images of cataractous eyes before and after pupillary dilation prior to surgery. After pupillary dilation, there was peripheral and anterior displacement of the iris, resulting in crowding of the iris base at the ICA, in cataractous eyes. It was not possible to subjectively evaluate for predilation-to-postdilation changes in the ICA or AOD measurement in noncataractous or cataractous eyes (Figure 4).

**Comparison of noncataractous and cataractous eyes**—Comparison of images obtained from dogs with cataracts with those obtained from dogs without cataracts revealed that the AODs before and after pupillary dilation were significantly (P < 0.001) smaller in cataractous eyes than in noncataractous eyes (Figure 5). All...
though not significantly different, the ICA in noncataractous eyes after pupillary dilation was smaller than the value in cataractous eyes after pupillary dilation (Figure 6). The ICAs before pupillary dilation of noncataractous and cataractous eyes were not significantly (P = 0.82) different.

Association of cataract stage and ICA and AOD before pupillary dilation—The stage of the cataract was not significantly (P > 0.05) associated with ICA or AOD before pupillary dilation; however, there was a decrease (albeit not significant) in mean ICA and AOD with increasing maturity of the cataract (Table 2). Stage of cataract and diabetes-mellitus–related cataracts were not significantly (P > 0.05) associated with the change in ICA from the value before pupillary dilation to that determined after pupillary dilation. A large range of ICA changes were detected with each cataract stage and with diabetes-mellitus–related cataracts.

Association of POH with ICA and AOD before pupillary dilation in cataractous eyes prior to surgery—Prior to surgery, ICA and AOD before pupillary dilation were significantly (P < 0.05) associated with POH in cataractous eyes. For every degree increase in the ICA and for every 10-µm increase in the AOD in the absence of pupillary dilation, the odds of an eye developing POH increased by 3.8% (odds ratio, 1.038; P = 0.02) and 3.9% (odds ratio, 1.039; P = 0.02), respectively. To explore the value of ICA at which eyes developed POH, the data were arbitrarily divided into 2 groups. Because the ICA for clinically normal dogs has not been established, the mean of all ICA measurements (13°) was used as the dividing point. Eyes for which the ICA before pupillary dilation was < 13° were assigned to group 1; eyes for which the ICA before pupillary dilation was ≥ 13° were assigned to group 2. In both sets of data, an increase in the ICA was associated with an increased likelihood of development of POH. The association was not significant (P = 0.36) when the ICA before pupillary dilation was < 13°, but was significant (P = 0.018) when the ICA before pupillary dilation was ≥ 13°. In group 2, the odds of an eye developing POH increased 11% with each degree increase in the ICA.

Association of POH with ICA and AOD after pupillary dilation in cataractous eyes prior to surgery—Prior to surgery, ICA and AOD after pupillary dilation were not significantly (P = 0.76 and 0.77, respectively) associated with POH in cataractous eyes. Values of ICA and AOD before and after pupillary dilation were not significantly (P = 0.36 and 0.72, respectively) different.

POH and changes in ICA and AOD associated with surgery—The values of ICA and AOD were assessed in cataractous eyes before and after surgery, and the changes in these values as a result of surgery were evaluated. The changes between preoperative and postoperative ICA and AOD values were not significantly associated with the incidence of POH (P > 0.2 for all comparisons). Generally, reductions in the ICA and AOD were detected after surgery, compared with the values determined before pupillary dilation prior to surgery; however, there was considerable variability in the changes in ICA and AOD in response to surgery. Among all the cataractous eyes, the ICA decreased by as much as 90% and increased by as much as 186%; the AOD decreased by as much as 90% and increased by as much as 688% (Table 3).

POH and development of anterior chamber debris after surgery—Varied amounts of echogenic debris were suspended in the anterior chamber of some eyes

Table 1—Mean ± SD (range) ICA and AOD in the eyes of 23 dogs without cataracts and 56 dogs with cataracts before and after pupillary dilation.

<table>
<thead>
<tr>
<th>Type of eye</th>
<th>ICA (degrees)</th>
<th>AOD (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noncataractous (n = 46 eyes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before pupillary dilation</td>
<td>12.6 ± 5.3</td>
<td>273.4 ± 88.9</td>
</tr>
<tr>
<td>After pupillary dilation</td>
<td>10.4 ± 5.0</td>
<td>275.6 ± 71.1</td>
</tr>
<tr>
<td>Cataractous (102 eyes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before pupillary dilation</td>
<td>13.6 ± 6.4</td>
<td>204.4 ± 96.6</td>
</tr>
<tr>
<td>After pupillary dilation</td>
<td>12.8 ± 5.8</td>
<td>192.3 ± 87.7</td>
</tr>
</tbody>
</table>

*Within a variable for a type of eye, values with a different superscript in a column were significantly (P < 0.05) different.
The presence of debris in the anterior chamber on postoperative images was not associated with POH (P > 0.05). At 1 hour after surgery, 27 of 102 (26.5%) eyes had POH, and only 3 of those 27 eyes had debris in the anterior chamber visible on UBM images. At 3 hours after surgery, 33 (32.4%) eyes had POH, and only 8 of those 33 eyes had debris in the anterior chamber visible on UBM images.

**Intraobserver reliability**—Intraobserver reliability associated with ICA and AOD measurements was assessed. The coefficient of variance for intraobserver reliability was 10% for the ICA measurement and 9.5% for the AOD measurement.

**Discussion**

In the present study, the mean ICA of noncataractous eyes of dogs was 12.6° ± 3.3° (range, 5° to 29°). This is smaller than the value determined in a study of nonglaucomatous eyes in Cocker Spaniels, in which the mean ICA was 26.2° ± 4.5° (range, 16° to 38°). The differences in findings between these 2 studies may be attributable to differences in breed population or minor differences in angle measurement. Also, other diseases of the eye that were not related to glaucoma, such as cataracts, may have been present in the Cocker Spaniels and contributed to changes in the ICA.

In the dogs of the present study, the ICA in noncataractous eyes after pupillary dilation was significantly smaller than the value before pupillary dilation; however, the AOD before and after pupillary dilation did not differ significantly. This may be attributed to the position of the iris following pupillary dilation. After pupillary dilation, the iris is displaced anteriorly and peripherally away from the lens capsule, which may reduce the size of the ICA, but at the level where the AOD is measured, the iris remains in a position similar to that detected in images obtained before pupillary dilation. In rats, the pupil dilation achieved after topical application of pilocarpine re-
ults in crowding of the iris base at the ICA and a decrease in the ICA measurement.\textsuperscript{18}

In dogs with cataracts in the present study, the difference in ICA before and after pupillary dilation was not significant, unlike the change in noncataractous eyes. This may be explained by the fact that the pupil dilates fully in noncataractous eyes, whereas the pupil does not always dilate completely in cataractous eyes because of low-grade LIU.\textsuperscript{13} Evaluation of the size of the ICA in dogs with LIU as a subgroup was not performed in our study; however, this information would have been valuable. Also, the difference in AOD before and after pupillary dilation was not significant, which was similar to the finding in noncataractous eyes.

On comparison of UBM images from dogs with and without cataracts, the AOD of eyes with cataracts was significantly smaller than that of eyes without cataracts. This may be caused by displacement of the iris anteriorly by an abnormally thick lens. In cataractous eyes of dogs with diabetes mellitus, the axial lens thickness is significantly greater than the thickness in noncataractous eyes, and eyes with mature cataracts frequently have increased lens thickness, compared with normal lenses.\textsuperscript{19} Also, the anterior chamber depth is smaller in eyes with diabetes-mellitus–related cataracts.\textsuperscript{19} Measurement of the anterior chamber depth may have provided more information as to the pathophysiology of the decrease in size of the AOD; however, this was not performed.

Another possible cause of the smaller AOD in cataractous eyes is an anatomic change of the iris. In an eye with a cataract, mild iritis secondary to LIU may develop. The inflammation of the iris may cause an increase in iridal blood flow resulting in engorged vessels and local infiltration of inflammatory cells that causes thickening of the iris stroma. The major arterial circle in the iris is adjacent to the trabecular meshwork,\textsuperscript{20} which is at

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure5.png}
\caption{Figure 5—Representative UBM images of the AOD (obtained without pupillary dilation) in a noncataractous eye (A) and a cataractous eye (B) of a dog. The AOD of the cataractous eye is smaller than that of the noncataractous eye as a result of anterior displacement of the iris and crowding of the iris at the base. Image scale is in millimeters.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure6.png}
\caption{Figure 6—Representative UBM images of the ICA (obtained after pupillary dilation) in a noncataractous eye (A) and a cataractous eye (B) of a dog. Typically, ICA is smaller in noncataractous eyes because of the displacement of the iris when the pupil is completely dilated; however, this difference between cataractous and noncataractous eyes was not significant in the present study. In cataractous eyes, the pupil does not always completely dilate, resulting in less anterior displacement of the iris. Image scale is in millimeters.}
\end{figure}
the level of the AOD measurement. If the arterial circle was enlarged and local iridal swelling was present, this may result in a smaller AOD measurement. The ICA measurement would not change because it is measured closer to the pupillary margin of the iris where enlargement of the major and minor arterial circles would not affect the measurement.

Among the dogs of the present study, stage of cataract was not significantly correlated with the ICA or AOD before pupillary dilation or with the change in ICA as a result of pupillary dilation. Diabetes-mellitus–related cataracts were not significantly associated with the ICA change induced by pupillary dilation. Mean ICA and AOD values for immature cataracts were larger than the values for other cataract stages, and mean values decreased with increasing cataract maturity. The apparent decrease in the ICA and AOD of the mature and intumescent cataracts may be a result of an increase in axial length of the lens, which results in decreased ICA and AOD measurements. Eyes with mature and intumescent cataracts have an increased axial lens length, compared with lenses of noncataractous eyes. Hypermature cataractous lenses may be axially smaller than immature and mature lenses because of leakage of lens proteins from the capsular bag, a process that is termed resorption. A smaller hypermature cataractous lens may be expected to result in larger ICA and AOD measurements; however, in the present study, the ICA and AOD measurements were smaller in eyes with hypermature cataractous lenses than the measurements in eyes with mature cataractous lenses, instead of larger as expected. This may be a result of minimal lens resorption, as is evident in early hypermature cataracts in which focal changes of hypermaturity (caused by liquefaction and leakage of the liquefied cortex out of the capsular bag) result in changes such as capsular wrinkles and a lens that is the same size as that associated with an immature or mature cataract. In the present study, cataract stage was determined on the basis of findings of the examination performed by an ophthalmologist. To more accurately determine the extent of hypermaturity and lens size, 20-MHz B-mode ultrasonography could be used to measure the axial lens thickness. The lack of association of cataract stage with the pupillary-dilation–induced change in ICA is likely attributable to the high variability among ICA measurements before and after surgery.

The significant association of increasing ICA and AOD without pupillary dilation before surgery with development of POH was an unexpected result. Before surgery, the iris in a phakic eye was in contact with the lens; however, the iris in a pseudophakic eye was not in contact with the lens. This suggests that the iris may have been displaced anteriorly by the lens in phakic eyes and shifted posteriorly after lens removal. We speculate that the forward displacement of the iris caused by the lens may be greater in eyes with smaller ICA and AOD values before surgery than in eyes with larger ICA and AOD values before surgery. Therefore, a posterior shift of the iris induced by lens removal may have been greater in eyes with smaller ICA and AOD values before surgery. Conversely, the posterior shift of the iris in eyes with larger ICA and AOD values before surgery may have been less, resulting in a relatively diminished increase in size of the outflow tract than that achieved in eyes with smaller ICA and AOD values before surgery. This may partially explain the development of POH in eyes with large ICA and AOD measurements before pupillary dilation in our study. In humans, the lens in an eye with a narrow ICA and short anterior chamber depth is positioned more forward than it is in an eye with a wider angle before surgery. Therefore, a backward shift after lens removal is hypothesized to be more dramatic in an eye that has a shallow anterior chamber.

The changes in ICA and AOD values before and after surgery were not significantly correlated with the incidence of POH because of the variability in the ICA and AOD changes. The high variability in the ICA and AOD measurements in the immediate postoperative period may be related to many factors, including ciliary cleft collapse, the subjective evaluation of the amount of fluid needed to reinflate the eye after surgery, and the subjective evaluation of the subjective evaluation of the subjective evaluation of the amount of fluid needed to reinflate the eye after surgery, and the subjective evaluation of the amount of fluid needed to reinflate the eye after surgery, and the subjective evaluation of the amount of fluid needed to reinflate the eye after surgery, and the subjective evaluation of the amount of fluid needed to reinflate the eye after surgery.

### Table 2

<table>
<thead>
<tr>
<th>Cataract stage</th>
<th>No. of eyes</th>
<th>ICA (degrees)</th>
<th>AOD (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incipient</td>
<td>16</td>
<td>16</td>
<td>240</td>
</tr>
<tr>
<td>Immature</td>
<td>36</td>
<td>14.7 ± 7.0 (4–34)</td>
<td>220 ± 104.7 (60–510)</td>
</tr>
<tr>
<td>Mature</td>
<td>17</td>
<td>14.2 ± 6.8 (4–26)</td>
<td>212.9 ± 101.8 (60–390)</td>
</tr>
<tr>
<td>Intumescent</td>
<td>11</td>
<td>13.0 ± 3.7 (8–22)</td>
<td>195.0 ± 55.7 (120–330)</td>
</tr>
<tr>
<td>Hypermature</td>
<td>31</td>
<td>12.3 ± 6.4 (3–25)</td>
<td>183.9 ± 96.6 (45–375)</td>
</tr>
<tr>
<td>All</td>
<td>96</td>
<td>13.8 ± 6.4 (3–34)</td>
<td>204.4 ± 96.6 (45–510)</td>
</tr>
</tbody>
</table>

### Table 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Time after surgery (h)</th>
<th>Change in values before pupillary dilation*</th>
<th>Change in values after pupillary dilation†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean ± SD (%)</td>
<td>Range (%)</td>
</tr>
<tr>
<td>ICA</td>
<td>1</td>
<td>-10.4 ± 50.5</td>
<td>-90.5 to 150.0</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>-2.4 ± 56.4</td>
<td>-90.5 to 185.7</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>-2.6 ± 88.0</td>
<td>-90.5 to 688.1</td>
</tr>
<tr>
<td>AOD</td>
<td>1</td>
<td>-2.6 ± 56.4</td>
<td>-90.5 to 185.7</td>
</tr>
</tbody>
</table>

*Changes calculated by use of ICA and AOD values before pupillary dilation prior to surgery as the baseline. †Changes calculated by use of ICA and AOD values after pupillary dilation prior to surgery as the baseline.
passive ocular centesis performed in several dogs after surgery, which may have caused a reduction in the anterior chamber depth, ICA, AOD, and intraocular pressure. Also, in dogs, a scleral spur is not present. Therefore, on UBM images from dogs, a 500-µm line is drawn from at the apex of the junction of the iris and cornea to enable calculation of the AOD, whereas on images from humans, the AOD is measured by extending a 500-µm line from the scleral spur to a point on the corneoscleral surface. The procedure used for images from canine eyes may have contributed to variability in the measurements because of minor differences in identifying the location of the apex of the ICA. Topical application of medications after surgery may also have contributed to changes in the ICA and AOD measurements. Results of UBM indicate that 1 hour following topical administration of pilocarpine in humans, the AOD and trabecular iris angle increase in eyes with narrow measurements prior to treatment and decrease in eyes with wide measurements prior to treatment. In rats, pilocarpine causes the ICA to become narrow because of anterior bowing of the iris. In our study, 34 eyes received ocular administration of pilocarpine during the first 5 hours after surgery. Two eyes were treated with pilocarpine immediately after surgery, which may have caused changes in the ICA and AOD.

On images obtained from the dogs of the present study after surgery, detection of debris in the anterior chamber was not associated with POH. On some images, a large amount of debris was identified in the anterior chamber, but none was ever detected in the trabecular meshwork. This is consistent with the findings of a study in dogs that underwent phacoemulsification, in which there was no histologic evidence of residual lens fragments in the corneoscleral trabecular meshwork. This is consistent with the findings of a recent report of high-resolution ultrasonography in dogs.

In the present study, there were several confounding variables, including lack of standardization of anesthesia protocols and of protocols for postoperative administration of ocular medications; however, the use of medications was tailored specifically to each individual dog and to postoperative complications. The differences in duration of the phacoemulsification procedure may have contributed to differences in postoperative intraocular pressure and the inflammatory response. The IOL implants were made of either polymethyl methacrylate or foldable acrylic; the different materials may have contributed to differences in the prevalence of POH and inflammation in the anterior chamber of the eye. Although all surgeries were performed by board-certified ophthalmologists, differences in experience level and technique may have lead to differences in development of POH.

The results of the present study in dogs indicated that mean ICA and AOD decrease with increasing cataract maturity, which may be associated with the lens size in cataractous eyes. The significant difference in AOD between noncataractous and cataractous eyes may be attributable to thickening of the lens with cataract development. Dogs with larger ICA and AOD measurements before surgery were at greater risk of developing POH. This information may be useful for future studies to determine whether preventative treatment for POH prior to surgery may be beneficial. Ultrasonographically evident anterior chamber echogenic debris was not correlated with POH. Because ICA and AOD measurements are affected by state of pupillary dilation, assessment of the ICA should be performed on images obtained without pupillary dilation (and before surgery). Intraobserver reliability for the measurement of the ICA and AOD in dogs was good.

Intraobserver reliability for measurement of ICA and AOD in the human medical literature is highly consistent; good intraobserver reliability and less favorable interobserver reliability. Similar findings are described in a recent report of high-resolution ultrasonography in dogs.

References


