Use of color Doppler imaging for determining the resistive index of the medial long posterior ciliary artery in clinically normal conscious dogs

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Objective—To evaluate the use of color Doppler imaging (CDI) for determining the resistive index (RI) of the medial long posterior ciliary artery (mLPCA) in clinically normal conscious dogs.

Animals—18 (10 sexually intact males, 8 sexually intact females) dogs between 1 and 5 years old.

Procedure—Color Doppler ultrasonography was performed on both eyes with dogs in a sitting position. Each eye was imaged from the region dorsal to the zygomatic arch with the transducer positioned in a horizontal plane. The mLPCA was localized, and RI was calculated from velocities obtained for 3 similar Doppler waveforms. To determine the reproducibility of CDI-derived RI, measurements were repeated twice at a 10-day interval.

Results—Mean (± SD) RI of the mLPCA was 0.68 ± 0.07 (95% confidence interval, 0.65 to 0.70; n = 36 eyes). Resistive index did not significantly differ between right and left eyes or male and female dogs. In addition, body weight was not correlated with RI. Repeated measurements of RI did not yield significantly different results (interclass correlation coefficient, 0.8297).

Conclusion and Clinical Relevance—Color Doppler imaging appears to be a valid technique for determination of RI of the mLPCA in conscious dogs. This technique may be useful for investigating the pathophysiologic processes of many ocular and orbital vascular disorders in dogs. (*Am J Vet Res* 2002;63:211–214)

Ultrasonography is a noninvasive diagnostic procedure that can qualitatively and quantitatively evaluate various orbital and intraocular abnormalities.[1,2] It does not appear to be destructive to the intraocular tissues, and there is no exposure to radiation.[1] B-mode ultrasonography has been routinely used in veterinary ophthalmology in the diagnosis and as an aid in needle biopsy of orbital masses. In addition, ultrasonography can be used to image the globe when corneal, lenticular, and intravitreal opacities prevent direct viewing.[1-4] **Color Doppler imaging (CDI)** has been used to evaluate orbital structures in healthy humans[5-7] as well as in humans with orbital or intraocular diseases[8-10] and systemic disorders.[11-13] In veterinary ophthalmology, CDI has been used to evaluate the eyes of healthy dogs and dogs with glaucoma.[14,15]

The complexity of blood flow within the eye and orbit has resulted in the development of many methods for assessing blood flow, but none has satisfied all requirements. Notable artifacts may be engendered by use of invasive measurement techniques.[6] Noninvasive imaging methods for examining ocular blood vessels may be divided into those that do and do not require direct viewing of the vessels. Direct imaging of retinal and optic nerve surface blood vessels can be achieved by use of fluorescein angiography, scanning laser angiography, laser Doppler velocimetry, and retinal laser Doppler flowmetry.[1] In these methods, however, errors in blood flow measurements may be introduced by use of pharmacologic agents such as mydriatics or by application of pressure on the globe. Color Doppler imaging permits imaging of the deeper vessels of the eye, such as the long and short posterior ciliary arteries, that penetrate or remain in the choroid and sclera for long distances. This technique uses a combination of real-time imaging with superimposed color-coded vascular flow and thereby allows viewing of blood vessels below the resolution of real-time ultrasonography alone.[16] Color Doppler imaging is of particular benefit in the orbit, because orbital vessels are small and tortuous.[16]

The **resistive index (RI)** or Pourcelot ratio is a measurement designed to interpret the shape of the waveform of a vessel. Resistive index can vary from 0 to 1. A RI of 0 represents no resistance, whereas a RI of 1 represents high resistance.[17] A high RI correlates to increased distal vascular resistance and decreased perfusion.[18] Some authors suggest that determination of absolute values such as RI may help evaluate the functional variables of the vascular bed (eg, peripheral resistance) that may be altered during the course of several ocular disorders in humans.[5,16,19-21]

In humans, numerous orbital and ocular vessels have been mapped and their blood velocity and waveforms characterized by use of CDI.[5-7,16,21-23] Reports[14,15] describing the use of CDI to evaluate the orbit and eye of dogs are limited. Moreover, these studies were not conducted in conscious dogs. To our knowledge, the

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RI of any specific ocular vessel in clinically normal conscious dogs, as determined by use of CDI, has not been reported. However, knowledge of the RI of a normal ocular vessel is necessary for CDI to achieve its full potential in veterinary medicine. The purpose of the study reported here was to determine the feasibility and reproducibility of CDI for determination of the RI of the **medial long posterior ciliary artery (mLPCA)** in clinically normal conscious dogs.

Materials and Methods

Animals—Eighteen (10 sexually intact males and 8 sexually intact females) clinically normal dogs (36 eyes) were examined in this study. Dogs ranged in age from 17 to 51 months (mean, 25.1 months) and body weight from 1.3 to 11.4 kg (4.8 kg). Three breeds were represented: Maltese (4 females and 3 males), Yorkshire Terrier (2 females and 4 males), and Beagle (2 females and 3 males). Dogs were determined to be clinically normal on the basis of results of physical examination, CBC, serum biochemical analyses, measurement of systemic blood pressure by use of a Doppler pressure cuff,[24] and ophthalmic examination. The ophthalmic examination consisted of slit-lamp biomicroscopy, direct ophthalmoscopy, and tonometry. **Intraocular pressure (IOP)** was ≤ 30 mm Hg in all dogs, and abnormalities were not detected in the anterior segment or fundus.[25] There was no evidence of signs of orbital disease or neuro-ophthalmologic disease in any dog. The Animal Care and Use Committee at Seoul National University approved the experimental protocol.

Color Doppler imaging—Color Doppler imaging was performed, using an ultrasonograph[a] with a 7 MHz electronic sector probe. Doppler settings (pulse repetition frequency, 6,000 Hz; gain setting, medium; wall filtering, 100 Hz; color Doppler flow setting, low to medium) were kept constant to minimize technical errors. Both eyes and orbits were imaged with the dog lightly restrained in a sitting position. Dogs remained sitting throughout the trial.

In carnivores, the lateral bony wall of the orbit is incomplete, and the eye and anterior orbit can be imaged by scanning across the lateral orbital ligament. In the present study, coupling gel was applied to the region dorsal to the zygomatic arch, and the transducer was positioned in a horizontal plane. The lateral wall of each eye and the retrobulbar fat were imaged. Color Doppler imaging was initially performed at this area to identify the vessel of interest for subsequent spectral Doppler analysis. In this study, flow toward the transducer was depicted as red and flow away from the transducer as blue. When blue was detected along the lateral wall of the eye from the posterior to the anterior pole, spectral Doppler analysis was performed at the level of muscle insertion. The mLPCA could be distinguished from the vortex veins by detecting the arterial pulse (**Fig 1**). Because blood flow through the choroidal capillaries was too slow to detect by use of the color Doppler unit that we used, no color Doppler flow information was obtained for these vessels.

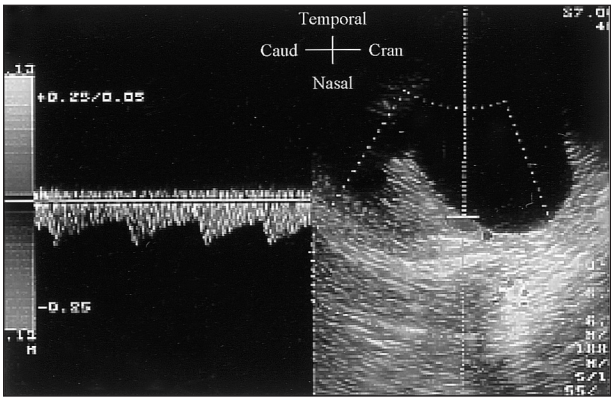

Figure 1—Doppler ultrasonogram of the left eye of a clinically normal conscious dog. The eye was imaged from the region dorsal to the zygomatic arch with the transducer positioned in a horizontal plane. The medial long posterior ciliary artery (mLPCA) is evident in the right panel. The left panel depicts the waveform of blood flow through the mLPCA.

Once the mLPCA was localized, it was examined, using the Doppler gate to obtain a spectral waveform and quantitative information (ie, **peak systolic velocity [PSV]** and **end diastolic velocity [EDV]**). Resistive index was calculated according to the formula:

$$RI = (PSV - EDV)/PSV$$

To reduce the effects of physiologic variation, measurements were obtained 3 times for each vessel imaged in sequence, values were averaged, and mean values were used to calculate RI.

Reproducibility of CDI—To determine the reproducibility of CDI for determination of RI, CDI of the left eye only (18 eyes) was performed twice at a 10-day interval. **Intraclass correlation coefficients (ICC)** were calculated for the paired measurements of RI according to the formula:

$$ICC = (\text{between dog variance} - \text{within dog variance})/(\text{between dog variance} + \text{within dog variance}).$$

Variance was determined by use of the ANOVA table.

Statistical analyses—To obtain a range of values for clinically normal dogs, 95% **confidence intervals (CI)** were calculated for PSV, EDV, and RI. Values were compared between left and right eyes by use of paired *t*-tests, whereas values were compared between sexes by use of unpaired *t*-tests. Relationships between body weight and velocity indices were assessed by use of Pearson product moment correlation. Effect of breed on velocity indices was determined by use of 1-way ANOVA. Statistical calculations were performed, using a commercially available software program.[b] For all tests, P values of < 0.05 were considered significant.

Results

We did not detect significant differences in PSV, EDV, or RI between right and left eyes or male and female dogs (**Table 1**). Moreover, body weight was not correlated with PSV ($r = -0.074$; $P = 0.666$), EDV ($r = -0.013$; $P = 0.940$), or RI ($r = -0.044$, $P = 0.800$). Values also did not significantly differ among breeds.

Table 1—Blood flow measurements for the medial long posterior ciliary artery of 18 clinically normal conscious dogs determined by use of color Doppler imaging

Measurement	Range	Mean ± SD	95% CI
Left eye (n = 18)			
PSV (cm/s)	10.00–29.00	18.00 ± 4.99	15.52–20.48
EDV (cm/s)	3.45–9.72	6.13 ± 2.11	5.09–7.18
RI (cm/s)	0.56–0.75	0.66 ± 0.05	0.64–0.69
Right eye (n = 18)			
PSV (cm/s)	10.00–30.00	17.50 ± 4.66	15.18–19.82
EDV (cm/s)	2.00–11.00	5.33 ± 2.36	4.16–6.51
RI (cm/s)	0.50–0.83	0.69 ± 0.08	0.65–0.73
Both eyes (n = 36)			
PSV (cm/s)	10.00–30.00	17.75 ± 4.76	16.14–19.36
EDV (cm/s)	2.00–11.00	5.73 ± 2.24	4.97–6.49
RI (cm/s)	0.50–0.83	0.68 ± 0.07	0.65–0.70

CI = Confidence interval. PSV = Peak systolic velocity. EDV = End diastolic velocity. RI = Resistive index.

Values for PSV, EDV, and RI determined during repeated measurements were not significantly different (PSV: F = 0.330, $P = 0.573$; EDV: F = 2.450, $P = 0.136$; RI: F = 1.038, $P = 0.323$). However, the ICC of EDV was low (0.6915), whereas those for PSV and RI were high (0.8282 and 0.8297, respectively).

Discussion

Results of our study indicate that the RI of the mLPCA can be determined by use of CDI in conscious dogs without the use of chemical restraint. However, mean RI in our study (0.68 ± 0.07) differed from that reported by Gelatt et al[14] for the long posterior ciliary artery of clinically normal dogs (0.51 ± 0.08). In our opinion, this difference was attributable to the use of a chemical agent that may have influenced orbital tension and ophthalmic blood flow in the previous study. Dogs in that study were lightly sedated with butorphanol tartrate and acepromazine sulfate. Lidocaine was also used as a local nerve block, and tetracaine hydrochloride was administered topically to anesthetize the cornea.

Resolution of CDI, bony structures in the orbit, and artifacts caused by eye movement limit the number of vessels that can be examined by use of CDI. It is almost impossible to obtain the best quality waveforms immediately; numerous attempts are necessary to obtain the highest velocity curves without artifacts.[21] For this reason, we performed sequential CDI studies on each eye until 3 similar waveforms were detected. Velocities from these waveforms were then averaged and used to calculate RI.

We did not detect significant differences in RI between left and right eyes or between male and female dogs. These results support the conclusions of Greenfield et al[5] and Lieb et al,[7] who also found no significant differences in vascular resistance in humans between right and left eyes or male and female subjects. To our knowledge, there are no reports examining the correlation between RI and breed in dogs. Although our sample size was small, we did not find a significant difference in RI among the 3 breeds examined (ie, Maltese, Yorkshire Terrier, and Beagle). Furthermore, RI was not correlated with body weight. Greenfield et al[5] suggested that age may affect normal orbital blood flow and vascular resistance patterns in humans. Baxter et al[16] demonstrated that RI increases with age in the central retinal artery and vein of humans. To reduce potential age-related differences in RI, dogs in our study were between 1 and 5 years old.

External pressure from the ultrasound transducer may result in an increase in IOP during the examination,[6] and this increase in IOP will affect subsequent measurements of blood-flow velocities and RI. To minimize external pressure on the eyeball, we obtained ultrasonographic images by use of a lateral approach, which allowed us to avoid direct contact on the eye.

Prior to ultrasonography, there was no evidence of disorders in any dog associated with low mean arterial blood pressure. Hydration status was considered adequate on the basis of physical examination (eg, skin turgor), and Hct was within reference range. In addition, heart rate and systemic arterial blood pressure for all dogs were within reference ranges. We did not monitor heart rate or peripheral arterial blood pressure during acquisition of Doppler flow spectra. Thus, we cannot address the potential effect of these physiologic variables on RI of the mLPCA.

If CDI is to be used to detect small differences in blood-flow velocities, such as those that may occur in dogs with orbital and intraocular diseases, measurements obtained by use of this technique must be highly reproducible. Past studies[16,22,26] of CDI used to evaluate normal orbital blood vessels in humans have yielded results that are highly reproducible. For example, repeated measurements of RI of the ophthalmic, central retinal, and medial posterior ciliary arteries in humans yielded coefficients of variation of 4.8, 6.4, and 10.0, respectively.[16] We also found that CDI yielded highly reproducible results for a selected ophthalmic blood vessel in clinically normal conscious dogs. We did not evaluate interobserver variation in the present study, and we recognize that this is a potential limitation of our results. Evaluation of orbital vessels (ophthalmic, central retinal, and posterior ciliary arteries and central retinal vein) by use of CDI has been described as an accurate and reproducible technique for determination of RI in humans.[16] Results of another study[22] revealed that PSV and EDV of the ophthalmic artery were highly correlated between and within observers. But in some studies,[20,27] significant interobserver variation has been detected. Further studies are required to determine whether interobserver variation will affect CDI-derived RI in dogs. Nonetheless, results of the present study suggest that CDI may be a useful technique for investigating the pathophysiologic processes of many ocular and orbital vascular disorders in dogs.

[a]Ultrasonograph, model SSA 260 A, Toshiba, Tochigi, Japan.
[b]SPSS software program, SPSS Inc, Chicago, Ill.

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