Comparison of ophthalmic measurements obtained via high-frequency ultrasound imaging in four species of snakes

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Objective—To measure the dimensions of the eyes of living snakes by use of high-frequency ultrasound imaging and correlate those measurements with age, length, and weight.

Animals—14 clinically normal snakes.

Procedures—Species, age, length, weight, and horizontal spectacle diameter were recorded, and each snake underwent physical and ophthalmic examinations; ultrasonographic examination of both eyes was performed by use of a commercially available ultrasound unit and a 50-MHz transducer. Ultrasonographic measurements included spectacle thickness, subspectacular space depth, corneal thickness, anterior chamber depth, lens thickness, vitreous cavity depth, and globe length. All measurements were made along the visual axis.

Results—2 corn snakes, 5 California king snakes, 1 gopher snake, and 6 ball pythons were examined. There were no significant differences within or between the species with regard to mean spectacle thickness, corneal thickness, or subspectacular space depth. However, mean horizontal spectacle diameter, anterior chamber depth, and axial globe length differed among the 4 species; for each measurement, ball pythons had significantly larger values than California king snakes.

Conclusions and Clinical Relevance—Spectacle thickness, subspectacular space depth, and corneal thickness were similar among the species of snake examined and did not vary significantly with age, length, or weight. Measurements of these dimensions can potentially serve as baseline values to evaluate snakes of these species with a retained spectacle, subspectacular abscess, or subspectacular fluid accumulation. Anterior chamber depth and axial length appeared variable among species, but axial length did not vary with age, length, or weight in the species studied. (*Am J Vet Res* 2007;68:1111–1114)

The ophthalmic features of snakes differ considerably from those of mammals and even other reptiles; perhaps the most clinically important difference in snakes is the lack of mobile eyelids, which are replaced by the spectacle (an embryonic fusion of the eyelids).[1-3] The superficial layers of the spectacle undergo periodic ecdysis with the rest of the skin.[3] The spectacle forms a permanent seal over the cornea creating the epithelial-lined subspectacular space. This space is filled with an oily, tear-like secretion produced by the Harderian gland. The secretion subsequently drains from the ventral aspect of the subspectacular space, through the nasolacrimal duct, and empties into the mouth.[1,2] This unique anatomic arrangement is the basis for the 3 most common ophthalmic conditions that develop in snakes: retained spectacle or dysecdysis[4,5]; subspectacular abscess formation secondary to ascending stomatitis, penetrating injuries, or systemic disease[2,5-7]; and subspectacular fluid accumulation secondary to nasolacrimal duct obstruction (also referred to as pseudobuphthalmos).[4-8]

For nearly 40 years, ultrasonography has been used in many species as a diagnostic tool and for anatomic determinations in various species both in vivo and in vitro.[9-15] More recently, high-frequency ultrasound probes have provided increased image resolution but with decreased tissue penetration.[16] Such probes are ideally suited for ophthalmic ultrasonography in which deep penetration is not required. Ultrasonography performed with ultrasound frequencies of 40 to 60 MHz provides image resolution of approximately 50 μm (similar to that achieved via low-power light microscopy) and is commonly referred to as ultrasound biomicroscopy.[17-21]

To the authors' knowledge, the specific anatomic dimensions of the eye and related structures have not been measured in living snakes. The purpose of the study reported here was to measure the dimensions of the eyes of clinically normal snakes by use of high-frequency ultrasound imaging and thereby establish baseline measure-

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ments for clinically important ophthalmic structures, to compare those dimensions among common species of snake, and to determine whether those features of snakes' eyes are affected by age, body length, or body weight.

Materials and Methods

Animals—Fourteen privately owned snakes (8 males and 6 females) were included in the study; 4 species were represented including 2 corn snakes (*Elaphe guttata guttata*), 5 California king snakes (*Lampropeltis getula californiae*), 1 gopher snake (*Pithuophis melanoleuces*), and 6 ball pythons (*Python regius*). Client consent was obtained, and the protocol for the study was approved by the Institutional Animal Care and Use Committee at the University of California, Davis.

Procedures—General data collected for each snake included species, age, body length (measured snout to vent), body weight, and horizontal spectacle diameter. Each snake underwent a complete physical examination by 1 author (AS) and ophthalmic examination of the anterior segment of both eyes by another author (SRH). The eyes then were examined ultrasonographically by use of a commercially available ultrasound unit and a 50-MHz transducer with a self-contained, 4-mm, water-filled standoff.[a] After application of a commercially available coupling gel,[b] the probe was placed directly on the spectacle. All ultrasonographic examinations of each snake were performed by the same person (BJH). Multiple images were collected from each eye of each snake. After ultrasonographic examination, the eyes were reexamined for any adverse effects from the procedure. No obvious procedure-related changes were detected. The ultrasonographic images were then evaluated, and the best image in the sagittal plane for each snake was selected for biometry. The best image was defined as the one in which the axial structures were most clear and distinct. Specific ophthalmic measurements were made from these images including central spectacle thickness, subspectacular space depth, central corneal thickness, anterior chamber depth, lens thickness (anterior-posterior direction), vitreous cavity depth (anterior-posterior direction), and axial globe length. All measurements were obtained along the visual axis.

Statistical analysis—To assess differences for each measurement among the 4 species, data were compared by use of an exact Kruskal-Wallis ANOVA; differences between sexes were assessed by use of an exact Mann-Whitney test. The quantitative relationships between continuous variables (ie, axial globe length, body length, body weight, and vitreous cavity depth) were evaluated by use of the Spearman rank correla-

Table 1—Mean ± SD values of physical and ultrasound biomicroscopy–derived ophthalmic measurements obtained from 4 species of snake.

	Type of snake			
Variable	**Corn (n = 2)**	**California king (n = 5)**	**Gopher (n = 1)**	**Ball python (n = 6)**
Body length (cm)	126 ± 1.414	104 ± 12.7	89.5	89.33 ± 11.6
Body weight (kg)	1.1 ± 0.099	0.654 ± 0.1832	0.45	0.935 ± 0.2734
Horizontal spectacle diameter (mm)	4.300 ± 0.163	3.670 ± 0.258	4.900	4.908 ± 0.162*
Central spectacle thickness (mm)	0.190 ± 0.014	0.184 ± 0.011	0.220	0.1883 ± 0.016
Subspectacular space depth (mm)	0.143 ± 0.011	0.124 ± 0.016	0.165	0.112 ± 0.025
Central corneal thickness (mm)	0.125 ± 0.007	0.118 ± 0.008	0.120	0.110 ± 0.02
Anterior chamber depth (mm)	0.190 ± 0.007	0.228 ± 0.044	0.255	0.426 ± 0.060*
Lens thickness (anterior-posterior direction; mm)	2.283 ± 0.187	2.084 ± 0.235	2.085	2.513 ± 0.083
Vitreous cavity depth (anterior-posterior direction; mm)	1.778 ± 0.180	1.601 ± 0.186	1.650	1.846 ± 0.145
Axial globe length (mm)	4.39 ± 0.0	3.99 ± 0.408	4.13	4.885 ± 0.195*

*For this anatomic measurement, the value for ball pythons is significantly ($P < 0.05$) different from that for California king snakes. There were too few gopher and corn snakes to enable meaningful pairwise comparisons of data to be made.

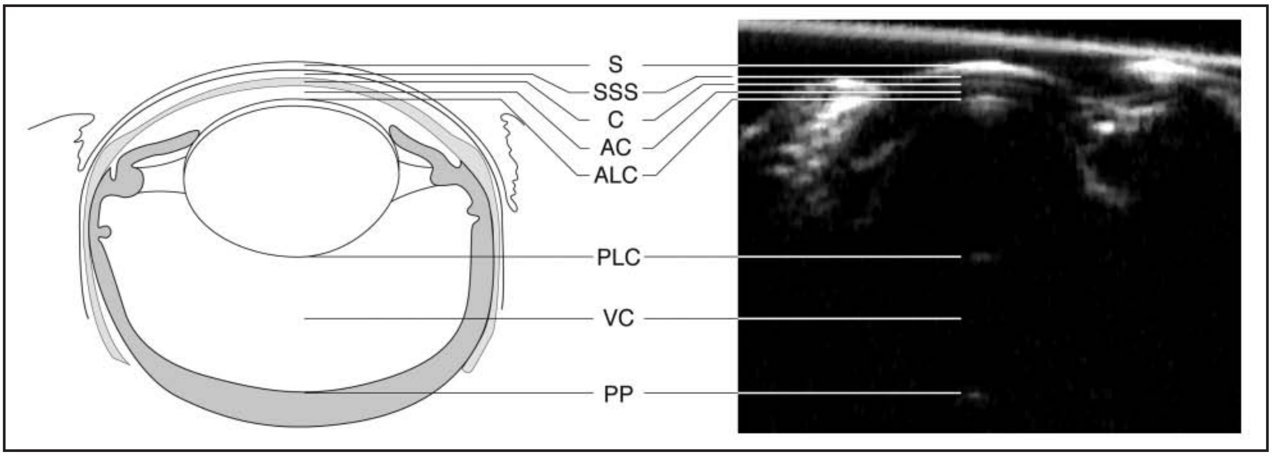

Figure 1—Schematic illustration of the anatomic features in relation to an ultrasound biomicroscopic image (obtained via high-frequency ultrasound imaging) of the eye of a clinically normal snake. Anatomic structures include the spectacle (S), subspectacular space (SSS), cornea (C), anterior chamber (AC), anterior lens capsule (ALC), posterior lens capsule (PLC), vitreous cavity (VC), and posterior pole (PP).

tion. Comparisons were made between the California king snakes and the ball pythons; the numbers of gopher and corn snakes were small, and no meaningful pairwise comparisons could be made. A value of $P < 0.05$ was considered significant.

Results

Body length and weight and all ophthalmic measurements were obtained for all 14 snakes (**Table 1**). Ultrasound biomicroscopy revealed the major anatomic features of the snakes' eyes (**Figure 1**). There were no significant differences within or between the species with regard to mean spectacle thickness, subspectacular space depth and corneal thickness. However, among the 4 species, there were significant differences in mean horizontal spectacle diameter ($P < 0.001$), anterior chamber depth ($P < 0.001$), and axial globe length ($P = 0.018$). Ball pythons had significantly larger values for horizontal spectacle diameter, anterior chamber depth, and axial globe length ($P = 0.004$, $P = 0.004$, and $P = 0.016$, respectively) than California king snakes. No significant correlation between body length ($r = -0.34$; $P = 0.27$) or weight ($r = 0.51$; $P = 0.094$) and axial globe length was identified.

Within each species, no significant differences in any measurement were detected between sexes. There was also no significant difference in the horizontal spectacle diameter between the left and right eyes; therefore, these values were pooled for analysis. No adverse effects were detected in any snake as a result of the ultrasonographic examination.

Discussion

In the present study, we were able to safely obtain high-resolution images of the anatomic features of clinically normal eyes of 4 species of snake by use of a commercially available high-frequency ultrasound unit.[a] Because B-scan ultrasonography is most commonly used to assess clinical disease states, it was the technique chosen for the present study, so that the measurements obtained could be used as baseline data for comparison with ultrasonographic images of snakes with ophthalmic disease.[12,15,17,22-24] Results of studies in cadaveric horse[25] and pig[26] eyes have indicated that ophthalmic dimensions measured via B-scan ultrasonography correlate well with actual anatomic dimensions. In a study[27] of clinically normal dog eyes, no significant differences in measurements obtained via A-scan and B-scan ultrasonography were detected. Ultrasound biomicroscopy provides highly accurate biometric information regarding the anterior segment of eyes in clinically normal humans[19] and has been used to evaluate changes in corneal thickness as small as 1 µm that develop secondary to photorefractive surgery and penetrating keratectomy.[18]

Because of the small sample size and limited number of species examined, the main purpose of the present study was to characterize in general the ophthalmic anatomic dimensions of snakes by use of high-frequency ultrasound imaging. Nevertheless, some information does appear to be noteworthy. With regard to spectacle thickness, corneal thickness, subspectacular space depth, lens thickness, or vitreous cavity depth, no significant differences were detected among individuals within a species or among the 4 species studied. However, differences in horizontal spectacle diameter, anterior chamber depth, and axial length were evident. Compared with findings in the California king snakes, the ball pythons had a significantly wider spectacle, deeper anterior chamber, and longer axial length. The comparative increase in axial length in the ball pythons appeared to be attributable to the deeper anterior chamber because there was no significant difference in lens thickness or vitreous cavity depth between the 2 species. It is interesting that although the ball pythons had larger eyes overall, there was no significant difference in the spectacle thickness, subspectacular space depth, or corneal thickness of those snakes, compared with findings in the California king snakes. In fact, these features were remarkably consistent in all 4 species examined. No correlation between age, weight, or length and any of the anatomic measurements was identified. Although snakes grow in length and weight throughout life, the results of the present study suggest that once a snake reaches maturity, the eyes cease to grow.

The most common ophthalmic abnormalities in snakes include retained spectacle, subspectacular abscess, and pseudobuphthalmos.[4-8] All of these conditions involve thickening or enlarging of anterior segment structures or spaces. On the basis of the findings of our study, ultrasound biomicroscopy appears to provide an excellent method with which these conditions can be diagnosed in snakes and could be useful for evaluation of the extent or severity of the pathologic changes. The biometric dimensions obtained in the study of this report have provided some baseline measurements for use in the assessment of pathologic changes within the anterior segment of the eyes of snakes.

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[a] UltraView 2.0 imaging system, E-Technologies Inc, Bettendorf, Iowa.

[b] Aquasonic 100, Parker Laboratories Inc, Fairfield, NJ.

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