Intraocular pressure in clinically normal dromedary camels (Camelus dromedarius)

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OBJECTIVE
To determine the intraocular pressure (IOP) in healthy dromedary camels (Camelus dromedarius).

ANIMALS
24 clinically normal dromedary camels.

PROCEDURES
For each camel, the IOP of both eyes was measured with applanation tonometry. Three measurements with < 5% variance were obtained for each eye on the same day of the week for 3 consecutive weeks. Mean IOP was calculated for each eye on each day for comparison purposes.

RESULTS
Mean ± SD IOPs for the right (31.1 ± 2.1 mm Hg) and left (30.8 ± 1.9 mm Hg) eyes of immature camels were significantly higher than those for the right (27.1 ± 1.2 mm Hg) and left (28.2 ± 1.2 mm Hg) eyes of mature camels. Intra-assay and interassay coefficients of variation (CVs) for IOP measurements of the right and left eyes did not differ significantly between immature and mature camels. Interassay CVs of IOP measurements for the right and left eyes ranged from 1.5% to 12.1% and 1.2% to 10.3%, respectively, for immature camels and from 1.2% to 17.2% and 1.7% to 18.8%, respectively, for mature camels. Intra-assay CVs of IOP measurements for the right and left eyes ranged from 1.5% to 10.6% and 1.9% to 9.6%, respectively, for immature camels and from 2.8% to 16.9% and 2.7% to 12.4%, respectively, for mature camels. Age was negatively correlated (r = -0.403) with IOP.

CONCLUSIONS AND CLINICAL RELEVANCE

Dromedary camels (Camelus dromedarius), also known as Arabian camels, are single-humped camels that are an important livestock species for people in harsh and difficult environments.1 Camels are maintained for the production of meat, milk, leather, and wool and are also used as pack animals and for sport, transport, riding, and tourism purposes.2 Despite the dromedary camel’s popularity, information regarding various ophthalmologic conditions in this species, including reference limits for various ophthalmic variables and diagnostic tests for ocular diseases, is limited.3–5

Measurement of IOP, or tonometry, is an important part of the routine ophthalmic examination in animals,6 and knowledge of IOP values in clinically normal animals is important for the diagnosis and monitoring of ocular disorders such as focal or diffuse corneal edema, red or painful eyes, orbital trauma, lens luxation, glaucoma, and uveitis.6–9 Indentation, applanation, and rebound tonometry have traditionally been used to measure IOP indirectly in veterinary ophthalmology.10,11 In recent years, measurement of IOP in animals has evolved tremendously with the development of portable handheld digital tonometers.5

Applanation tonometry has been used to measure IOP in numerous clinically normal domestic and nondomestic animals, including dogs,12–14 cats,15,16 horses,17 ponies,18 dairy cattle,19 sheep,20 goats,21,22 llamas,23,24 alpacas,23,24 rabbits,25,26 rats,27 ferrets,28,29 chinchillas,30 capybaras,31 hedgehogs,32 beavers,33 Nubian ibex (Capra nubiana),34 Grant’s zebra (Equus quagga boehmi),34 oryxes,35 Arabian oryxes (Oryx leucoryx),7 Thomson gazelles (Eudorcas thomsonii),35 elands,36 fallow deer,36 addax antelope,34 impalas,34 wildebeests,34 rhinoceroses,34 capuchin monkeys,37 koalas,38 and lions.39 However, to our knowledge, the IOP for clinically normal dromedary camels has not been reported. The purpose of the study reported here was to use applanation tonometry to determine the IOP in clinically normal dromedary camels.

ABBREVIATIONS
CI Confidence interval
CV Coefficient of variation
IOP Intraocular pressure

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Materials and Methods

ANIMALS

The study protocol was approved by the Animal Care Committee of Kafrelsheikh University, in accordance with Egyptian ethical codes for studies on experimental animals. The study included 24 camels that were determined to be healthy on the basis of results of a physical examination and a complete ophthalmic examination that included a Schirmer tear test, fluorescein staining, slit-lamp biomicroscopy, and indirect ophthalmoscopy. The camels were allocated into 2 groups (immature and mature) on the basis of age and sex. The immature group consisted of 6 males and 6 females that were all < 5 years old (mean ± SD age, 2.5 ± 1.0 years). The mature group consisted of 6 males and 6 females that were all between 5 and 10 years old (mean ± SD age, 7.3 ± 1.6 years). All camels belonged to the same herd and were housed together in an indoor and outdoor setting with ad libitum access to food and water until the beginning of each experiment. Prior to study initiation, owner consent was obtained for the use of the camels.

IOP MEASUREMENTS

All IOP measurements were obtained between 9 AM and 11 AM on the same day of the week for 3 consecutive weeks during May by the same investigator (MAM) to minimize individual, seasonal, and diurnal variations. The IOP was determined for both eyes of all camels. During measurement of IOP, camels were physically restrained in a sitting position in a familiar and quiet indoor environment by the same individuals. Chemical sedation and local nerve blocks were not used. For each camel, the head was maintained in a physiologically normal position above the heart with the aid of a halter. The head was maintained in this position for a minimum of 2 minutes prior to each IOP measurement to allow sufficient time for oculomotor pressures to normalize, and the eyelids and neck were manipulated gently to avoid false increases in IOP caused by excessive eyelid manipulation or pressure on the globe and neck. The order (right vs left) in which the IOP was obtained from both eyes was determined in a random manner. Before each measurement, the cornea of both eyes was anesthetized by the topical application of 0.2 mL of a 0.5% proparacaine solution. The IOP was determined by lightly touching the central aspect of the cornea with an applanation tonometer at 5-second intervals. The tonometer was calibrated by the factory prior to study initiation. For each eye on each day, 3 IOP measurements with a variance < 5% were recorded; IOP measurements with a variance > 5% and those suspected to be falsely increased because of excessive eyelid manipulation or pressure on the globe or neck were discarded. Thus, by the end of the study, there were 9 IOP measurements for each eye from each camel.

DATA ANALYSIS

The distribution of the IOP data was assessed by the Kolmogorov-Smirnov normality test, and the data were determined to be normally distributed. The frequency distribution and the summary statistics (mean ± SD, 95% CI, median, range, and 10th, 25th, 75th, and 90th percentiles) of the IOP measurements for the right and left eyes of each group (immature and mature) of camels were reported. The reproducibility of the IOP measurements was assessed by calculation of the intra-assay and interassay CVs. For each of the 3 days that data were collected, the intra-assay CV was calculated by dividing the SD of the measurements for that day by the mean of the measurements for that day. For each camel, the interassay CV was calculated for each of the 3 measurements (1, 2, and 3) of IOP obtained on each day by dividing the SD for that particular measurement by the mean for that particular measurement. A t test was used to compare the mean IOP between immature and mature camels and between males and females. A paired t test was used to compare the mean IOP between the right and left eyes. Similarly, a t test was used to compare the interassay CV for the IOP measurements between immature and mature camels, and a paired t test was used to compare the interassay CV for the IOP measurements between the right and left eyes.

| Table I—Frequency distribution of IOP measurements for the right and left eyes of 12 immature and 12 mature dromedary camels (Camelus dromedarius). |
|---------------------------------------------|----------------|----------------|----------------|----------------|
| IOP category (mm Hg) | Immature camels | Mature camels | Immature camels | Mature camels |
| | Right eye | Left eye | Right eye | Left eye |
| 18 to 22 | 11 (10.2) | 11 (10.2) | 1 (0.9) | 5 (4.6) |
| > 22 to 28 | 35 (32.4) | 38 (35.2) | 17 (15.7) | 13 (12.1) |
| > 28 to 34 | 57 (52.8) | 44 (40.8) | 46 (42.6) | 44 (40.7) |
| > 34 to 38 | 5 (4.6) | 15 (13.8) | 31 (28.7) | 36 (33.3) |
| > 38 to 42 | 0 (0) | 0 (0) | 13 (12.1) | 10 (9.3) |

Values represent the number (%) of measurements in that particular IOP category for the given eye. There were no IOP measurements < 18 mm Hg or > 42 mm Hg. The immature camel group consisted of 6 males and 6 females that were all < 5 years old. The mature camel group consisted of 6 males and 6 females that were all between 5 and 10 years old. For each camel, 3 measurements were obtained for each eye on the same day of the week for 3 consecutive weeks during May. Thus, there were 108 measurements for each eye of each group.
tion for immature and mature camels were also compared by use of a $t$ test, and those for the right and left eyes were compared by means of a paired $t$ test. The mean IOP measurement obtained for each eye of each camel on the first data collection day was used to assess the correlation between age and IOP by means of the Pearson correlation coefficient. For all analyses, values of $P < 0.05$ were considered significant. All statistical procedures were performed with a commercially available software program.

**Results**

Applanation tonometry was easy to perform and well tolerated by the camels with no evidence of ocular irritation or pain at any time during the study. The frequency distribution of IOP measurements in both immature and mature camels was summarized (Table 1); 191 of 432 (44%) measurements were $> 28$ to $34$ mm Hg. The IOP data for the right and left eyes of the camels in Table 1 were also compared by means of a paired $t$ test, and those for the right and left eyes, respectively. However, the mean IOPs for the right and left eyes of mature camels were significantly lower than those for immature camels. For the immature camel group, the mean ± SD IOP of the right eye was $31.3 \pm 1.9$ mm Hg for males and $30.7 \pm 2.6$ mm Hg for females, and the mean ± SD IOP of the left eye was $30.9 \pm 3.1$ mm Hg for males and $30.5 \pm 4.0$ mm Hg for females. For the mature camel group, the mean ± SD IOP of the right eye was $27.9 \pm 3.2$ mm Hg for males and $27.4 \pm 2.4$ mm Hg for females, and the mean ± SD IOP of the left eye was $28.0 \pm 2.5$ mm Hg for males and $27.7 \pm 2.8$ mm Hg for females. The mean IOPs of the right and left eyes did not differ significantly between males and females within either the immature or mature group.

The intra-assay CVs (Table 3) and interassay CVs (Table 4) for right and left eyes of each group of camels were summarized. Neither the intra-assay CVs nor the interassay CVs differed significantly between the right and left eyes or between the immature and mature camels.

Age was negatively correlated with IOP ($r = -0.323$). A 36-month-old camel had the highest IOP measurements ($40$ and $42$ mm Hg for right and left eyes, respectively), whereas a 10-year-old camel had the lowest IOP measurements ($18$ and $22$ mm Hg for the right and left eyes, respectively).

**Discussion**

The aims of the present study were to determine the IOP of clinically normal immature and mature dromedary camels and assess the reproducibility of IOP measurements in camels. Knowledge of the IOP

| Table 2—Summary of IOP (mm Hg) data for the right and left eyes of the camels in Table 1. |
|-------------------|-------------------|-------------------|-------------------|
|                     | Immature camels    | Mature camels      |
| Variable            | Right eye         | Left eye          | Right eye         | Left eye          |
| Mean ± SD           | 31.1 ± 2.1*       | 26.5–33.5         | 26.0–35.8         | 23.0–28.0         |
| 95% CI              | 30.8–1.9          | 24.4–27.7         | 25.3–30.8         | 21.6–26.5         |
| Median              | 32.0              | 28.0              | 29.0              | 28.0              |
| Range               | 17.0–42.0         | 16.0–40.0         | 17.0–39.0         | 16.0–39.0         |
| Percentile          |                   |                   |                   |                   |
| 10th                | 18.2              | 18.4              | 18.6              | 20.6              |
| 25th                | 24.0              | 25.0              | 24.0              | 24.0              |
| 75th                | 38.0              | 37.0              | 32.0              | 32.0              |
| 90th                | 41.4              | 38.8              | 33.0              | 35.0              |

*Value differs significantly ($P < 0.05$) from the corresponding value for immature camels. 
See Table 1 for remainder of key.
in clinically normal dromedary camels is important for the evaluation of the ocular health of camels and will be beneficial in the diagnosis and monitoring of ocular disorders. Uveitis and corneal ulcers are common ocular diseases of dromedary camels that are frequently associated with changes in IOP. Glaucoma is also associated with changes in IOP; although it is an infrequent disease of camelids.

Camels reach puberty at approximately 5 years of age; therefore, in the present study, camels < 5 years old were categorized as immature, whereas camels ≥ 5 years old were categorized as mature. Interestingly, the mean IOP for the immature camels was significantly higher than that for the mature camels; a similar finding has been reported for dogs, cats, and lions. In the present study, IOP was negatively correlated with age; however, in another study in which rebound tonometry was used to measure the IOP of healthy cats, age was not associated with IOP. Results of the present study provided novel data regarding the IOP in healthy dromedary camels, and the IOP for dromedary camels was similar to the IOP of dairy cattle, rhinoceroses, and horses. In healthy dairy cattle, the mean ± SD IOP as determined by applanation tonometry was 26.9 ± 6.7 mm Hg (range, 16 to 42 mm Hg). In healthy horses without an auriculopalpebral nerve block, the mean ± SD IOP ranged from 24.5 ± 4.0 mm Hg to 28.6 ± 4.8 mm Hg. Among all species, the highest mean IOP reported was 32.1 ± 10.4 mm Hg in a rhinoceros, and the lowest mean IOP recorded was 3 mm Hg in a chinchilla. Thus, given that IOP varies among species, it is important to establish a reference interval for IOP in each individual species. For example, the mean ± SD IOPs for the right and left eyes of llamas and alpacas are 15.27 ± 4.02 mm Hg and 17.64 ± 3.63 mm Hg, respectively, whereas the mean ± SD IOPs for the right and left eyes of the immature camels of the present study were 31.1 ± 2.1 mm Hg and 30.8 ± 1.9 mm Hg, respectively. These data suggest that the IOP for immature dromedary camels was almost twice that for other camelid species. Thus, an IOP reading of 31 mm Hg would be considered clinically normal for an immature camel but would be considered suggestive of glaucoma in a llama or alpaca.

In human medicine, multiple studies have been conducted to assess the reliability and reproducibility of IOP measurements obtained by single or multiple instruments. Although, the CV is commonly used to determine the precision of a measurement instrument, to our knowledge prior to the present study, only 1 study had assessed the CV for IOP in a species of veterinary interest (ie, cats). In the present study, we calculated the CV to assess the precision of the IOP measurements in both immature and mature camels. The mean intra-assay and interassay CVs and the associated 95% CIs (Tables 3 and 4) were within acceptable limits. Results of 1 study indicate that the reproducibility of IOP measurements by rebound tonometry in freshly enucleated eyes of dogs was good, although the reproducibility decreased linearly as IOP increased. Also, the reproducibility of IOP measurements was worse for the eyes of live dogs, compared with that for enucleated eyes, and was better for the eyes of sedated dogs, compared with that for the eyes of unsedated dogs. In a study in which rebound tonometry was used to measure the IOP of conscious ferrets, there was a study-ordered decrease in the CV. The IOP was measured for 104 eyes, and the CV was 21.2 ± 1.4% for the first 52 measurements and 14.4 ± 1.1% for the last 52 measurements, which suggested

| Table 4—Interassay CVs of the IOP data for the right and left eyes of the camels in Table 1 for each of the 3 measurements obtained on 3 data collection days. |
|---|---|---|---|---|---|---|
| Group | Variable | Measurement 1 | Measurement 2 | Measurement 3 | Measurement 1 | Measurement 2 | Measurement 3 |
| Immature | Mean ± SD | 5.7 ± 2.6 | 5.6 ± 2.5 | 4.7 ± 2.1 | 4.5 ± 1.9 | 5.2 ± 3.3 | 3.5 ± 1.3 |
| 95% CI | 4.0–7.4 | 4.1–7.1 | 3.3–6.0 | 3.2–5.7 | 3.0–7.3 | 2.6–4.2 |
| Median | 5.8 | 5.9 | 5.1 | 4.3 | 6.1 | 3.2 |
| Range | 1.5–12.1 | 1.7–10.2 | 1.5–8.1 | 1.1–8.1 | 1.2–10.3 | 1.8–6.5 |
| Percentile | 10th | 2.1 | 2.1 | 1.6 | 1.5 | 0.5 | 1.9 |
| 25th | 3.8 | 3.4 | 3.1 | 3.4 | 1.8 | 2.7 |
| 75th | 7.1 | 7.5 | 6.3 | 6.1 | 7.7 | 4.2 |
| 90th | 10.8 | 9.6 | 7.7 | 6.1 | 7.6 | 4.2 |
| Mature | Mean ± SD | 6.7 ± 2.7 | 6.3 ± 4.2 | 6.1 ± 2.6 | 5.7 ± 2.6 | 9.2 ± 4.2 | 7.4 ± 4.1 |
| 95% CI | 5.0–8.4 | 3.6–8.9 | 4.3–7.7 | 4.1–7.4 | 6.4–11.8 | 4.8–10.0 |
| Median | 6.6 | 5.7 | 6.7 | 5.5 | 9.1 | 6.9 |
| Range | 2.3–11.6 | 1.2–17.2 | 2.2–10.8 | 1.7–11.1 | 2.8–18.8 | 3.1–17.6 |
| Percentile | 10th | 2.6 | 0.8 | 2.2 | 2.1 | 3.0 | 3.2 |
| 25th | 4.9 | 4.6 | 3.5 | 3.7 | 6.5 | 3.8 |
| 75th | 8.5 | 6.5 | 7.7 | 7.2 | 11.7 | 9.1 |
| 90th | 11.2 | 14.9 | 10.1 | 10.5 | 16.8 | 15.6 |

Values are percentages. See Table 1 for remainder of key.
that the reproducibility (ie, precision) of the IOP measurements got better as the study progressed.

All measurements in the present study were obtained between 9 AM and 11 AM during May to avoid diurnal and seasonal variations in IOP.3 The camels were gently restrained in the sitting position to avoid variations in IOP caused by head position,40,53 and care was taken to avoid excessive manipulation of the eyelids or pressure on the neck, which could falsely increase IOP measurements.54

The age of the camels in the present study ranged from 1 to 10 years, and the reason the mean IOP for camels in the mature group (age, ≥ 5 years) was significantly lower than that for the camels in the immature group (age, < 5 years) is unknown. The decrease in IOP with age might be a consequence of a reduction in active secretion of aqueous humor associated with declining systemic health.9

In the present study, the IOP did not vary significantly between male and female camels. Investigators of other studies2,21 have likewise reported a lack of association between sex and IOP; however, IOP is significantly associated with sex in lions39 and humans.55

A limitation of the present study was its small sample size; therefore, percentiles were reported to better describe the range of values for IOP in clinically normal dromedary camels. One investigator performed all IOP measurements; thus, the reproducibility of measurements between observers (ie, interobserver CV) could not be calculated. Also, IOP was determined by applanation tonometry only. Further studies are necessary to compare the reproducibility of IOP measurements as determined by applanation tonometry with the reproducibility of IOP measurements as determined by other tonometry instruments.

Results of the present study provided an initial reference for IOP in dromedary camels, which will be beneficial for clinicians who perform ophthalmic examinations in these animals. The intra-assay and inter-assay CVs for IOP measurements indicated that applanation tonometry was a feasible and precise method for determining IOP in dromedary camels.

Footnotes
a. Akaline (proparacaine hydrochloride 0.5% ophthalmic solution), Alcon Laboratories Inc, Fort Worth, Tex.

References


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