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ORIGINAL ARTICLE

Ultrasonographic and Macroscopic Anatomy of the Enucleated Eyes of the Buffalo (*Bos bubalis*) and the One-Humped Camel (*Camelus dromedarius*) of Different Ages

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With 1 figure and 2 tables

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Summary

The ultrasonographic appearance and measurements of the normal buffalo and camel eye globes were described in 60 buffaloes (*Bos bubalis*) aged 1 year (28 eyes) and 10 years (32 eyes), and in 51 humped camels (*Camelus dromedarius*) aged 1 year (26 eyes) and 10 years (24 eyes). Ocular measurements were recorded by A- and B-scan ultrasonographic examination of 40 buffalo eyes (18 young and 22 adult eyes) and 34 camel eyes (14 young and 20 adult eyes) using a KANGH ultrasound scanner equipped with 10 MHz probe. For gross measurements, 20 buffalo and 16 camel eye globes were frozen and dissected and the same measurements were made using fine callipers macroscopically. The aqueous and vitreous humour of the buffalo and camel eyes appeared anechoic. The cornea, anterior and posterior lens capsule and iris appeared hyperechoic. The ocular measurements for the axial length, vitreous chamber depth (VCD), corneal thickness, lens thickness and scleroretinal rim thickness increase with the advance of age in both buffaloes and camels. Except for the anterior chamber depth, VCD and lens thickness, which were larger in adult camels than in adult buffaloes, no other differences between ocular dimensions were observed in both species. The results of this study are valuable for comparative ocular anatomy and will be useful for ultrasonographic evaluation of ocular diseases in buffaloes and camels.

Introduction

The buffalo and dromedary camel play an important role in the economy of the developing countries. Buffaloes are used for breeding and meat production in Egypt, while camels are used for transport and as a source of food and other essential products to the desert inhabitants. However, the anatomy and ultrasonography of the eye are poorly documented in these animals.

Ocular opacity occurs frequently in bovine ocular diseases such as infectious bovine keratoconjunctivitis (Punch and Slatter, 1984). This condition precludes the use of ophthalmoscopy, whereas ultrasonography enables evaluation of intra-ocular structures in opaque eyes (Rogers et al., 1986; Williams and Wilkie, 1996; Wilkie and Gilger, 1998; Gonzalez et al., 2001; Potter et al., 2008).

Knowledge of the ocular dimensions is required for vision research and better understanding of clinical problems such as phthitis bulbi, microphthalmia, pseudoexophthalmia, scleral ectasia and congenital glaucoma (Potter et al., 2008).

The ocular dimensions have been investigated extensively in cadaveric specimens of domestic animals (Getty, 1998; Barone and Simoens, 2010). Although novel medical imaging techniques are increasingly used in veterinary medicine to provide clinically relevant information on internal organs and soft tissue structures (Boehart et al., 2010), only few papers reported the ultrasonographic appearance and dimension of the eyes in cattle and sheep (El-Maghraby et al., 1995; Potter et al., 2008), horses (Rogers et al., 1986; Saroori et al., 2009), camels (Osuobeni and Hamidzada, 1999), elephants (Bapodra et al.,

2010) and dogs (Ekestin and Torrang,1995). In contrast, no available reports have been found concerning ultrasonic anatomy and ophthalmic parameters in relation to age differences in the buffalo and camel. In both species, animals older than 49 months have attained adulthood (Khan et al., 2004).

Therefore, the objectives of this study were to describe the ultrasonographic appearance and measurements of the normal buffalo and camel eyes, and to compare the ocular dimensions of eyes of buffaloes and camels of different ages.

Materials and Methods

Animals

Eye globes of 60 buffaloes (*Bos bubalis*) aged 1 year (28 eyes) and 10 years (32 eyes) and of 51 humped camels (*Camelus dromedarius*) aged 1 year (26 eyes) and 10 years (24 eyes) were used for this study. The eyes were collected from healthy buffaloes and camels of both sexes (38 male and 22 female buffaloes and 30 male and 20 female camels). Immediately after slaughtering, the eyes were gently removed from the orbit by initially cutting through the upper eye lid at the orbital margin. The extraocular muscles were also cut near their insertion on the globe. Finally, the optic nerve was transected close to its exit from the globe and then the eyes were immersed in a water bath. Ultrasonography was performed in the enucleated eyes 1–4 h after slaughtering.

Ultrasonography

A- and B-scan ultrasonographic examination was performed on forty buffalo eyes (18 young eyes and 22 adult eyes) and 34 camel eyes (14 young eyes and 20 adult eyes) using an ultrasound scanner (KANGH Ultrasound, Ultrasonic Satalalo, China) equipped with a linear 10-MHz transducer probe. The transducer was placed in a longitudinal position (sagittal plane) until optimal B-scan images, according to echoes of the A-mode, were obtained. Ocular dimensions were recorded by using both the transpalpebral technique, by which scanning is performed through the upper eyelid, and the transcorneal method that involves the transducer and coupling gel being applied directly to the corneal surface.

The probe was applied perpendicular to the centre of the cornea using ultrasonic transmission gel until optimal B-scan images, according to echoes of A-mode images, were obtained. Reflected ultrasonic waves were captured and transferred to CPU (connected to the ultrasound machine) where they were saved. Optimum positioning was considered when the posterior wall of the globe could be visualized on the B-scan ultrasonogram, the globe appeared symmetrical and the reflections from the four principle landmarks (cornea, anterior lens surface, posterior lens surface and retinal surface) along the globe axis were perpendicular, and when four distinct echo spikes could be visualized on the A-scan image. For all measurements, the velocity sound was 1535 m/s for the anterior chamber and 1650 m/s for the lens.

The axial length (AL) was measured from the anterior corneal surface to the retina. The corneal thickness (CT) was measured between the echoes from the anterior and posterior corneal surfaces. The anterior chamber depth (ACD) was measured as the distance between the echoes from the posterior corneal surface and the anterior lens surface. The lens thickness (LT) was the distance between echoes from the anterior and posterior lens surfaces. The vitreous chamber depth (VCD) was the distance between the echoes from the posterior lens surface and the retina.

Anatomical morphometry

Immediately after slaughtering, 20 buffalo and 16 camel eye globes were frozen at −20 to −30°C and stored. After thawing, they were dissected and the same measurements (AL, CT, ACD, LT and VCD) were made macroscopically using fine callipers.

Statistical analysis

Measurement values were statistically analysed by means of a computer program (KaleidaGraph, 3.5; Synergy Software, Reading, PA, USA). Comparison of ocular dimensions was made using Student's *t*-test. A value of $P < 0.05$ was considered statistically significant.

Results

The aqueous and vitreous humour of the buffalo and the camel eyes appeared anechoic, whereas the cornea, anterior and posterior lens capsule and iris were hyperechoic (Fig. 1a and b). The anterior lens capsule appeared as a convex echogenic line, the posterior lens capsule appeared as a concave echogenic line, and the lens tissue in between appeared anechoic. The iris was identified adjacent to the anterior lens capsule with the ciliary body located adjacent to it. The scleroretinal rim appeared as a concave echogenic line at the posterior margin of the eye ball. The head of the optic nerve casts acoustic shadows from its margins, allowing measurement of its diameter.

The ocular dimensions of the buffalo and camel eye are summarized in Table 1 and Table 2, respectively.

Within either species, there was no statistically significant difference in ocular dimensions between the left and right eyes ($P > 0.05$; AL $P = 0.35$, ACD $P = 0.28$, VCD $P = 0.29$, corneal thickness $P = 0.47$, lens thickness

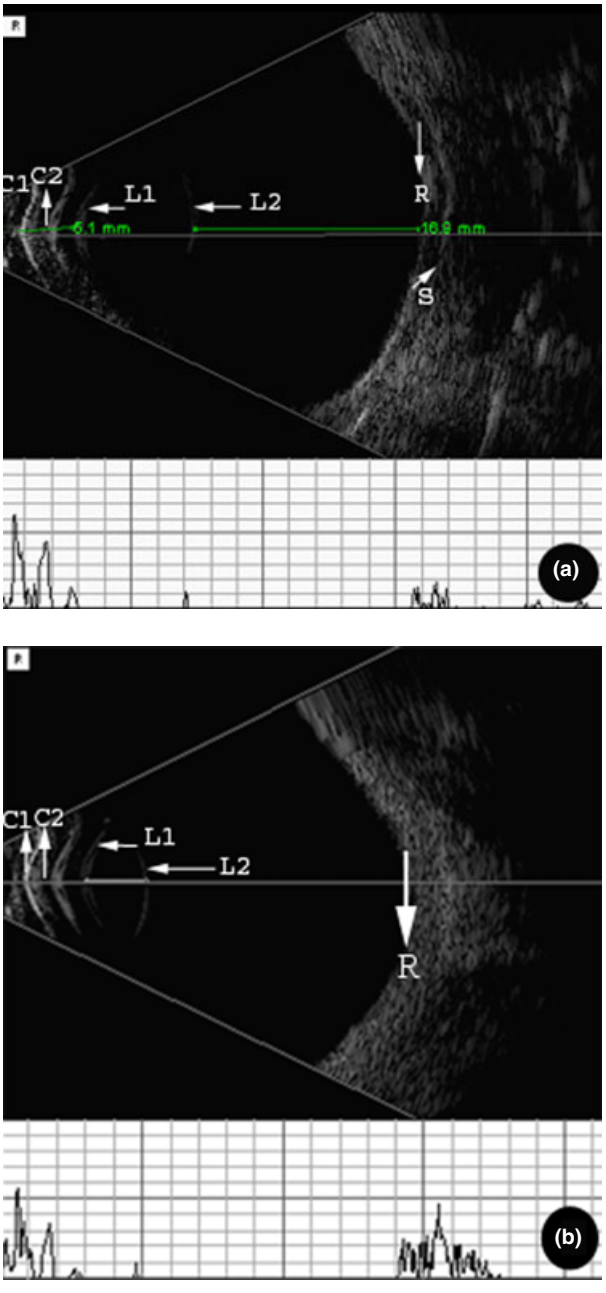

Fig. 1. A and B mode – ultrasonogram of the buffalo eye (a) and camel eye (b). C1: anterior surface of the cornea, C2: posterior surface of the cornea, L1: anterior lens capsule, L2: posterior lens capsule, R: retina, Axial length: C1–R, Corneal thickness: C1–C2, Anterior chamber depth:C2–L1, Lens thickness: L1–L2, Vitreous chamber depth: L1–R, S: Scleroretinal rim, I: Iris.

$P = 0.61$, scleroretinal rim thickness $P = 0.16$, diameter of the optic nerve head $P = 0.13$).The values from males and females were also found to be statistically similar ($P > 0.05$; AL $P = 0.52$, ACD $P = 0.44$, VCD $P = 0.34$, corneal thickness $P = 0.26$, lens thickness $P = 0.75$, scleroretinal rim thickness $P = 0.21$, diameter of the optic nerve head $P = 0.19$).

Table 1 and 2 illustrates that the ocular dimensions increase significantly with the advance of the age ($P < 0.05$).

The ACD, VCD and lens thickness were larger in adult camels than in adult buffaloes. No other differences between ocular dimensions were observed when eyes of camels were compared with eyes of buffaloes.

Discussion

The present ultrasonographic appearance of the enucleated buffalo and camel eyes is similar to observations in live cattle (Potter et al., 2008), horses (Rogers et al., 1986), sheep (El-Maghraby et al., 1995) and goats (Ribeiro et al., 2009). However, the main artery to the eyeball, which was seen in 70% of the bovine eyes by Potter et al. (2008), could not be visualized in this study. The difficulties in finding this artery may be related to slaughtering process, which results in loss of the circulating blood and arterial pulsation arrest.

The ocular dimensions of the AL, VCD, corneal thickness, lens thickness and scleroretinal rim thickness reported in this study were similar to those reported for ultrasonographic examination of cadaveric cattle eyes (El-Maghraby et al., 1995) and live cattle (Potter et al., 2008).

The results from the transcorneal technique were better than that of the transpalpebral method. Transpalpebral imaging increases artifacts and reduces image quality but may be desirable where the possibility exists of further damage to the cornea through direct probe contact (Read and Barnett, 1995).

Our results revealed that the ocular dimensions increase with the advance of age in both buffaloes and camels, which is in agreement with similar findings reported by Bapodra et al. (2010) in the Asian elephant by Ribeiro et al. (2009) in the goat and Tauntivanich et al. (2007) in the dog.

Age was found to be the most significant predictor of the lens dimensions, which is true for all mammalian species, as the lens cortex enlarges throughout life as the result of new lens fibre production (Williams, 2004; Bapodra et al., 2010).

The differences between the ultrasound and anatomical measurements were small in the buffaloes and camels, which is similar to the finding in equine eyes by Rogers et al. (1986).

The AL and the ACD of the one-humped camel eye reported in this study correspond with the data recorded by Osuobeni and Hamidzada (1999), while the VCD is higher and the lens thickness is smaller than reported by these authors. The differences of the lens characteristics

Table 1. Ultrasonographic and biometric measurements of the ocular dimensions in the buffalo eye (in mm)

	Young		Adult	
	Ultrasound	Macroscopic	Ultrasound	Macroscopic
Axial length (mm)	22.27 (±1.5)	23.5 (±1.9)	32.1 (±2.2)	33.4 (±2.4)
Anterior chamber depth (mm)	2.84 (±0.3)	3.14 (±0.6)	4.35 (±0.4)	4.0 (±0.5)
Vitreous chamber depth (mm)	12.56 (±0.9)	13.77 (±1.3)	17.5 (±1.3)	17.1 (±0.9)
Corneal thickness (mm)	0.75 (±0.2)	0.9 (±0.4)	1.22 (±0.3)	1.67 (±0.3)
Lens thickness (mm)	5.54 (±1.1)	6.44 (±1.4)	6.23 (±1.6)	6.8 (±1.5)
Scleroretinal rim thickness (mm)	1.50 (±0.1)	–	1.92 (±0.1)	–
Diameter of the optic nerve head (mm)	11.86 (±1.4)	12.56 (±1.8)	13.5 (±1.7)	13.9 (±1.6)

Mean dimension ± standard deviation.

Table 2. Ultrasonographic and biometric measurements of the ocular dimensions in the camel eye (in mm)

	Young		Adult	
	Ultrasound	Macroscopic	Ultrasound	Macroscopic
Axial length (mm)	25.48 (±1.2)	26.75 (±1.2)	31.4 (±2.1)	33.0 (±2.2)
Anterior chamber depth (mm)	3.14 (±0.7)	3.98 (±0.8)	5.8 (±0.9)	6.5 (±0.8)
Vitreous chamber depth (mm)	14.72 (±1.0)	15.5 (±1.2)	18.61 (±1.5)	17.9 (±1.6)
Corneal thickness (mm)	0.84 (±0.1)	0.95 (±0.2)	1.15 (±0.1)	1.5 (±0.2)
Lens thickness (mm)	6.91 (±1.2)	7.23 (±1.3)	7.71 (±1.1)	7.9 (±1.3)
Scleroretinal rim thickness (mm)	1.12 (±0.3)	–	1.63 (±0.2)	–
Diameter of the optic nerve head (mm)	10.00 (±1.1)	10.9 (±1.0)	13.66 (±1.4)	14.2 (±1.5)

Mean dimension ± standard deviation.

and of the techniques used may lead to these discrepancies in the ultrasonographic measurements (Coleman, 1979).

The velocities set in the ultrasound equipment used in our study are recommended for human ophthalmologic research but not for studies in large animals. The dimensions of lens thickness of buffalo and camel eye globes described in this study are much larger than that of humans, which may lead to underestimation of this parameter (Ribeiro et al., 2009).

Ophthalmic ultrasound examination has become an indispensable diagnostic tool that has increased our ability to detect and differentiate many ocular and orbital diseases (Ahmed et al., 2009). Echography is indicated whenever opacity of the ocular media does not allow the examiner to visualize the posterior ocular segment (Mcleod and Restori, 1979).

In conclusion, the normal ocular dimensions of buffaloes and camels recorded in this study offer a novel contribution to comparative ocular anatomy and may be useful for ultrasonographic evaluation of ocular diseases in these species.

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