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Ocular ultrasonography and echobiometry in sheep

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Abstract: Ocular sonography and echobiometry was performed in local nondescript sheep (N = 36) of different age group and in adult corriedale (N = 60), crossbred Fec B (N = 48), and Poll Dorset cross breed sheep (N = 48). Cornea, anterior, posterior lens capsule, and retinal rim appeared hyperechoic whereas aqueous, vitreous humor, and nucleus of lens were anechoic. Significant increase ($P < 0.05$) in all the echobiometric measurement of the ocular distance except central corneal thickness and retinal rim thickness was recorded in the older animals (2 year old) compared to values recorded in animals at one month of age in local nondescript sheep. Significant differences ($P < 0.05$) in few recorded ocular biometric measurements were also noticed among different sheep breeds. However, the difference in the various ocular biometric measurements between the right and left eyes was nonsignificant. The results of this study provide the base line information regarding the ocular echobiometry in sheep that are relevant to comparative ocular anatomy and can be useful for ultrasonographic evaluation of different ocular affections in sheep.

Key words: Echobiometry, sheep, corriedale, nondescript sheep, age

1. Introduction

Good vision has a crucial role in the life of animals, not only for quality of life but to safely thrive in their environment and to successfully compete for food. Most of the ocular diseases produce considerable discomfort leading to poor weight gain, reduced milk production, behavioral problems, and poor performance [1]. In food producing animals, significant economic losses due to ocular diseases have been observed [2,3].

Sonographic appearance and echobiometry of the eyes have been investigated in dogs [4], horses [5], donkeys [6], cattle [7,8], buffaloes [9], sheep [7,10], goats [11,12], parrot [13], ferret [14], pigs [15], rabbits [16] camel [17], and hares [18].

Ultrasonography is one of the important tools for the assessment of varied ocular abnormalities like phthisis bulbi, microphthalmia, pseudoexophthalmia, scleral ectasia, and congenital glaucoma [8]. Ocular biometry was one of the early uses of ultrasound in human ophthalmology [19]. Echobiometric values are often used for the construction of schematic eyes in optics [15]. It is used in the calculations of intraocular lens dioptric power to be employed in the eyes of animals that have undergone cataract surgery to achieve emmetropia [20].

Most of the ocular diseases produce morphological abnormalities; therefore, knowledge of normal anatomical appearance and dimensions of the eye is valuable when assessing eye health using ultrasound [21–23].

Loss of corneal opacity occurs due to various reasons like keratitis, corneal ulcers, or various systemic diseases. Documentation of normal ultrasonographic appearance and ocular dimensions of sheep may facilitate the diagnosis of ocular disease especially when the opaque anterior segment precludes complete ophthalmoscopic examination.

There are changes in the intraocular dimensions from newborn to adult [24], which are probably due to the concomitant increase in size of the eye during growth. Therefore, to accurately build a schematic model of a specific animal species echobiometric values are needed

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to properly describe its visual properties.[1] Eyes of sheep are frequently used as practice eye for ophthalmic surgery training in skills laboratory [25]. On perusal of the available literature, a wide variation in the published echobiometric measurements of the different ocular structures in sheep was observed. Also, no published paper regarding ocular biometric study in sheep of different age group was found in literature. The study was therefore aimed to provide the normal ultrasonographic appearance and ocular biometry in adult sheep of different breed as well as age wise ocular echobiometric changes in nondescript sheep of Kashmir.

2. Materials and methods

The animals chosen for the study comprised of adult (24 months of age) female Corriedale (N = 60), Crossbred Fec B (N = 48) and Poll Dorset Cross breed sheep (N = 48) obtained from the University farm (Mountain Research Centre for Sheep and Goat, Shuhama) and local nondescript sheep (N = 36) of different age group brought to Division of Veterinary Clinical Complex, Shuhama for non ocular problems. All the animals underwent thorough ophthalmic examination and only those with normal eyes and vision formed part of the study.

B-mode ultrasonography in standing sheep was performed using esoate My Lab 40 vet system. A drop of local anesthetic proparacaine (Paracin, Proparacine 0.5%, Sunways, India) was instilled into each eye before ultrasonography. Ultrasound gel was smeared over the desensitized cornea, and a linear probe (10-18 MHz) was gently placed over corneal surface perpendicular to the centre of the cornea. Care was taken to avoid any corneal indentation. Optimal positioning was confirmed when the ultra sonogram appeared symmetrical and the reflections from the four principal landmarks (cornea, anterior lens capsule, posterior lens capsule, and retina) along the optic axis were perpendicular [26]. The optimal image was frozen and echobiometric measurements were taken (Figure).

The statistical analysis was performed using SPSS 20.0 version for Windows (IBM Corp., Armonk, NY, USA). For comparison between different sheep breeds and different age group, one way ANOVA was used. For comparison of left vs. right eyes, Student's t test was used. A P value less than 0.05 was considered significant.

3. Results

3.1. Echobiometric values of nondescript sheep at different stages of age

The ocular echobiometric values of these animals are summarized in the Table1.

Central corneal thickness (CCT): There was a nonsignificant increase in the CCT as the sheep aged.

Anterior chamber depth (ACD): Significant ($P < 0.05$) increase in the ACD was recorded in 24 months of age sheep as compared with rest of sheep.

Anteroposterior depth of lens (APDL): There was a significant ($P < 0.05$) increase in the APDL as the sheep aged.

Latero-medial diameter of lens (LDML): LDML increased continuously up to 24 months of age; however, significant increase ($P < 0.05$) was noticed from 12 months of age onwards as compared to the values in sheep at one month of age.

Vitreous chamber depth (VCD): VCD in sheep was significantly ($P < 0.05$) greater at 12 and 24 months of age in comparison with values in animals aged 6 months or less.

Axial globe length (AGL): The axial length of globe increased significantly ($P < 0.05$) with the advancement of the age.

Retinal rim thickness (RRT): Retinal rim thickness increased nonsignificantly with the advancement of the age.

3.2. Echobiometry of adult sheep of different breeds

The ocular echobiometric values of these animals are summarized in the Table 2.

CCT: Significant ($P < 0.05$) difference in this parameter was recorded only between sheep of Poll Dorset cross and nondescript sheep.

APD: Significant ($P < 0.05$) difference in the anterior chamber depth was noticed only between the nondescript and Poll Dorset cross sheep.

APDL: The values of different breeds of sheep were significantly different from one another except crossbred Fec B and Poll Dorset sheep where difference was nonsignificant.

LDML: Animals of local nondescript breed had significantly ($P < 0.05$) lowest lateromedial diameter of lens among all the breeds.

VCD: Significant ($P < 0.05$) difference in local nondescript and Corriedale sheep. Comparison among the groups further revealed that vitreous chamber depth values of Corriedale and Poll Dorset Cross bred sheep varied significantly ($P < 0.05$) in between them and from those of Fec B cross and local nondescript sheep.

AGL: Highest axial length of globe was recorded in Corriedale sheep and lowest was measured in local nondescript sheep. AGL values of local nondescript sheep and those of crossbred Fec B cross differed significantly ($P < 0.05$) on individual basis from those of all other breeds and in between them.

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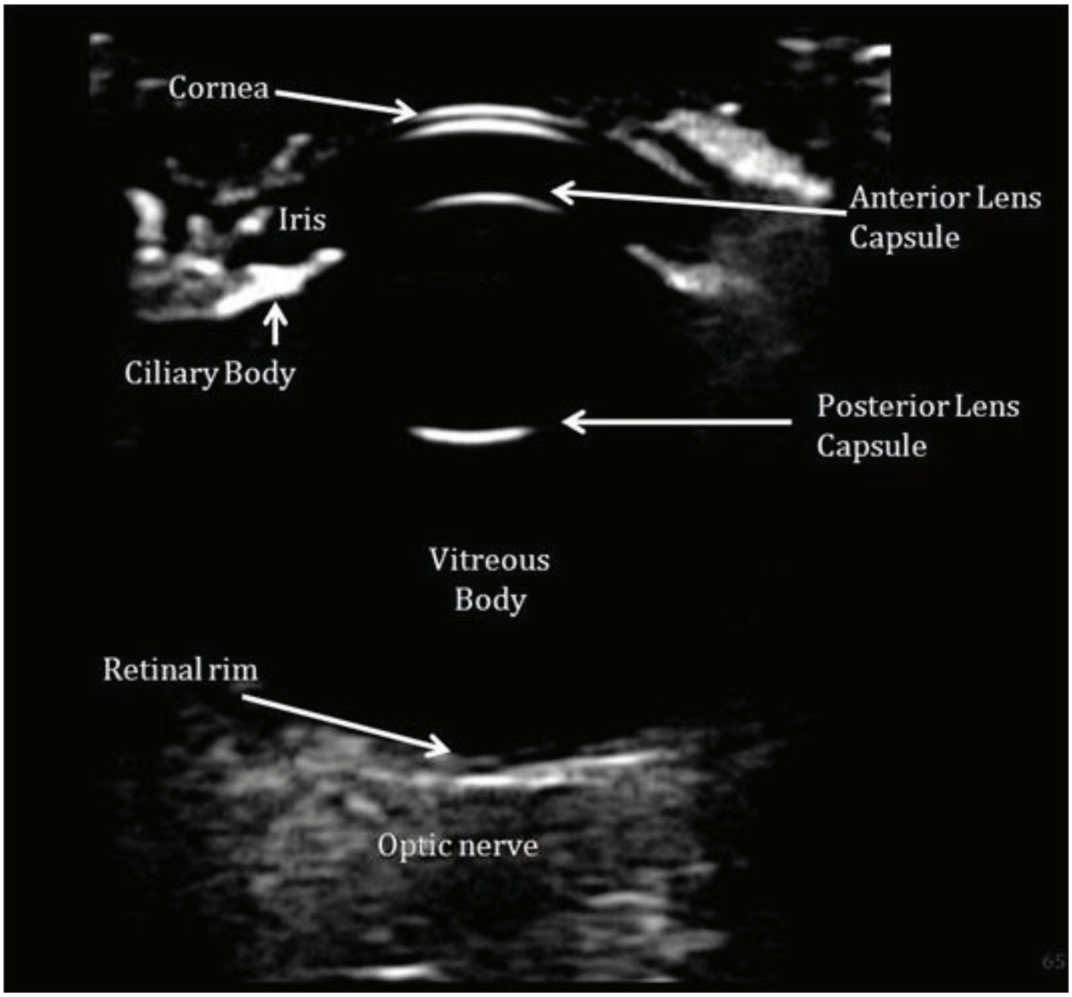

Figure. Ultrasonographic appearance of sheep eye.

RRT: Nonsignificant difference was recorded in the retinal rim thickness in sheep of different breeds.

3.3. Echobiometry of right and left eyes in adult sheep

Mean ± SE value of ultrasonographic biometric measurements of ocular structures of right and left eyes in adult sheep is presented in Table 3. Comparison between the ultrasonographic biometric measurements of different ocular structures of two sided eyes of the adult sheep showed no significant difference.

4. Discussion

Detailed study of various ocular dimensions and how these are influenced with age are important in understanding growth of the eye and the development of pathologies such as myopia and presbyopia [27]. Ultrasonography is commonly used to measure AGL in vivo and is considered reasonably accurate method for AGL determination [26]. Biometry has been employed to determine the ideal predicted power of intraocular lens (IOL) for several species [20,28,29,30]. Ocular biometry is an important contribution of ultrasound in ophthalmology. It was one of the early uses of ultrasound in human ophthalmology [19]. The axial measurements of the globe are important in evaluating conditions such as glaucoma, micro-ophthalmia, macro-ophthalmia, phthisis bulbi, or persistent hyperplastic primary vitreous [31]. In veterinary medicine, ocular biometry can be used in establishing lens implant size, calculating lens power, and estimating prosthetic globe size after enucleation [32]. The ultrasonographic appearance of sheep eyes in the present study was similar to the eyes of Barbary and Iraqi sheep as well as other domestic species [8,12,10,33].

Transpalpebral ultrasound imaging increases artifacts and reduces the image quality but may be desirable where the possibility exists of further damage to the cornea through direct contact of probe [34].

CCT measurement is essential when functional and morphological evaluation of the cornea is undertaken for

Table 1. Mean±SE value of ultrasonographic biometric measurements of ocular structures in local nondescript sheep at different age intervals.

Age (months)	Number of animals	CCT (mm)	ACD (mm)	APDL (mm)	LMDL (mm)	VCD (mm)	AGL (mm)	RRT (mm)
1	6	0.76 ± 0.02	2.2 ± 0.1^{A}	6.8 ± 0.11^{A}	10.3 ± 0.34^{A}	9.0 ± 0.17^{A}	18.8 ± 0.18^{A}	1.7 ± **0.**06
6	6	0.85 ± 0.05	2.0 ± 0.07^{A}	8.1 ± 0.05^{B}	11.4 ± 0.1^{AB}	9.8 ± 0.1^{AB}	20.8 ± 0.11^{B}	1.8 ± **0.**03
12	6	0.86 ± 0.01	2.4 ± 0.1^{A}	8.2 ± 0.3^{B}	12.1 ± 0.2^{BC}	10.4 ± 0.3^{BC}	22.1 ± 0.9^{B}	1.9 ± **0.**13
24	6	0.85 ± 0.03	3.0 ± 0.1^{B}	9.3 ± 0.4^{C}	13.3 ± 0.7^{C}	11.1 ± 0.6^{C}	24.6 ± 0.6^{C}	1.9 ± **0.**11

*Values with different superscript differ significantly at $P < 0.05$ at different age group.
CCT: Central corneal thickness; ACD: Anterior chamber depth; APDL: Anteroposterior depth of lens; LMDL: Lateromedial depth of lens; VCD: Vitreous chamber depth; AGL: Axial globe length; RRT: Retinal rim thickness. **Table 2.** Mean ± SE value of ultrasonographic biometric measurements of ocular parametersin adult sheep of different breeds.

Table 2. Mean ± SE value of ultrasonographic biometric measurements of ocular parametersin adult sheep of different breeds.

Breed		Parameter						
	Number of animals	CCT (mm)	ACD (mm)	APDL (mm)	LMDL (mm)	VCD (mm)	AGL (mm)	RRT (mm)
Corriedale	60	0.9 ± 0.01^{AB}	3.2 ± 0.1^{AB}	10.4 ± 0.12^{C}	15.3 ± 0.4^{B}	13.1 ± 0.29^{C}	27.5 ± 0.35^{C}	1.89 ± 0.06
Crossbred Fec B sheep	48	0.9 ± 0.01^{AB}	3.2 ± 0.1^{AB}	9.9 ± 0.07^{B}	14.5 ± 0.13^{B}	11.7 ± 0.21^{AB}	25.9 ± 0.31^{B}	1.74 ± 0.07
Poll Dorset cross	48	0.93 ± 0.04^{B}	3.5 ± 0.1^{B}	10.1 ± 0.23^{BC}	15.2 ± 0.2^{B}	12.4 ± 0.17^{BC}	27.3 ± 0.25^{C}	2.0 ± 0.09
Local nondescript sheep	24	0.85 ± 0.03^{A}	3.0 ± 0.1^{A}	9.3 ± 0.4^{A}	13.3 ± 0.7^{A}	11.1 ± 0.6^{A}	24.6 ± 0.6^{A}	1.9 ± 0.11

Values with different superscript differ significantly at $P < 0.05$ among different sheep breeds.
CCT: Central corneal thickness; ACD: Anterior chamber depth; APDL: Anteroposterior depth of lens; LMDL: Lateromedial depth of lens; VCD: Vitreous chamber depth; AGL: Axial globe length; RRT: Retinal rim thickness.

Table 3. Mean±SE value of ultrasonographic biometric measurements of ocular parameters of adult sheep.

Eye	Parameter						
	CCT (mm)	ACD (mm)	APDL (mm)	LMDL (mm)	VCD (mm)	AGL (mm)	RRT (mm)
Left	0.9 ± 0.01	3.3 ± 0.1	10.02 ± 0.1	14.9 ± 0.2	12.2 ± 0.25	26.4 ± 0.3	1.8 ± 0.06
Right	0.93±0.02	3.3±0.1	10.10 ± 0.1	14.8 ± 0.2	12.3 ± 0.2	26.6 ± 0.3	1.8 ± 0.07

Values with different superscript differ significantly at $P < 0.05$ between right and left eye.
CCT: Central corneal thickness; ACD: Anterior chamber depth; APDL: Anteroposterior depth of lens; LMDL: Lateromedial depth of lens; VCD: Vitreous chamber depth; AGL: Axial globe length; RRT: Retinal rim thickness.

either for diagnosis or before various surgical interventions [35]. A nonsignificant increase in CCT was recorded in sheep with the advancement of age. A wide variation in the reported value of CCT in sheep (Table 4) has been reported in literature. Fornazari et al. (2016) [10] recorded a CCT value of 0.63 ± 0.02 mm in Barbary sheep at a mean age of 4 ± 2.0 years. SimilarlyEl-Maghraby et al.,1995 [7] reported corneal thickness of 0.7 5± 0.006 mm in Rambouillet breed of sheep at 10 month of age. In contrast, [12] Al-Redah et al. (2016) recorded CCT values of 1.14 ± 0.08 mm in Iraqi sheep at the age of (8–12 months). The value of CCT for the Iraqi sheep was much greater than the value of CCT obtained in the present study. CCT appears to be a continuous variable that changes with eye growth, with thicker corneas being more likely to be found for larger eyes [36].

Table 4. Comparison of measurement of various ocular parametersby different studies.

Parameters (mm)	Samuelson, 1991 [47] Range	Prince et al., 1960 [48] Range	El-Maghraby et al.,1995 [7]			Fornazari et al., 2016[10] Mean ± SD	Al-Redah et al., 2016[12] Mean ± SD
			B-Mode	Physical	A-Mode		
			Range				
CCT	0.8–2.0	0.50–0.60	0.7–0.9	0.6–1.5	0.7–0.9	0.63 ± 0.02	1.14 ± 0.08
ACD	–	–	3.7–5.2	2.5–5.3	3.5–5.0	5.03 ± 0.17	1.85 ± 0.1
APDL	8.5–12.0	17.2–19.5	7.5–9.4	7.5–10.0	7.5–9.1	9.4 ± 0.33	8.95 ± 0.31
VCD	–	–	8.1–12.0	10.5–13.2	8.4–12.3	14.1 ± 0.53	9.82 ± 0.25
AGL	26.80	28.0–30.0	21.9–24.8	22.3–27.0	21.4–25.4	28.43 ± 0.88	20.05 ± 0.32
RRT	–	–	–	–	–	–	1.07 ± 0.09

CCT: Central corneal thickness; ACD: Anterior chamber depth; APDL: Anteroposterior depth of lens; LMDL: Lateromedial depth of lens; VCD: Vitreous chamber depth; AGL: Axial globe length; RRT: Retinal rim thickness.

There have been conflicting reports regarding changes in the CCT with age in dogs. Paunksnis et al. 2001 [37] recorded thickest value of CCT in 20 day old pups. In contrast, Gwin et al. (1982) [38] observed that the corneal thickness increased throughout the dog's life. The CTT values obtained in different breeds of the adult sheep in the present study (0.085–0.093 cm) were greater than the value 0.063 cm obtained by [10] Fornazari et al. (2016) in adult Barbary sheep. Further, intraocular pressure depends upon corneal thickness. A thick cornea provides falsely elevates intraocular pressure, while a thin cornea is associated with the falsely low intraocular pressure [39]; hence, necessitates its measurement.

Anterior chamber depth represents the distance between corneal endothelium and anterior capsule of crystalline lens. It is an important preoperative parameter for intraocular surgery. Inaccurate measurement of the ACD may result in reflective errors after intra ocular lens implantation [40]. ACD in local nondescript sheep of this study showed increasing trend with advancement of age. Wide ranges of values of ACD in sheep have been reported in literature. ACD value of 5.03 ± 0.17 mm in Barbary sheep at a mean age of 4 ± 2.0 years by [10] Fornazariet al. (2016) while as [7] El-Maghraby et al. (1995) reported ACD values of 4.3 ± 0.03 mm in Rambouillet breed of sheep at 10 month of age. In contrast, [12] Al-Redah et al.(2016) reported ACD value of 1.85 ± 0.1 mm in Iraqi sheep at an age of 8–12 months.ACD values obtained in different breeds of adult sheep of ranged from 0.30–0.35 cm are comparatively lesser than the value (0.53 cm) obtained by [10] Fornazariet al. (2016) in adult Barbary sheep. Increase in the depth of anterior chamber from infancy to adulthood has been reported in human literature [41]. In one study, there was an increase in the anterior chamber depth from 2.31mm in 21 day old to 3.40 mm in 1745 day old rhesus monkeys. This increase accounted for 22% increase in axial globe length during 4 year period [42]. Significant differences in the ACD values among certain breeds of the present study could be due to the breed variability.

The APDL values in local nondescript sheep showed a significant ($P < 0.05$) increase till 24 month of age. The APDL values recorded in local nondescript sheep during this study were 0.68 ± 0.11 cm at 1 month of age and 9.3 ± 0.4 cm at 24 month of age. Similarly, Fornazariet al.(2016) [10] recorded a APDL value of 9.4 ± 0.33 mm in Barbary sheep at a mean age of 4 ± 2.0 years and [12] Al-Redah et al. (2016) recorded the similar value of 8.95 ± 0.31 mm in Iraqi sheep at an age of 8–12 months. The value of the APDL recorded in different breeds of adult sheep of this study ranged from 9.0–10.4 mm. Contrarily, in humans, there are reported complex age related changes in the thickness of the lens. The lens thickness decreases from birth to early adulthood due to lens remodeling before increasing during adult life [27].

Scanned literature could not provide any detail regarding the ultrasonographic measurements of LMDL in sheep. However, during this endeavor, an attempt has been made to study the changes in LMDL values with advancement of age in nondescript sheep. The LMDL value increased till 24 month of age with significant ($P < 0.05$) increase starting at 12 month of age as compared to 1 month age value.

The values of VCD increased with the advancement of age with significant ($P < 0.05$) increase noted starting at 12 month of age. [10] Fornazari et al.(2016) recorded a VCD value of 14.1 ± 0.53 mm in Barbary sheep at a mean age of 4 ± 2.0 years and [12] Al-Redah et al. (2016) recorded the values of 9.82 ± 0.25 mm in Iraqi sheep at an age of 8–12 months. The values of VCD obtained in different breeds of adult sheep ranged from 1.11–1.31 cm, which is lesser than the value (1.41 cm) obtained by [10] Fornazari et al. (2016) in adult Barbary sheep. Increase in the VCD with age has been reported in humans as well [27]. In a study conducted on Rhesus monkeys, increases in VCD accounted for 82% of the 4 year increase in the axial globe length [42].

During the study, AGL was 2.21 ± 0.09 cms at this stage (1 year) of life in the nondescript sheep. These observations are similar to those of [12] Al-Redah et al.(2016) who recorded the AGL values as 20.05 ± 0.32 mm in Iraqi sheep at an age of 8–12 months and [7] El-Maghraby et al.1995 who recorded AGL of 23.0 ± 0.075 mm in sheep. The AGL values obtained in different breeds of adult sheep ranged from 2.46–2.74 cm, which was lesser than the value 2.84 cm obtained by Fornazariet al. [10] in adult Barbary sheep. Age related increase in the AGL in ovine has been reported in literature [36]. In humans, globe length has been found to increase up to 16–18 years of age, after which it ceases to grow [43].

Retinal rim thickness (RRT) increased nonsignificantly with the advancement of age. However, the RRT values obtained at 12 month age in the present study were much higher (0.19 ± 0.013) than those of [12] Al-Redah et al.(2016) who recorded the values of 1.07 ± 0.09 mm in Iraqi sheep at an age of 8–12 months.

There was no significant difference between RRT in adult sheep of different breed.

In the present study, no significant difference was found between the ocular biometry of the left and right eyes which is in agreement with the finding of other authors for other animal species [44–46]. No such study as to compare the ultrasonographic biometric values of different ocular structures of left and right eyes in sheep was reported in the available literature. The observations of the study and those of others although conducted in different species suggest that there is no need to repeat such study in sheep.

This study is the first to describe the ocular echobiometric measurements in different breeds of sheep as well as in sheep at different age interval. The study is thus significant as it establishes the echobiometry of different ocular structures at different stages of age as well as for different breeds of sheep for future reference while performing ocular sonography for any kind of its affection.

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