# Comparative Morphological and Computed Tomographical Measurements of the Orbit in Cattle and Pig Eyes

Mediciones Morfológicas y Tomográficas Computarizadas Comparativas de la Órbita en Ojos de Bovinos y Porcinos

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**SUMMARY:** Understanding species intraocular parameters using computed tomography (CT) scanning is initial and crucial step in ophthalmology. There is a lack of studies that have specialized in estimating the cattle and pig eyes using CT scans. Therefore, this study aimed to describe the anatomical and computed tomography features of cattle and pig eyes and its internal structures. Animal heads that not suffer from any diseases related to the eye were disarticulated. CT scan was performed. Moreover, 10 % fixed buffered formalin Specimens were used for the anatomical description of the eye and the optic nerve in particular. The values of length, width of the lens and globe, radio density of the optic nerve, lens, the anterior chamber, the vitreous chamber, and orbital dimensions were measured. Statistically, all parameters of cattle optic nerve increased significantly than that of the pig except for radiodensity, and angle of the optic nerve. Furthermore, all intraocular parameters of cattle increased significantly than that of the pig except the radiodensity of aqueous and vitreous humor. There was no significant difference between species in the opening angle of the orbit. This study's findings represent a first step toward developing CT reference values for cattle and pigs intraocular structural assessments.

KEY WORDS: Cattle; Pig; Computed Tomography; Optic Nerve; Morphometry.

# INTRODUCTION

Cattle and pig are ungulates, even-toed, a hoofed mammal belonging to the Artiodactyla order (cloven hooves) (Olopade et al., 2011; Underwood et al., 2014), cattle is in the suborder Ruminantia (cud-chewing animals), the genus Bos, family Bovidae and obligate herbivores (Underwood et al., 2014). While the pig is a member of the Suidae family of non-ruminant animals, genus Sus, which includes European wild boars and domestic pigs (Moeller & Crespo, 2009). Cattle may perform a variety of tasks, including providing meat, milk, and working animal. Pigs play a vital role as food providers (Moeller & Crespo, 2009). They may be used in translation studies as substitutional to a monkey or a dog for evaluating pharmaceuticals (Swindle et al., 2012). Pigs being a reliable source of the precorneal tear film (Loewen et al., 2016), they may be used in applied ophthalmological research with bioengineering technologies, especially in dry eye research (Menduni et al., 2018). The orbit serves as a house for the eyeball and its components of

vision which included the optic nerve, bulbus oculi, the eyelids, the lacrimal gland, and nictitating gland, ocular and extra-ocular muscles, and the orbital bones which protect the organ of vision of the vertebrate (Olopade et al., 2011). Eye protection when considering lens replacement surgery to treat cataracts, blindness due to the globe or optic nerve disease, or during radiotherapy as a sort of interventional therapy, requires determining the size and measurements of the intraocular structure. Also knowledge of the anatomical features of the visual system can serve to increase the diagnostic, therapeutic, and preventive management of ocular diseases for these animals, whether they are kept for human consumption, rescued, or used in research (Lantyer-Araujo et al., 2019). Ocular MRI and Ultrasound are the modalities of choice in cases of ophthalmological disease (Penninck et al., 2001; Nöller et al., 2006). In contrast, CT is more effective at analyzing the orbital cortical bone than MRI and takes less time to scan (Morgan et al., 1994; Dennis,

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2000). Many studies describe the ocular anatomy of pig and cattle eyes using ultrasound and MRI (Williams et al., 1990; El-Maghraby et al., 1995; Lagalla et al., 2000; Potter et al., 2008; Gholamreza & Majid, 2011; Wang et al., 2021) and to the best of our knowledge, there is some publication which deals with the determination of the dimension of the intraocular structure by CT (Salgüero et al., 2015; Chandrakumar et al., 2019; Hollis et al., 2019) in feline, canine, equine. But there are no studies published which described intraocular measurements of presumed normal cattle and pig eyes using CT, and therefore this study aimed to describe the normal CT of cattle and pig eyes, described and measured the dimensions, and radio densities of intraocular structures using CT scan within presumed normal cattle and compared it with the pig eye, determined Optic nerve sheath diameter (ONSD) in a different location on CT.

## **MATERIAL & METHOD**

**Animals.** 15 adult cattle in addition to 15 adult pigs used in this study (obtained from Al Basateen Slaughterhouse, Egypt). All techniques had been performed in accordance with the Association for Research in Vision and Ophthalmology (ARVO). Postmortem evaluation of the eye and adnexa were performed to verify the absence of any gross abnormalities.

**CT imaging.** The head had been examined by CT immediately within 2 hours, the study was performed in the rostrocaudal direction with the head kept in ventral

recumbence. Images had been obtained in the axial, coronal, and sagittal plane using a multidetector 128 – slice helical CT scanner (Fast, High-Speed CT scanner, Somatom Perspective, Egypt) of 130 kV, 180 mA, and slice thickness range from 0.6 to 1.5mm, scanning time rage from 8 to 13 Sec. All images were uploaded to DICOM viewer Radiant for data manipulation and measurements, which is a widely available software package that allows clinical measurements of intraocular structure parameters on CT images.

**CT Data manipulation and measurements.** In the softtissue window algorithm (WW 300, WL 40) a single examiner conducted manual contouring on each slice of the CT images. The attenuation (in Hounsfield Units (HU) of the vitreous humor, optic nerve, aqueous humor, lens, and the width of the optic nerve, was performed. The procedure for taking measurements was followed exactly as defined in the pig (Olopade *et al.*, 2011), in canines (Salgüero *et al.*, 2015) and in felines (Chandrakumar *et al.*, 2019). To maintain the independence of the variables, all comparisons between clinical data were made with the right eye of both species and the same for the left eyes separately. All multiplanar planes in globe size were optimized. The methods used to obtain intraocular measurements were described in the figures.

#### Intraocular structures Parameters (Fig. 1a)

- Anteroposterior (rostro-caudal) distance of the anterior chamber: from the internal surface of the cornea to the anterior margin of the lens.
- Anteroposterior distance of the vitreous chamber: from the



Fig. 1. Soft tissue window of non-contrast CT scan, Axial plane of the globe detailing the measurements of (a) showed A- the anteroposterior distance of the anterior chamber, B- the anteroposterior distance of the vitreous chamber, C- the anteroposterior distance of the lens, D- the lateromedial distance of the lens E- the anteroposterior distance of the globe, and F- the lateromedial distance of the globe. (B) Showed non-contrast CT scan multiplanar reconstruction (MPR) in the sagittal plane of the globe of soft tissue window, Region of interest in the middle of aqueous humor A- aqueous humor, B- lens, and C- vitreous humor pointed to the density in Hounsfield (HU) of each structure.

posterior aspect of the lens to the internal surface of the choroid/retina/sclera.

- Anterior-posterior distance (axial length) of the lens: taken at the widest dimension of the lens.
- Maximum lateromedial distance (equatorial width) of the lens: taken at the widest dimension of the lens.
- Maximal anteroposterior distance of the globe (axial length): from the internal surface of the cornea to the internal surface of the choroid/retina/sclera.
- Maximal lateromedial distance of the globe (equatorial width): measured perpendicular to the axial length just caudal to the lens.

Radio densities of the aqueous and vitreous humor, and

**lens** (Fig. 1b):Multiplanar reconstruction (MPR) was used to obtain the radiodensities in the sagittal or other planes of each globe where the structures were visible to measure. To allow reporting of mean attenuation in HU, an area in the anterior chamber ( $\approx 4 \text{ mm}^2$ ), the vitreous chamber ( $\approx 10 \text{ mm}^2$ ) in cattle and pigs was performed, but in pigs, the area of the lens ( $\approx 10 \text{ mm}^2$ ) and cattle ( $\approx 20 \text{ mm}^2$ ) was performed.

#### **Optic nerve**

A. Optic nerve width. In MPR mode, the width was taken only caudal to the optic disc, where the nerve exits the globe, the coronal and sagittal planes were used to align parallel to the nerve, and the axial plane was used to calculate the nerve's cross-sectional diameter (Fig. 2).

- B. Optic nerve sheath diameter measurement (ONSD). We tried to measure the width from one side of the optic nerve sheath to the other as described by Legrand *et al.* (2013), to verify that both methods will give the same result in either animal or not animal (Fig. 3a).
- C. Optic nerve radiodensity. To measure mean attenuation in HU, a circular area of interest (≈1.4 mm<sup>2</sup>) was placed in the center of the optic nerve (Fig. 3b).
- D. Optic nerve length (intraorbital). By reviewing many of the previous veterinary medicine or human being studies, the calculation of the nerve length was not done using CT scans. This is due to its anatomical characteristics, as it was found that it has two bends along its path from the posterior pole of the globe to the optic foramen, from this standpoint, the calculation of its length was been based on dividing it into several straight parts and then calculating the total length as an arithmetic sum of those parts (Fig. 3c).
- E. The Opening angle of the optic nerve (Fig. 4). The angle was calculated by a vertical line passing through the middle of the nose and a line passing through the optic nerve (Tsukitome *et al.*, 2015), where the optic nerve was appeared clear in on CT slice, and the measurements were carried out by two independent observers to minimize interobserver variance.



The Opening angle of the orbit (Fig. 4). It is the angle formed between a vertical line passing through the center of the nose and a line running diagonally along the lateral wall of the left orbit (Tsukitome *et al.*, 2015).

Fig. 2. Multiplanar reconstruction (MPR) of non-contrast CT images in a soft tissue window of the optic nerve of cattle. The sagittal (A) and coronal planes (B), (C & D) represent the axial plane where the transverse plane shows the width of the optic nerve just caudal to the optic disk.



Fig. 3. Three-dimensional multiplanar reconstruction indicates (A) Optic nerve sheath diameter measurement (B) Region of interest in the center of the nerve to measure attenuation in (HU) Hounsfield Units. (C) Intraorbital length of the Optic nerve.



Fig. 4. The opening angle of the optic nerve and the opening angle of the orbit in the coronal plane of soft tissue window.

## **Orbital parameter**

- A. The horizontal orbital diameter. In pigs, between the orbit's median canthus (lacrimal bone) and the point of intersection of the line drawn from the frontal bone's zygomatic process to the zygomatic arch (Olopade *et al.*, 2011), we used the same method but calculated it in 3D, but in cattle was measured as the distance between medial canthus to supraorbital process. In CT image it was calculated in the axial scan as the widest diameter between the lateral and medial orbital wall of cattle (Gupta *et al.*, 2019), in pigs was measured as the distance between the medial wall of orbit to the point where a line drawn from the zygomatic process of the frontal bone intersects the zygomatic arch (Fig. 5).
- B. The vertical orbital diameter. We used 3D to measure the orbit's full vertical diameter from the ventral rim of the frontal bone to the dorsal rim of the zygomatic bone in a

straight line (Fig. 5) (Olopade *et al.*, 2011), but in CT scan measured as the widest distance between the inferior and superior orbital wall on the axial scan (Gupta *et al.*, 2019).

- C. Orbital index (OI). Was calculated using the following formula: Maximum vertical distance of the orbital cavity/ maximum horizontal distance ¥ 100 (Olopade *et al.*, 2011; Gupta *et al.*, 2019).
- D. Inter-canthi Distance (ICD). The smallest distance between the orbits' medial margins (Olopade *et al.*, 2011).
- E.Interorbital Distance (Fig. 6). On the axial scan, the minimum distance between medial orbital walls was calculated (Gupta *et al.*, 2019).
- F.Inter zygomatic Distance (Fig. 6). In the anterior part of the zygomatic arch, the maximum distance between these points was measured as inter zygomatic distance (Gupta *et al.*, 2019).

G.Orbital Area (OA). 22/7 ab, where a and b are half the orbital length and width, respectively (Silva *et al.*, 2017; Lantyer-Araujo *et al.*, 2019).

H. Interorbital distance CT3D:

- At the rostral level: distance between the rostral edge of the orbit and the junction of the frontolacrimal sutures on either side.
- At the middle level: distance between the supraorbital margins of the cattle orbit on either side and distance between the zygomatic process of the frontal bone of pig on either side.
- At the caudal level: the distance between the zygomatic bone connections at the orbit's caudal edge on either side.

I. Orbital Depth (OD). The distance between the optic foramen and the center of the orbital rim.

**Globe position (Fig. 6).** On axial scans in the mid-globe slice, the distance between the interzygomatic line and the posterior ocular surface was measured (Gupta *et al.*, 2019).

**Morphometric Assessments.** Three heads of cattle compared to three heads of domestic pigs were fixed using 0.1 mL of 10 % buffered formalin (Lantyer-Araujo *et al.*, 2019). Macroscopic evaluation of the visual system was performed using a topographic dissection and exenteration method, with a Digital Vernier Caliper (Silva *et al.*, 2017) the eye was sectioned in the sagittal plane, including the optic nerve. All steps were photographed with a camera. The parameter of the optic nerve was calculated; the length of the optic nerve was calculated from the posterior pole of the globe to the optic foramen; the width of optic nerve was calculated from side to side using a caliper.

**Statistical analysis.** Differences between treatment groups' cattle and pigs were tested by independent t- test. All data were statistically analyzed using SPSS for Windows: 22, SPSS, Inc. (2001) (Statistical Package for Social Sciences). The results were considered as significant when P- values were less than 0.05 and 0.01. Spss, Inc, (2001).



Fig. 5. (A), (B)- showing measurement of orbital dimensions of cattle in axial scan in bone window and 3d respectively. (C), (D), showing the same dimensions in pigs.



Fig. 6. Axial scan in soft tissue window showing interzygomatic distance (red arrow), yellow arrow (intraorbital distance), and green arrow (globe position).

## RESULTS

**Computed tomography.** The eye presented as a single layer tissue (Figs. 7a and 9a) with internal component hypoattenuating. Internally (Figs. 7b and 9b) CT images differentiated only the hyper attenuating lens, vitreous chamber, anterior chamber, and sclera-choroid-retina complex, however, the iris and ciliary body were not as clearly visualized, and the supraorbital process in the pig is replaced by an orbital ligament which is clear (Fig. 7c). Extraocular muscle location was illustrated in (Fig. 7d) in pigs and (Figs. 9c,d) in cattle. Medial rectus muscle appeared hypoattenuating tissue with ill definite contours and difficulty of following its caudal direction to optic foramen or isolate it from other structures, situated parallel to the frontal bone in cattle and pigs, but lateral rectus muscle situated parallel to supraorbital process in cattle, and orbital ligament in pigs, surround by periorbital. Ventral oblique muscle appeared hypo attenuated, ventrally situated near the insertion of the



Fig. 7. Non-contrast CT image, the axial plane of the eye and adnexa of pigs (A) in the bone window, (B) in the soft tissue window, 1- orbital ligament 2- lacrimal gland 3- medial rectus muscle 4- lateral rectus muscle 5- optic nerve 6- lens 7- choroid- retina- sclera complex.



Fig. 8. Three-dimensional reconstruction technique showing bone of the cattle and pigs orbit.



Fig. 9. Non-contrast CT image of eye and adnexa of cattle axial plane (A) bone window (B) soft tissue widow showing 1- lens 2- choroid- sclera- retina complex (C) 3-lacrimal gland 4- dorsal rectus muscle 5- medial rectus muscle 6- ventral rectus muscle 7- lateral rectus muscle 8- optic nerve 9- dorsal oblique muscle 10- ventral oblique muscle.

ventral rectus muscle. Lacrimal gland visualization was not possible, due to the presence of fat between the eyeball and its ventral surface, so difficult to determine its contour, it is situated ventrally to the orbital ligament in pig (Fig. 7d) which facilitate its definite, and ventrally to supraorbital process in cattle (Fig. 9c). The maxillary bones, lacrimal, frontal, and zygomatic bones, as well as the sphenoid, palatine form the orbital cavity (Fig. 8) which is bounded in cattle by frontal bone dorsally, ventrally by zygomatic bone, lacrimal bone rostral, supraorbital process (Fig. 9/c12) caudally, which replaced in pigs by an orbital ligament (Fig. 7/c7). The measurement of various statistical measurements of cattle and pigs intraocular structures have been summarized in Table I, which clarified that all intraocular parameters of cattle were significant increase (p<0.05) or (p<0.01) than that of pigs exclusively some parameters that will be listed later in the results pane. The distance of the anterior chamber of cattle was significantly increased than that of the pigs with right eye mean (4.26 mm), (2.83 mm) in cattle and pigs respectively, while left eye means (4.30 mm), (2.71 mm) in cattle and pigs respectively. Radiodensity of pigs aqueous humor which is hypodense and homogenous was significant (p<0.05) increased than

that of cattle in the left eye with a mean (52.54 HU), but right eye mean (53.71HU), in cattle mean (15.41 HU), (14.78 HU) in right and left eye respectively. There was a significant (p<0.05) increased of cattle vitreous chamber anteroposterior distance either right and left than that of pig which was isodense to aqueous humor, where the mean of the right pigs and cattle eye was 0.64cm, 1.45cm respectively, whilst of the left a mean (0.66cm) in pig, (1.40cm) in cattle respectively. There was a significant (p<0.05) increase in pigs vitreous density either right and left than that of cattle, was the mean of right vitreous density (27.35HU), (10.66HU) in pigs and cattle respectively, however, the mean of the left eye was (28.27HU) in cattle, (10.75HU) in pigs. The lens was hyperdense structure, the mean of the maximum anteroposterior distance of cattle right and left eye (1.54cm), (1.51cm) respectively, in contrast, the pigs had a mean of (0.61 cm) in the right eye, (0.62 cm) in the left eye, so statistical analysis indicate that there was a significant increase in anteroposterior distance of cattle lens than a pig (p<0.05). In addition, there was a significant increase in the cattle lens width than that of pigs with the mean of the lateromedial distance of the right pig lens (0.88cm) whilst of cattle (1.23cm). In contrast, the left eye lens of pigs had a mean (0.88cm), (1.24 cm) in pigs and cattle respectively.

Statistical analysis connotes that there was a significant increase in cattle density of lens than that of pig,

where mean of the pig right and left lens was 123.27 HU, 123.83 HU respectively, while that of cattle mean 129.88 HU, and 129.62 HU in right and left respectively. The cattle and pig ocular right globe had a mean anteroposterior distance (3.12 cm), (1.94cm) respectively, and the left one of both animal had a mean (3.08 cm), (1.95 cm) in cattle and pigs respectively. The mean of the width of cattle left globe (3.14cm), but pigs (1.77cm), the right globe of cattle had a mean (3.14cm) although pigs had mean (1.92 cm), the statistical analysis showed that there was a significant increase of cattle ocular globe length and width either in right and left globe than that of the pigs. The orbital parameters of cattle and pigs as summarized in Table I. There was a significant (p<0.05) (p<0.01) increase in cattle orbital diameter than that of the pigs. The mean horizontal orbital diameter was 5.85 and 3.03 cm for the right cattle and pigs orbits respectively, on the other hand, the left orbital width of cattle was 5.76 and 2.88 cm in pigs and cattle respectively. While 3D image showed that mean of the right orbital width was 5.70 cm or cattle, and 2.77 cm in pigs, but the left was 5.86 and 2.88 cm for cattle and pigs respectively.

The mean vertical orbital diameter was 6.31 and 3.44 cm for the right orbits of cattle and pigs respectively, while the mean in 3D was 6.29 cm in cattle and 3.31cm in pigs, and the mean of the left orbit was 6.30, 3.56 cm in cattle and pigs respectively, however, the mean of 3D length was 6.33

Table I. CT measurement of the orbital and internal structures of cattle and pig eye.

	Parameter	Right Eye					
		Cattle	Pig	P value	Cattle	Pig	P value
		Mean±SE	Mean±SE		Mean±SE	Mean±SE	
1	Anteroposterior distance of the anterior chamber (mm)	4.26±0.16	2.83±0.39	*	4.30±0.02	2.71±0.34	*
2	Anterior-posterior distance of the lens (cm)	$1.54\pm0.01$	0.61±0.40	**	.015±0.01	0.62±0.49	**
3	Anteroposterior distance of the vitreous chamber (cm)	1.45±0.18	0.64±2.68	*	1.40±0.04	0.66±2.70	*
4	Maximal anteroposterior distance of the globe (cm)	3.12±0.02	1.94±0.04	**	3.08±0.02	1.95±0.04	**
5	Maximum lateromedial distance of the lens (cm)	1.24±0.05	0.88±0.10	*	1.24±0.07	0.88±0.11	*
6	Maximal lateromedial distance of the globe (cm)	3.14±0.04	1.92±0.04	**	3.13±0.01	1.77±0.07	*
7	Radio densities of the anterior chamber (HU)	15.41±0.69	53.71±0.26	**	14.78±1.29	52.54±1.22	*
8	Radio densities of the vitreous chamber	10.66±1.67	27.35±4.58	*	10.75±1.65	28.27±3.61	*
	(Hu)						
9	Radio densities of the lens (HU)	129.88±6.29	123.27±14.78	*	129.62±6.23	123.83±13.80	*
10	The horizontal orbital diameter (cm)	$5.85\pm0.06$	3.03±0.35	*	$5.76\pm0.07$	$2.88\pm0.44$	*
11	The horizontal orbital diameter in 3D (cm)	$5.70\pm.019$	2.77±0.14	*	$5.86\pm0.05$	2.88±0.13	**
12	The vertical orbital diameter (cm)	6.31±0.14	3.44±0.17	**	6.30±0.16	3.56±0.13	**
13	The vertical orbital diameter in 3D (cm)	6.29±0.11	3.31±0.05	**	6.33±0.04	3.32±0.04	*
14	Orbital index (OI) (%)	107.71±1.54	118.91±4.05	*	109.33±1.38	127.85±3.78	*
15	Orbit al index (OI) in 3D (%)	$110.44 \pm 1.72$	119.77±4.32	n s	107.90±0.46	115.62±3.95	ns
16	Orbit al depth in 3D (cm)	4.54±0.23	$2.44\pm0.11$	**	$4.66\pm0.08$	2.59±0.14	**
17	Orbital area (cm <sup>2</sup> )	29.04±0.98	8.30±1.42	**	28.55±1.13	8.12±1.54	**
18	Orbital area in 3D (cm <sup>2)</sup>	28.26±1.46	7.23±0.49	**	29.17±0.47	7.53±0.45	**
19	Globe position (cm)	$1.24\pm0.12$	0.66±1.66	*	1.23±0.12	.067±1.64	*
20	The opening angle of the orbit (°)	73.22±0.26	67.50±3.75	n s	73.35±0.27	68.23±3.84	ns
No / 1							

\* (p<0.05) or \*\* (p<0.01), ns non-significant.

cm for cattle and 3.32 cm for pigs. Regarding orbital index, the Statistical test revealed that there was a significant (p<0.05) increase in OI of pigs than cattle in CT images, but for 3D there was no significant difference between pigs and cattle in either right or left orbit. The right orbit of cattle and pigs showed that the average orbital index in CT images and 3D reconstruction were (107.71 %, 118.91 %) in cattle, (110.44 %, 119.77 %) in pigs respectively. The left orbital index average in cattle and pigs respectively was 109.33, 127.85 %, although in 3D the mean was 107.90, 115.62 %. The orbital area of the cattle's right eye was (29.04, 28.26 cm<sup>2</sup>) in CT image and 3D, however, pigs showed (8.30, 7.23 cm<sup>2</sup>) respectively. The left eye of cattle had (OA) (28.55 cm<sup>2</sup>) in CT image and pigs (8.12 cm<sup>2</sup>), in 3D (29.17, 7.53 cm<sup>2</sup>) in cattle and pigs respectively. The orbital area in the CT image and 3D cattle's eye was significantly (p<0.01) larger than in the domestic pigs. Statistical analysis viewed that cattle orbital depth of both eyes on 3D had a significant increase (p<0.01) than that of the pigs. Cattle had the orbital depth of right and left eye (4.54, 4.66 cm), while pig had (2.44, 2.59 cm) respectively. However, there was no significant difference between the opening angle of orbit measured for both species where the right angle was ( $73.22^\circ$ ,  $67.50^\circ$ ) in cattle and pigs respectively, and the left angle was ( $73.35^\circ$ ) in cattle, ( $68.23^\circ$ ) in the pigs. Globe position, there was a significant increase (p<0.05) globe position of cattle than that of the pigs, where in cattle right globe position mean (1.24cm), in pig (0.66 cm), the mean of position in the left cattle globe was (1.23 cm), in pigs (0.67 cm).

The intraorbital parameter on CT3D of both species was illustrated in (Tabla II) All parameters were significantly increased in cattle than pigs (p<0.01). (Table III) illustrated that all parameters of the optic nerve in CT images were increased significantly in cattle than in pigs except for opening angle and radiodensity of the nerve.

Table II. Orbital parameter of cattle and pig using CT three dimensional technique.

#	Parameter	Cattle	Pig	P value
		Mean±SE	Mean±SE	
1	Inter orbital distance in bone window (cm)	5.10±030	2.21±0.36	**
2	intra zygomatic distance in bone widow (cm)	17.50±0.03	9.83±0.05	**
3	Inter orbital distance in 3D at rostral level (cm)	14.77±0.63	6.09±0.32	**
4	Inter orbital distance in 3D at middle level (cm)	16.51±0.14	$7.80\pm0.09$	**
5	Inter orbital distance in 3D at caudal level = intra zygomatic distance (cm)	17.31±0.07	10.48±0.09	**
6	Inter Canthi distance (cm)	12.18±0.71	5.79±0.20	**

\*\* (p<0.01)

Table III. CT parameter of optic nerve of cattle and pig.

#	Parameter	Right Eye			Left Eye		
		Cattle	Pig	Р	Cattle	Pig	Р
		Mean±SE	Mean±SE	value	Mean±SE	Mean±SE	value
1	The opening angle of the optic nerve (°)	51.30±0.43	58.20±0.10	**	51.60±0.55	58.16±0.08	**
2	Optic nerve sheath diameter measurement	6.71±0.55	$3.92\pm0.10$	*	6.76±0.47	4.08±0.20	*
	(ONSD) intra orbital (mm)						
3	Optic nerve width just caudal to optic disk (mm)	6.96±0.63	$4.60\pm0.06$	*	6.63±0.65	4.14±0.24	*
4	Optic nerve length (intraorbital) (cm)	$7.02\pm0.10$	2.17±0.13	**	$7.04\pm0.02$	2.31±0.17	**
5	Optic nerve radiodensity(HU)	$38.50 \pm 0.07$	47.23±0.49	**	39.57±0.23	47.28±0.53	**

\* (p<0.05) or \*\* (p<0.01), ns non-significant.

**Morphometric Assessments.** The optic nerve of cattle is thick and cord-like, with left sclera at the caudolateral quadrant of the eyeball, making a flexuous course with two curvatures to facilitate movement without causing tension on the nerve, before entering the canal the optic nerve pass between the retractor bulbi and medial rectus muscles which with the surrounding fat form what is known as the muscular cone (Fig. 10c). The pig nerve was thin cord-like in comparison with that of cattle leaving sclera from the caudal aspect, having flexure along its intraorbital length from sclera to optic foramen, also it is surrounding by extraocular muscle along its course (Fig. 10f). Statistical test (Table IV) of morphometric data revealed that intraorbital length and diameter of the optic nerve either for right and left eye of cattle increase significantly than that of pigs.

# DISCUSSION

MRI and ultrasound are useful soft-tissue diagnostic methods and imaging modalities of choice for ocular

	1 1						
#	Parameter	Right Eye			Left Eye		
		Cattle	Pig	Р	Cattle	Pig	P value
		Mean±SE	Mean±SE	value	Mean±SE	Mean±SE	
2	Optic nerve sheath diameter measurement (ONSD) intra orbital (mm)	4.74±0.35	4.03±0.08	**	4.95±0.08	3.80±0.33	* *
4	Optic nerve length (intraorbital) (cm)	$7.56 \pm 0.21$	$3.18 \pm 0.01$	*	7.64±0.13	3.27±0.10	*

Table IV Morphometric dimension of cattle and pig optic nerve.

\* (p<0.05) or \*\* (p<0.01), ns non-significant.



Fig. 10. Gross anatomical image of the eye and adnexa of cattle (A, B, C) and pig (D, E, F) 1-medial canthus 2-lateral canthus 3- upper eyelid 4- lower eyelid 5- third eyelid 6-sclera 7- cornea 8-lacrimal gland 9- optic nerve yellow arrow indicated the nerve flexures along its length.

examination of the eye and periorbital tissues. Ultrasonography allows imaging of the retrobulbar soft tissues, evaluation of the eye's interior (ciliary body, iris, anterior chamber, lens, optic nerve, retina, and sclera), provides a simple, inexpensive, and non-invasive image of the eye that does not require sedation or anesthesia; however, multiplanar imaging is not feasible. MRI has capabilities of multiplanar imaging and provides excellent contrast resolution of soft tissues without exposing the patient to ionizing radiation in comparison to CT, however, general anesthesia and much longer acquisition times are needed. On the other hand, CT provides faster image acquisition and tends to be more commonly available in veterinary practice than MRI, images are transparent and unobstructed, lack superimposition, and however Computed Tomography exposes the patient to ionizing radiation (Salgüero et al., 2015; Madkour et al., 2016; Chandrakumar et al., 2019; Mattoon et al., 2021).

During the CT examination of the head by the radiologist, the orbit, globe, and intraocular structures are included, occasionally, any ocular exchange or pathological defect may be identified, which can affect the diagnosis, management, and treatment of the cases. This is the first step in long-term research that the authors are aware trying to provide reference values to parameters of orbit and intraocular structures of cattle and pigs through CT scan to facilitate investigation of any ocular defects. In this study, statistical differences in intraocular measurements and parameters of orbit between cattle and pigs had been noted. All intraocular and orbital parameters of cattle increased significantly (p<0.05),

(p<0.01) than that of the pig except for radiodensity of aqueous and vitreous humor, radiodensity of optic nerve, and the angle of the orbit. The anteroposterior distance of the anterior chamber of cattle using US by B- mode has been reported to range from (5.6-7.5 mm) with a mean of 6.2 mm (El-Maghraby *et al.*, 1995) in this study the distance varied from (4.03- 4.59 mm) with mean 4.28 mm, the result

is little different, this may be attributed to the fact that in this report we calculate the distance from the internal surface of the cornea to the anterior margin of the lens, however (El-Maghraby et al., 1995) measure it from mid of cornea to the lens. In human or veterinary medicine except for some studies on felines and canines (Salgüero et al., 2015; Chandrakumar et al., 2019) normal densities of the ocular components in CT have never been recorded. As it is important to minimize doses to organs at risk, such as the lens and optic nerve while preparing radiation therapy for nasal tumors, HU is used in many CT-based radiation planning software algorithms to calculate the dose of radiation administered to particular tissues, it allows accurate measurement of the expected value by inputting acceptable HU for each of these structures (Klüter et al., 2011; Chandrakumar et al., 2019). This study found a significant (p<0.01) increase in density of pig right and left optic nerve than that of cattle this may be attributed to the increasing (g ratio) of pigs than other mammals (Guy et al., 1989), in addition, the density of pig aqueous humor and vitreous humor was significant (p<0.05) increased than that of cattle. This may be traced back to some reasons. The first one is the age, which has a major impact on the composition of the aqueous humor. The second is postmortem change in the content of aqueous humor especially in carbohydrate and amino acid concentration, so immediate extract of aqueous humor is necessary when requiring it for study. The third one may be due to the change in volume or composition of humor between species. The fourth one that is especially related to the vitreous humor, there are significant variations in protein amounts and types between species as mentioned in sheep, rabbits, and bovine studies (Swann & Caulfield, 1975) as, noncollagenous protein makes up the bulk of total protein (70 percent) content in pigs vitreous (Noulas et al., 2002), The rabbit vitreous contains a lot of non-collagenous protein (60 percent of total protein), while the collagenous protein is relatively low in bovine and canine vitreous (Jacobson, 1984). Regardless of the previously mentioned potential assumptions, further studies on these species are needed to support these causes. On the other hand, the pig optic nerve angle showed higher significance (p<0.01) than that of cattle this is due to the visual behavior of pig as it has 35-50 binocular vision, prioritize their lateral monocular vision, which improves their ability for detecting any danger, however, cattle have binocular vision 25 - 50 degree. This study has some limitations, we did not determine the eye position and eye movements before the CT recordings, so we attempted to have radiologists who are board-certified to assess the images. Complete ophthalmological exams through CT scanning before testing led to the possibility of including non-healthy eyes and animals with ocular abnormalities such as cataracts or nuclear necrosis which may affect the value of radiodensity. This study predominantly included females and this may skew the result so it is suggested that more research be done to investigate if there is a difference between the intraocular structures of male and female cattle and pigs. With manual evaluation of the image and a large number of parameters analyzed, the difference in slices thickness may contribute to measurement differences. There was a small population so we cannot measure the value of density of the previous parameter of each animal and if there is a significant difference between right and left eye or male and female. Further studies are required in each species separately to recommend the best location for cases where ONSD is used for intracranial pressure control. Separate determination of the intraorbital length of the optic nerve in each species and comparing the result with the morphological length obtained, provide a standard radiodensity value of the lens, aqueous, vitreous chamber, and optic nerve of cattle and pigs radiation therapy patients, this value may be used for future preparation of radiation therapy.

## CONCLUSION

All orbital and intraocular parameters of cattle increase significantly than that of pigs except radiodensity of optic nerve, aqueous and vitreous humor, angle of the orbit and the optic nerve.

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ABDO, M.; TAHER, R.; ERASHA, A. & FERICEAN, L. Mediciones morfológicas y tomográficas computarizadas comparativas de la órbita en ojos de bovinos y porcinos. *Int. J. Morphol.*, *41*(1):134-145, 2023.

**RESUMEN:** Comprender los parámetros intraoculares de especies mediante la tomografía computarizada es un paso inicial y crítico en oftalmología. Faltan estudios enfocados en la estimación de ojos de bovinos y porcinos mediante tomografías computarizadas. Por tanto, este estudio tuvo como objetivo describir las características anatómicas y de tomografía computarizada de los bulbos oculares de bovinos y porcinos y sus estructuras internas. Se desarticularon cabezas de animales que no padecieran alguna enfermedad relacionada con el ojo. Se realizó una tomografía computarizada. Se fijaron las muestras en formalina tamponada al 10 % para la descripción anatómica del bulbo ocular y del nervio óptico en particular. Se midieron los valores de longitud del bulbo ocular, ancho del lente y la radio densidad del nervio óptico, lente, cámara anterior, cámara vítrea y dimensiones orbitarias. Estadísticamente, todos los parámetros del nervio óptico del ganado aumentaron significativamente con respecto al del cerdo, excepto la radio densidad y el ángulo del nervio óptico. Además, todos los parámetros intraoculares del ganado bovino aumentaron significativamente respecto a los del cerdo, excepto la radio densidad del humor acuoso y cuerpo vítreo. No hubo diferencia significativa entre especies en el ángulo de apertura de la órbita. Los hallazgos de este estudio representan un primer paso hacia el desarrollo de valores de referencia de tomografía computarizada para evaluaciones estructurales intraoculares de ganado vacuno y porcino.

PALABRAS CLAVE: Ganado; Cerdo; Tomografía computarizada; Nervio óptico; Morfometría.

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