Doppler ultrasonographic estimation of ocular resistive and pulsatility indices in normal unsedated cows

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SUMMARY

Introduction - Resistive index (RI) and pulsatility index (PI) are indirect measurements of blood flow resistance that may be used to evaluate the vascular pattern in ophthalmology. The application of ultrasonography on ocular structures of cattle are limited at the biometric evaluation of the bovine eye. To our knowledge, no reports are available describing values for ocular RI and PI indices in unsedated cows.

Aim - The main purpose was to report normal values for RI and PI of internal ophthalmic artery (IOA) and long posterior ciliary arteries (LPCAs) in unsedated clinically healthy cows, performing the Doppler ultrasonographic examination.

Materials and methods - Twenty Brown Swiss dried healthy cows were subjected to a complete ophthalmic examination. IOA and LPCAs were scanned using Colour Doppler Imaging (CDI) in order to calculate RI and PI. Transpalpebral ultrasonographic images from both eyes were obtained using a 7.5 MHz duplex sectorial transducer. For each vessel the mean value and the standard deviation of RI and PI were expressed. The t-student test was applied to evaluate differences between right eye and left eye. P<0.05 was considered significant.

Results and discussion - The mean RI (± SD) was 0.57±0.07 and 0.58±0.09 for IOA of right and left eye respectively; 0.54±0.11 and 0.53±0.08 for LPCAs of right and left eye. The mean PI (±SD) was 0.95±0.07 and 0.93±0.09 for IOA of right and left eye; 0.80±0.11 and 0.84±0.08 for LPCAs of right and left eye. No significant differences in RI and PI values between left and right eye were reported.

Conclusion - The CDI of ocular vessels and the measurement of blood flow parameters are feasible in cow and it may be used to evaluate vascular changes of certain ocular disorders affecting food animals.

KEY WORDS
Color Doppler Imaging; Cattle; Internal ophthalmic artery; Long posterior ciliary arteries; Pulsatility and Resistive Indices.

INTRODUCTION

Colour Doppler Imaging (CDI) is a non-invasive technique in order to study the real-time anatomic state and dynamic vascular pattern in both humans and animals1,2. Ocular ultrasonographic examination is routinely performed on different species3-5. During the CDI examination the resistive index (RI) and the pulsatility index (PI) are evaluated; they represent indirect measurements of blood flow resistance that may be used to evaluate vascular changes in several diseases6.

In the ophthalmological practice since orbital vessels are small and difficult to locate, CDI is especially beneficial in determining the blood velocity parameters in these vessels. Furthermore, most of vessels of this region run nearly parallel to the ultrasound beam providing ideal conditions for studies of blood flow7.

In human medicine, CDI has been used to describe the course of ocular vessels and to assess their blood flow patterns2; furthermore, the determination of RI allowed to improve the evaluation of vascular changes during several ocular abnormalities8.

In veterinary medicine specific normal orbital and ocular blood velocity parameters in healthy and affected by ocular and orbital disorders dogs were reported6,9-11. Several ophthalmic studies on normal or pathological bovine eyes have been carried out, although it seems that the ocular diseases in food-producing animals are underestimated12. The application of ultrasonography on ocular structures of cattle are limited at the biometric evaluation of the bovine eye in both cadavers and living subjects12,13.

Ultrasonography of the cattle eye revealed many similarities to that described for dogs9,10, buffaloes14 and horses15, with some variations in the shape and dimensions. Given the complex anatomy of the eye, a brief look at the ocular vasculature is appropriate.

The internal ophthalmic artery arises from the anterior cerebral artery at the level of the chiasm optic. It anastomoses with the external ophthalmic artery and from this anastomosis two long posterior ciliary arteries and 6-10 short posterior ciliary arteries. The long posterior ciliary arteries support the anterior segment of the eye primarily through the basal iridial circle. The short posterior ciliary arteries supply the optic nerve head, scleral lamina cribrosa, retina and choroid. The retina of the cow is holangiotic: three or four major venules accompanied by paralleling arterioles drain and supply the retina, respectively7,14.

The main purpose of this study was to report normal values for RI and PI of internal ophthalmic artery (IOA) and long posterior ciliary arteries (LPCAs) in unsedated clinically healthy cows, performing the Doppler ultrasonographic examination.

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MATERIALS AND METHODS

The study was performed on 20 adult Brown Swiss dried cows. The cows ranged from 4 to 8 years old, and their body weight ranged from 500 to 600 kg. All animals enrolled were considered healthy on the basis of a physical examination and they showed no ocular lesions as determined by a complete ophthalmic examination, including slit-lamp biomicroscopy and indirect ophthalmoscopy. Applanation tonometry (TonoPen-XL; Mentor®, Norwell, MA, USA) was performed to evaluate intraocular pressure.

CDI was performed using ultrasonography (Pandion Vet machine) with a 7.5 MHz duplex sectorial transducer. Doppler setting (Doppler frequency: 4.0 MHz, sample width: 7 mm, wall filter: 50 Mhz) were kept constant, in order to minimize technical errors.

The animal were restrained in a crush, without use of sedation or loco-regional anaesthesia. The transducer was placed in contact with eyelids applying a sterile gel on the eyelid surface. Scansions were obtained in a horizontal planes. The ultrasound examination was performed by the same operator with an extensive imaging experience.

The identification of ocular vessel were obtained using the B-mode ultrasound, visualizing the retrobulbar fat and the lateral wall of each eye. CDI has been used to form an image of the deeper vessels in the eye, thus determining their location; subsequently, a colour flow imaging and a spectral Doppler analysis were performed, evaluating the spectral characteristics of the IOA and LPCA with blood velocity parameters, like peak systolic velocity (PSV), end diastolic velocity (EDV), mean velocity of blood (MV), pulsatility index (PI) and resistive index (RI). At the end of the procedure each eye was washed with a sterile physiological solution, in order to remove the ultrasound gel.

The PI and RI were calculated using the internal software of the ultrasound unit. The PI was calculated as: 
\[ PI = \frac{PSV - EDV}{MV} \]

The RI was determined using the following formula: 
\[ RI = \frac{PSV - EDV}{PSV} \]

On each cow, all measurements were performed three times to minimize technical errors. For each data mean values and standard deviation were expressed.

Statistical analysis was performed applying the t-student test in order to compare RI values in the IOA and LPCA of left and right eye. Calculations were carried out by commercially available software. For all tests, P<0.05 were considered significant.

RESULTS

In conventional B-mode ultrasound the anterior and posterior lens capsules and the ocular posterior surface appeared hyperechoic. The anterior aqueous chamber and the vitreous chamber appeared as anechoic areas. The anterior and posterior lens capsules appeared respectively as convex and concave echogenic lines, while the lens was anechoic. The iris and ciliary body were observed as linearly shaped moderately echoic structures. The posterior ocular wall had a good echoicity. The IOA and LPCAs appeared as anechoic lines. The IOA was detected in the deep ventral orbit behind the posterior ocular wall. Its spectral waveform morphology is shown in Figure 1. LPCAs were detected in either the 3- or 9-o’clock within the sclera. Their spectral waveform morphology is shown in Figure 2.
**DISCUSSION**

Doppler ultrasonography in veterinary medicine has been widely applied in echocardiography and to assess a vascular damage in various districts of body, as kidneys and eyes of dog, cats and horses [12]. Ultrasonography is an inexpensive, painless and less surgical technique and it provides important information about ocular and retroorbital anatomy. In human and veterinary ophthalmology, doppler imaging was used to differentiate and measure intraocular and orbital tumours, to identify retinal detachment, to detect orbital abnormalities as microphthalmia, to diagnose glaucoma and to evaluate an orbital or ocular trauma [10].

Blood velocity parameters obtained with CDI, as PI and RI, reflect ocular haemodynamics and especially the RI is indicator of vascular resistances, while the PI is used to vascular identification, as the venous flow continuous for example [1].

Vascular resistance increases due to obstruction or vasoconstriction, causing an extreme reduction in diastolic blood flow in comparison with systolic blood flow. RI values can vary between 0 and 1. When the value is 0 this means that there is no resistance, whereas an RI of 1 indicates high resistance into the vessel. A high RI demonstrates an increase in vascular resistance and a decrease in perfusion [1, 2].

PI is generally applied to more oscillatory and high resistance and impedance vascular beds. PI values range from 0.00 (systolic = diastolic velocity to infinity (mean velocity = 0) and represent minimal and maximal arterial input resistances and impedances, respectively. Both RI and PI indices increase with increased vascular tone and vasoconstriction and decrease with vascular relaxation and vasodilatation. Both indices are independent of the Doppler angle of insonation and thus are simple, inexpensive, robust, and portable non-invasive surrogates of relative arterial impedances [2, 3].

Our results showed the feasibility of Doppler examination of ocular vessels in bovine species, likely related to the large dimension of the ocular globe in cattle. Furthermore, in accordance with literature the majority of the ocular vessels in cattle course nearly parallel to the ultrasound beam; that is ideal for the Doppler Imaging. The measurements of blood velocity parameters are highly reproducible and comparable in the different ocular disorders characterized by vascular changes [12].

In this study, in agreement with Gelatt-Nicholson, the IOA was detected in the deep ventral portion of globe, in central-medial position. The long posterior ciliary arteries were detected in the sclera at the 3 and 9 o’clock positions. The IOA shows the same velocimetric characteristics as the internal carotid except for spectral amplitude: a high PSV, due to higher systolic acceleration, followed by the rapid drop in velocity until low EDV, related to low arterial resistance. These data are comparable with previously published data for other species [10].

We reported that there were no significant differences in the RI and PI mean values between the left and right eyes of examined cows, in accordance with other Authors [16, 17]. Greenfield et al. (1995) suggested that age may affect normal blood flow and vascular resistance in human beings. In the current study all examined cows were adult, although the age-related variation of RI and PI indices were not investigated. So, further studies could be carry out in order to investigate the changes of ocular blood flow velocity related to the age and to the different breeds of cattle. It is reported that sedative or analgesic drugs have the potential effect to lower the intraocular pressure, as well as the systemic blood pressure and they may influence the ophthalmic blood flow patterns in the eyes [11]. The effects of pre-anesthetic agents on blood velocity parameters for ocular vessels in cattle need to be assessed.

In this study the animals were examined without the use of sedatives, what it allows us to assert that our data could provide mean values of blood velocity parameters for the major ocular vessels in normal unsedated cows. They can represent ocular diagnostic reference parameters in the bovine species, as useful data to the evaluation of certain ocular diseases that exhibit vascular changes, such as glaucoma, retinal detachments, cataract and corio-retinitis. The knowledge of ocular parameters on ruminants are fundamental for veterinary practitioners, in order to evaluate systemic or local diseases [18].

In conclusion, ultrasound technique can be used also in large animal ophthalmology for investigating changes in ocular blood flow as diagnostic and prognostic tool.

**References**