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RESEARCH ARTICLE

Resistive Index (RI) Obtained in Renal Interlobar Arteries of Normal Dogs and Cats by Means of Doppler Ultrasonography

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A B S T R A C T

As ultrasound equipment with Doppler applications is being widespread, quantitative analysis of the intrarenal arteries Doppler spectra has been quickly extrapolated to veterinary medicine. However, there is no agreement between authors about the site of the measurements and the value of the upper threshold of the RI in dogs and cats. The aim of this study was to verify the influence of age, sex and body weight on the intrarenal RI of dogs and cats, as well as determining the qualitative character of the Doppler spectra. Additionally, average difference of the RI between kidneys (delta RI) was calculated. All measurements were performed in the interlobar renal arteries of manually restrained animals, accordingly to the overall standards of the procedure of Doppler ultrasound examination. In total, 44 dogs and 31 cats were examined. Mean RI±SD was 0.64±0.04 in dogs and 0.6±0.04 in cats. An average, positive correlation between animals age and the RI was found. No relationships of the sex with the RI and body weight of the dogs with the RI were observed. In contrast to dogs, waveforms of 16% of cats did not present a double systolic peak. In conclusion, the authors consider 0.71 and 0.68 as an upper normal limit of RI measured in interlobar renal arteries in dogs and cats, respectively.

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INTRODUCTION

Ultrasonography is one of the basic methods of investigation in a common clinical problem such as kidney disease of dogs and cats. A serious disadvantage of standard B-mode ultrasonography is very low sensitivity and specificity of abnormal renal echotexture (Tublin *et al.,* 1999; Murphy and Tublin, 2000). Moreover, there is commonly a lack of agreement between renal morphology and its function. Doppler ultrasonography of the kidneys is being a widespread complementary method of renal imaging in both humans and companion animals such as dogs and cats (Morrow *et al.*, 1996; Carvalho and Chammas, 2011; Sugiura *et al.*, 2011; Hanamura *et al.,* 2012). The analysis of the Doppler spectra and calculating resistivity and pulsatility indices, provides unique physiological informations related to peripheral resistance, vascular compliance, conductance and transmural pressure. The higher the interstitial pressure, arterial wall stiffness and resistance of capillary bed, the lower the flow velocity at the end of the diastole, eventually resulting in high resistivity index (Murphy and Tublin, 2000).

The results of the examination are presented as precise numeric data, where hundredths are relevant as borderline of the reference values. According to this, several repeated measurements are recommended during one examination to make the data more reliable. Published data concerning Doppler ultrasound of the kidneys in small animals are divergent in obtained values as well as in the type of the renal vessel where the measurements were taken. Suggested upper limits for intrarenal RI in dogs presented in prior studies are 0.67 (Morrow *et al.*, 1996), 0.7 (Nyland *et al.*, 1993), 0.72 (Novellas *et al.*, 2007a) and 0.73 (Rivers *et al.*, 1997, Choi *et al.*, 2003). According to the published data, intrarenal RI in cats should not exceed 0.69 (Pollard *et al.*, 1999), 0.7 (Mitchell *et al.*, 1998, Novellas *et al.*, 2007a,) and 0.71

(Rivers *et al.*, 1996). Carvalho and Chammas (2011) were measuring RI particularly in the renal interlobar arteries of normal Persian cats and obtained 0.52±0.06 (mean±SD). As majority of authors rely on the following formula (mean±2x SD) when settling the reference values, 0.64 should be considered as an upper RI limit for Persian cats.

The aim of this study was to determine upper reference RI values obtained particularly in the interlobar arteries in normal dogs and cats, verify the influence of sex and age and body weight of the animals on the renal RI value and compare the character of the Doppler spectra in normal dogs and cats. Additionally, the objective was to calculate the mean difference between the RI assessed in right and left kidney in both examined species.

MATERIALS AND METHODS

Doppler ultrasound of the kidneys was performed in client-owned animals (44 dogs and 31 cats) with a normal renal status based on serum urea and creatinine. Animals with signs of urinary tract disease, cardiac diseases, liver dysfunction, hyperadrenocorticism, or other systemic conditions or symptoms such as neoplasia or fever, receiving NSAID or with history of renal diseases, as well as arrythmia were excluded from the study. All examined kidneys were normal in ultrasonographic morphology. To increase the variability of the population, animals of different age, sex and breeds were used in this study (Table 1). All animals were manually restrained to avoid the influence of the anesthetics on the renal blood flow (Mitchell *et al.*, 1998, Novellas *et al.*, 2007b). Dogs and cats were examined in dorsal and right lateral recumbency, after the hair of the flanks was clipped and the coupling gel applied.

Table 1: Characterization of the animals used in the study

	N		Age (years)	body weight (kg)
Dogs	44*	26 M 18 F	6.7±4.0	21.7±12.0
Cats	31**	16M 15F	3.6±2.7	N/D

Data presented as mean±SD. *Mix-breed (13); 3 each of miniature poodle, Labrador retriever, dachshund; 2 each of American Staffordshire terrier, American Staffordshire bullterrier, Yorkshire terrier, beagle, boxer; 1 each of Irish setter, Alaskan malamute, briard, giant schnautzer, black Russian terrier, springer spaniel, German shepherd, foxterrier; **domestic shorthair (25), maine coon (2); 1 each of Devon rex, ragdoll, Siberian cat, sphinx; M-male; F-female; N/D – no data.

Duplex Doppler ultrasonography was performed using Philips EnVisor C ultrasound machine, with microconvex (5-8MHz) and linear (3-12MHz) transducers. All kidneys were assessed in B-mode ultrasound examination, determining its size, shape, echotexture, cortex : medulla ratio and evaluation of renal pelvis and ipsilateral ureter. Pulse repetition frequency was set as low as possible but avoiding the aliasing artifact. Doppler gain was adjusted in a manner to fill in the entire vessel with color, up until the noise artifact occurred. With the use of pulsed-wave Doppler, a sample volume not exceeding the diameter of the vessel (usually <2mm) was placed on the interlobar artery. The dorsal section of the kidney was preferred to obtain the lowest angle between the ultrasound beam and the long axis of the interlobar artery. The Doppler angle was corrected if needed but care was taken not to overstep the value of 45º. Three to six measurements were performed in each kidney (in cranial and caudal pole and hilar area of the kidney). Resistivity index was automatically calculated, basing on the Pourcelot equation, after manual analysis of the Doppler waveform by pointing the peak systolic velocity (PSV) and end-diastolic velocity (EDV).

STATISTICA 8.0 sheet was used for the statistical analysis, with statistical significance defined at $P<0.05$. Resistivity index value for each patient was the mean of all the performed measurements in both kidneys (6-12 calculations). Additionally, mean RI for the left and right kidney was calculated. Determining upper limits of the RI and ΔRI values (difference between mean value obtained in the left and right kidney calculated for each patient individually) was based on the following formula (mean + 2 x SD). Student's *t* test and Mann-Whitney U test were used for comparison between groups of parametric and nonparametric data, respectively. Correlation was calculated with the Spearman rank order correlation test.

RESULTS

The obtained results of RI are summarized in Table 2. In 14 dogs (32%) a medullary rim sign was present, which was considered as a non-pathognomic sign of kidney disease but it is known to occur in normal animals (Mattoon and Nyland, 2015). Doppler spectra of all dogs presented low-resistance, forward flow with the presence of early or accessory systolic peak during systole (Fig. 1).

Renal cortex of 8 cats (25%) was described as hyperechoic, which is considered as normal finding in cats (Debruyn *et al.*, 2012). In two cats (6%) medullary rim sign was found. All feline Doppler waveforms were characterized by a forward flow and a low-resistant pattern (Fig. 2). In contrary to dogs, 5 cats (16%) did not present either early or accessory systolic peak.

In both dogs and cats there was no statistically relevant difference between mean RI values in the left and right kidney ($P>0.05$). However, difference of RI between both kidneys in each specimen was calculated and shown in table 2. Both species groups revealed average, positive and statistically significant correlation between animals age and RI ($r=0.4$ in dogs and 0,47 in cats) (Fig. 3,4).

No significant difference of the mean RI value was found between males and females of dogs and cats ($P>0.05$). In dogs, there was no statistically significant correlation between the animal body weight and RI. Additionally, no differences were found after comparison

Table 2: Obtained values of resistive index in dogs and cats.

	RI	RI(L)	RI(R)	ΔRI	M	F
Dogs	0.63±0.04	0.63±0.04	0.63±0.05	0.01±0.02	0.63±0.04	0.64±0.04
Cats	0.6±0.04	0.61±0.05	0.6±0.05	0.03±0.02	0.6±0.05	0.61±0.04

Data presented as mean±SD. RI-mean value from both kidneys, RI(L)-measurements obtained in left kidney, RI(R)-measurements obtained in right kidney, ΔRI – difference between two kidneys calculated individually in each animal, M-males, F-females.

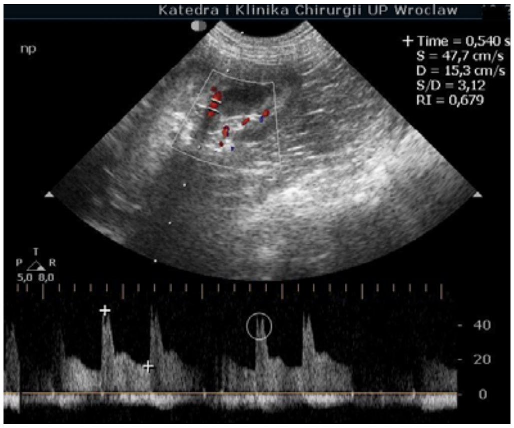

Fig. 1: Normal Doppler waveform established in interlobar artery of a dog. Double systolic peak is encircled.

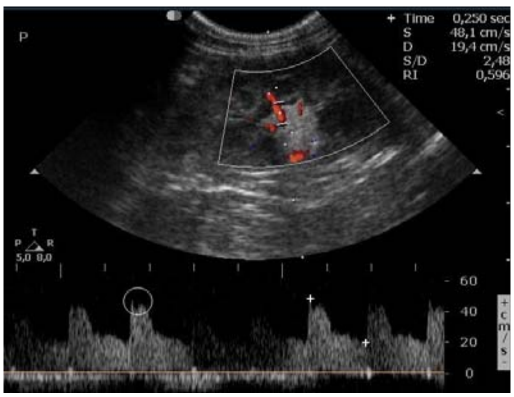

Fig. 2: Normal Doppler spectrum obtained in interlobar artery of a cat. Early systolic peak is marked by circle.

of three groups of dogs (<10kg, from 10 to 30kg and >30kg) in ANOVA non-parametric multiple comparison test of variance.

DISCUSSION

Facing the human medicine where 0.7 is treated as an upper limit of the renal RI, in small animal studies, there is no unique statement referring to the normal values of RI. The authors hypothesized that one of the reasons of the aforementioned variability could be the changeability of the renal vessels, in which the measurements were obtained. Some authors set arcuate arteries as a site of the measurement (Pollard *et al.*, 1999; Rivers *et al.*, 1996; Rivers *et al.*, 1997) whereas others treat interlobar and arcuate arteries interchangeably (Morrow *et al.*, 1996; Mitchell *et al.*, 1998; Choi *et al.*, 2003; Novellas *et al.*, 2007a). It was proved that values of the RI vary depending on the type of the renal vessel, gradually decreasing in smaller and peripherally located arteries: renal, interlobar, arcuate and interlobular, respectively (Martinoli *et al.*, 1998). Therefore, the goal was to obtain the measurements particularly in the interlobar arteries.

Great diversity of the veterinary patients in comparison to humans could be a probable factor influencing the discrepancy in the renal RI among different studies. Thus, possibly high heterogeneity of the body weight and among breeds of the examined

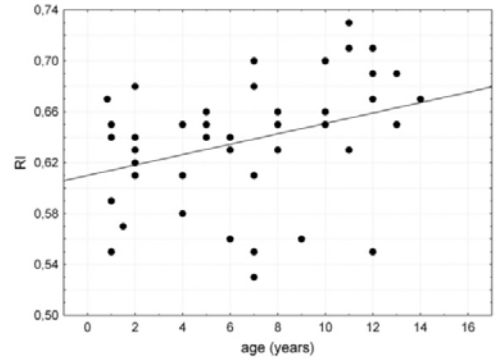

Fig. 3: Scatter plot for RI versus age in dogs.

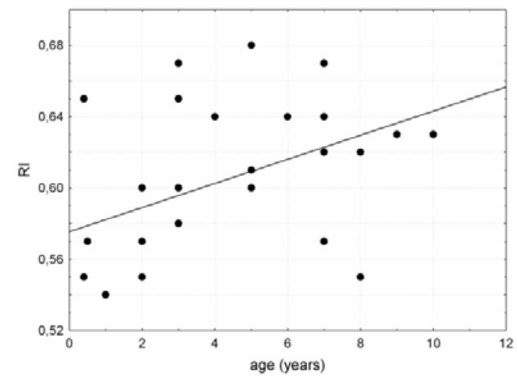

Fig. 4: Scatter plot for RI versus age in cats.

population was the authors goal. However, no statistically relevant relationship between the RI and body weight of the dogs was found in this study.

The guideline of this study was to maximally increase the range of age of the used animals to verify the influence of maturity on RI. To our best knowledge, no data concerning influence of age on renal RI in small animals were published. However, Chang *et al.* (2010) proved that, similarly to young children, in dogs below four months of age, RI is significantly higher than in older puppies, due to an increased plasma renin activity. In the study, the youngest animals were a 10-month-old dog and two 5-month-old cats.

In both of the species groups, there was an average positive correlation of the RI with the age of the animals. Interestingly, opposite to elderly people, imbalance between elastin and collagen within the arterial wall is not observed in dogs ageing process. Then, higher RI in older animals should not be directly related to the decrease in arterial vessels compliance as it is observed in people with atherosclerosis (Stefan, *et al.*, 2014). According to this, we suspect that RI can be considered a more reliable diagnostic factor of impaired renal function than in humans. Presumably, interaction between age and RI could be a result of renal ageing, which is observed in companion animals (Waters *et al.*, 2011). Apart from vascular changes, mechanisms of age-related decline of the kidney include i.a. interstitial damage, impaired autoregulation and increased renal vasoconstriction. Hence, further evaluation of greater sample of geriatric dogs and cats with detailed renal status data would be invaluable.

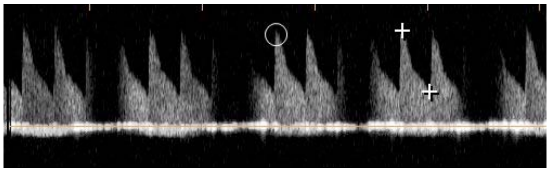

Fig. 5: Waveform with solitary systolic peak (encircled) obtained from interlobar artery of a cat.

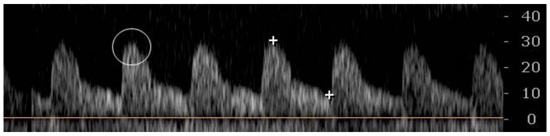

Fig. 6: Doppler spectrum presenting broad systolic peak marked with a circle. Measurement obtained in feline interlobar artery.

As expected, gender plays a role in the rate of renal RI neither in canine nor in feline group.

In low resistance arteries a reflected pulse manifests on the spectrum as a double peak during systole. When it appears before a peak systolic velocity it is called an early systolic peak, when it comes afterwards – an accessory systolic peak. In the study, waveform in 5 cats (16%) straightforwardly revealed a single systolic peak (Fig. 5). Unfortunately, in some feline specimens, the quality of the Doppler spectra was insufficient to state clearly the absence of early systolic peak. Moreover, in cats waveforms with a rounded shape were also encountered during systole, which were classified as a double systolic peak but with poorly visible early systolic peak (Fig. 6). Early systolic or accessory systolic peak is considered as related to the arterial wall compliance and left ventricular systolic function. As the arterial wall compliance decreases, the flow becomes less dynamic and accessory systole reflections disappear (Szatmari *et al.*, 2001). Special care must be taken when setting the sweep parameters, since an "impacted" Doppler waveform in patients with a high heart rate may make the analysis of the spectrum shape challenging. In animal and in vitro studies, it has been shown that no relationship exists between heart rate, blood pressure and RI in dogs and cats, although it was not a subject of this study (Mitchell *et al.*, 1998; Tublin *et al.*, 1999; Novellas *et al.*, 2007a).

Relevant difference between RI in the left and right kidney is considered as an important diagnostic factor in detecting an upper urinary tract obstruction in human patients (Sayani *et al.*, 2012). Even though the majority of authors find RI in both kidneys similar, Choi *et al.* (2003) noticed differences in RI between kidneys in dogs and give 0.03±0.01 as a normal value. In this study, mean RI difference beneath kidneys were 0.01±0.02 in dogs and 0.03±0.02 in cats. Therefore, 0.05 should be an acceptable difference of the RI between kidneys, in both dogs and cats.

Conclusions: The authors suggest 0.71 and 0.68 as an upper limit of reference values of RI obtained in renal interlobar arteries in dogs and cats, respectively. Renal resistivity index seems not to depend on sex and body weight, but positively correlates with animals age. Differences were noted in the shape of Doppler spectra of dogs and cats, where few of the latter did not reveal the presence of a double systolic peak. Since Doppler examination is not sufficient to state about the arterial impedance, further studies are needed to confirm and explain this observation.

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