Acta Scientiae Veterinariae, 2026. 54: 2009.

RESEARCH ARTICLE
Pub. 2009

ISSN 1679-9216

Early Diagnosis of Chronic Kidney Disease in Asymptomatic Cats - Association of Renal Doppler Resistive Index with Elevated Symmetric Dimethylarginine

Rafaelle Cristine Dea Gerez, Fabiana Rodrigues de Freitas, Rosangela Locatelli Dittrich, Camila Marinelli Martins & Tilde Rodrigues Froes

ABSTRACT

***Background*:** Chronic kidney disease (CKD) in cats often progresses silently, making early diagnosis challenging. Symmetric dimethylarginine (sSDMA) is a sensitive biomarker for early renal dysfunction, while the resistive index (RI), obtained via Doppler ultrasonography, reflects renal vascular resistance. Combining these tools may improve early CKD detection. This study aimed to evaluate the correlation of RI with sSDMA in asymptomatic cats.

***Materials, Methods & Results*:** A prospective, blinded cohort study assessed the correlation between renal RI and sSDMA in 101 clinically asymptomatic cats. Examinations were performed without sedation, with manual restraint, and approved by the Federal University of Paraná's Animal Ethics Committee. Triplex Doppler ultrasonography used a GE Logic 5 machine with a 7.5-12 MHz linear transducer. B-mode assessed renal morphology, followed by color and pulsed Doppler for vasculature and interlobar arteries. RI was automatically calculated from three waveforms per kidney. An RI ≥0.59 (left) or ≥0.54 (right) was considered elevated. Blood samples were collected from the jugular vein. Creatinine and sSDMA were measured at IDEXX Laboratories (São Paulo, Brazil) using liquid chromatography-mass spectrometry. Urine was collected via cystocentesis. sSDMA values ≥ 14 µg/dL were considered elevated. Cats were grouped by sSDMA levels. Statistical analysis used SPSS 21.0, with $P < 0.05$ set as significant. Reliable RI measurements were obtained in 91 cats; 10 were excluded due to poor waveform acquisition (e.g., patient movement, panting, poor corticomedullary definition). Mean RI was 0.61 ± 0.07 (left) and 0.62 ± 0.07 (right), with no significant difference. Increased RI was seen in 55.9% (47/84) of left kidneys and 86% (74/86) of right kidneys. Elevated sSDMA was detected in 14.9% (15/101) of cats. A statistically significant correlation was found between elevated RI in the right kidney and increased sSDMA ($P = 0.001$), but not the left ($P = 0.246$). Creatinine also positively correlated with elevated sSDMA ($P = 0.022$), supporting the link between renal hemodynamic changes and early biochemical markers. These results suggest RI, particularly in the right kidney, may be a useful non-invasive parameter for early CKD detection in cats, especially with sSDMA.

***Discussion*:** While renal ultrasonography is common in cats, few studies explore RI's diagnostic potential in asymptomatic animals. Doppler ultrasonography was feasible but sometimes limited by patient stress, obesity, and altered renal morphology, affecting waveform quality. No significant difference was found between right and left kidney RI values, though some cats showed inter-kidney discrepancies, possibly indicating unilateral disease. Mean RI values were normal but near early CKD values.The significant correlation between elevated RI in the right kidney and increased sSDMA was not observed in the left. The asymmetry is unclear, but extrarenal factors and comorbidities might influence both RI and sSDMA. Despite limitations, creatinine also correlated positively with sSDMA, supporting its reliability in early renal assessment. RI should not be a standalone CKD screening method but a complementary tool, especially with sSDMA. Bilateral assessment is recommended, and interpretation should be cautious with morphological abnormalities or poor patient cooperation. Overall, RI measurement is feasible in unsedated cats and may aid early detection of renal changes in subclinical disease.

Keywords: feline, resistive index, doppler, kidney, SDMA.

DOI: 10.22456/1679-9216.147594

Received: 15 October 2025 Accepted: 6 January 2026 Published: 28 February 2026

Department of Veterinary Medicine, Federal University of Paraná (UFPR), Curitiba, PR, Brazil. CORRESPONDENCE: T.R. Froes [tilde@ufpr.br]. Department of Veterinary Medicine - UFPR. Rua dos Funcionários n. 1540. CEP 80035-050 Curitiba, PR, Brazil.

INTRODUCTION

B-mode ultrasonography is the preferred modality for feline kidney imaging, providing non-invasive assessment of internal architecture, size, and shape [9]. Doppler ultrasound evaluates vascular anatomy and function, including blood flow velocity, direction, and type [15], while also measuring peripheral vascular resistance indirectly [8]. Increased resistance reduces diastolic flow more than systolic, raising the resistive index (RI) [9].

Introduced by Pourcelot, RI calculates arterial resistance via peak systolic (PSV) and end-diastolic (EDV) velocities, independent of transducer angle, ensuring accuracy [13,17]. It is derived as (PSV - EDV)/PSV (ranging 0-1, indicating downstream resistance) and measured in renal/interlobar/arcuate arteries [8,15].

RI aids in diagnosing and prognosticating renal disease in multiple species [14]. Chronic kidney disease (CKD) often remains asymptomatic until advanced stages. RI may complement lab markers like symmetric dimethylarginine (SDMA), which rises earlier than creatinine but is affected by ureteral obstruction [3]. Glomerular filtration rate (GFR) is ideal but impractical in routine practice [10].

RI in feline arcuate arteries was 1st described in sedated healthy cats [16], with subsequent studies in normal [8,17] and diseased kidneys [1,7,17], including Persian and Korean domestic cats [2,11]. However, no correlation exists between RI and early CKD in asymptomatic cats.

This study assesses RI's utility in asymptomatic cats and its correlation with elevated SDMA.

MATERIALS AND METHODS

Animals

A prospective, cohort, blinded study for diagnosis of CKD was conducted in 101 asymptomatic cats of different ages and approved in accordance with guidelines of the Animal Ethics Committee from the Federal University of Paraná Teaching Animal Hospital. Client-owned, and cats belonging to hospital staff and students were recruited from August 2018 to September 2019. Triplex Doppler ultrasonography was performed with a GE Logic 5 ultrasound machine (GE Healthcare, Milwaukee, Wisconsin) with a 7.5-12MHz linear multifrequency transducer. The cats were fasted for 6 h before examination. For analysis of the kidney vascular bed the cats were manually restrained by their owners in a calm environment without sedation. Hair was clipped and acoustic gel was applied to the skin. Cats were kept in dorsal recumbency to scan both kidneys, starting with the left kidney. There was no time limit for acquisition of images for measurement of RI.

Imaging protocol

B-mode ultrasound was used to view the kidney in the longitudinal section. Subsequent color Doppler was used to visualize the intrarenal vasculature. Pulsed Doppler interrogation of the interlobar artery was obtained with a sample width of 1-3 mm and a frequency of 7 MHz. A single sonographer (with 5 years of experience) performed all exams. The interlobar artery selected for examination was the one which could be best visualized using the triplex color Doppler. Once the wave spectrum in the pulsed Doppler was optimized the waveform and RI measurements were made. This minimized the time taken for the examination to reduce the stress on the cats. The smallest scale that displayed the flow without aliasing was selected. The mean RI for each kidney was determined by averaging a total of 3 consecutive Doppler waveforms from the interlobar artery at 3 different times.

RI was calculated automatically by the ultrasound machine software, after manual delimitation of peak systolic velocity, end diastolic velocity, and time average maximum velocity. The RI values for each individual kidney were averaged from 3 waves, and the resulting value was used for correlation analysis (Figure 1). Pearson correlation analysis was performed to determine whether a statistically significant ($P < 0.05$) correlation existed between RI and concurrent sSDMA.

Laboratory analysis

Creatinine and SDMA concentrations were measured using a blood sample collected from the jugular vein before the ultrasound exam toprevent detection of changes due to stress. Urine was collected by cystocentesis after the Doppler exam. sSDMA was determined by liquid chromatography-mass spectrometry. The blood was centrifuged, and the analysis was done by IDEXX[1].

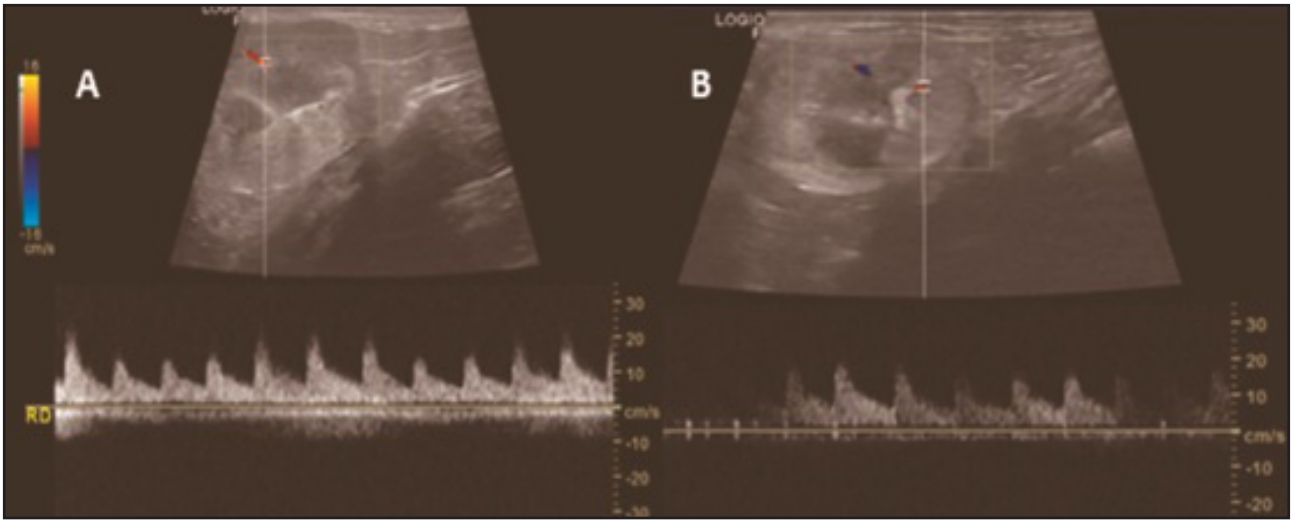

Figure 1. Color Triplex Doppler ultrasound image and the RI measurement. A- RI in the right kidney with partial loss of corticomedullary differentiation. B- RI in left kidney, with loss of corticomedullary differentiation. Note the low general vascularity in the Color Doppler image and the abnormal waveform in the left kidney. The patient shown had increased sSDMA.

Statistical analysis

For our classification, sSDMAequal to or greater than 14 µg/dL was considered high, and the cat assigned to the increased SDMA group for further statistical analysis. Inclusion criteria were cats asymptomatic for CKD. RI equal to, or greater than, 0.59 for the left kidney and 0.54 for the right was considered increased. The population of cats was divided into 2 groups: 1)- asymptomatic cats with sSDMA in the normal range and, 2)- asymptomatic cats with sSDMA >14 µg/dL. The tests were considered significant when $P < 0.05$, and the analysis were performed using SPSS 21.0.[2]

RESULTS

A total of 101 one cats participated in this study. The RI of the interlobar arteries values were obtained from 91 cats because in 10 cats it was not possible to acquire data due to difficulties optimizing the ultrasound images. It was more difficult to obtain good quality recordings from the left kidney than the right. In some animals, pulsed Doppler registration was more difficult and time consuming due to panting and stress. For these reasons, and also due to morphological changes resulting in loss of corticomedullary differentiation in some kidneys, 5 right kidneys and 7 left kidneys were not evaluated.

The mean RI was 0.61 ± 0.07 in the left kidney and 0.62 ± 0.07 in the right kidney. There were no statistically significant differences between the mean RI in left and right kidneys. The lowest RI was 0.45, in a cat which had normal serum creatinine and sSDMA. The highest RI was 0.83 and this cat also had normal serum creatinine and sSDMA.

In 6 cats RI in one kidney was at least 0.1 higher than the contralateral kidney. Overall RI was increased in 55.9% (47/84) of left kidneys, and normal in 44.1% (37/84) left kidneys. Regarding the right kidney, 86% (74/86) had increased RI values and 13% (12/86) normal values. In the blood and urine tests, 86 cats (89.1%) had normal values of SDMA and 15 cats (14.9%) had increased sSDMA (>14 µg/dL).

The right RI was significantly higher in cats with increased SDMA than those with normal SDMA ($P = 0.001$) [Table 1]. This difference was not found for values of RI in the left kidney ($P = 0.246$).

The relative frequencies of RI and creatinine in groups, normal or increased SDMA are showed in Table 2. Creatinine concentration was positively correlated within higher SDMA concentrations. Analyzing the relative frequencies of RI for each kidney, there was no correlation between any group nor any kidney.

The correlation coefficient of left renal RI with increased SDMA was - 0.170 with *P*-value 0.136. The correlation coefficient of right renal RI with increased SDMA was - 0.058 with *P*-value 0.603.

Table 1. Inference statistics performed to detect RI and creatinine as a factor or not of increase SDMA in 101cats.

Feature	Classification	SDMA			*P*- value*
		MD	25% Perc.	25% Perc.	
Left Kidney RI*	Normal	10	8	13	0.121
	Increased	12	10	14	
Right Kidney RI*	Normal	9	8	10	0.001
	Increased	12	10	14	
Creatinine	Normal	11	9	13	0.082
	Increased	12	10	15	

*Note that it was possible to measure resistive index (RI) in 84 left kidneys and RI and 86 right kidneys. *P* was calculated using the Mann-Whitney U test. $P < 0.05$

Table 2. Statistical values of RI and creatinine associated with 2 groups of cats (101), with normal and abnormal SMDA values.

Item	Classification	Normal		Abnormal		Total		*P*-value
		N	%	N	%	N	%	
Left Kidney RI	Not rated	13	76.50%	4	23.5%	17	100%	0.542
	Normal	32	86.5%	5	13.5%	37	100%	
	Increased	41	87.2%	6	12.8%	47	100%	
Right Kidney RI	Not rated	12	80.0%	3	20.0%	15	100%	0.144
	Normal	12	100%	0	0.0%	12	100%	
	Increased	62	83.8%	12	16.2%	74	100%	
Creatinine	Normal	66	90.4%	7	9.6%	73	100%	0.022
	Increased	20	71.4%	8	28.6%	28	100%	

RI: Resistive index was measure only in 91 cats, 84 left kidneys and RI and 86 right kidneys. Increased sSDMA defined as > 14 µg/dL. *P* was calculated using the Mann-Whitney U test. $P < 0.05$

DISCUSSION

A number of papers have shown the value of 2 dimensional ultrasonographic analysis of kidneys. However, few studies score the diagnostic value of the RI and there are no studies in patients with subclinical CKD that attempt diagnosis of the early stages of disease. SDMA is a known biomarker in relation to creatinine [3], which is why we chose to correlate this with RI to predict CKD.

Doppler is non-invasive, painlessdiagnostic modality, and has been described by other authors as rapid and easy to perform on unsedated cats [2,11,17]. However, we disagree with at least part of this statement since it was not easy to perform renal triplex Doppler in some cats in our study. In some cats it was difficult to produce high quality interlobar artery waveforms for both kidneys for accurate assessment of the RI. As previously reported obesity, bowel movements, tachypnea associated with stress or pain, and poor hemodynamics due to severe renal injury are considered major factors limiting the performance of renal Doppler analysis [12]. Many cats in this study had severe loss of corticomedullary differentiation and other renal morphological changes, making it hard to assess RI. Even in cats in which the renal morphology was preserved, it was difficult to assess RI in agitated or aggressive patients. The selection of an interlobar

artery to measure the RI in our study was based on the literature, which suggests that the best signals for vascular assessment are always from large segmental arteries and, consequently, the arcuate arteries from the kidney periphery wereavoided[2,5].

There was no significant difference between RI in right and left kidneys. In a sample study of RI in a population of healthy and diseased cats there was no statistically significant difference between the mean RI of the 2 kidneys [7]. Often, when severe disease is already established, evaluationof just a single kidney will have little effect on the patient's final RI result. However, in early disease changes can start unilaterally and might be clinically silent.

Six patients in this study had a difference of at least 0.10 in the RI between the left and right kidneys. A difference of 0.10 or more between the kidney indices of the same patient may help to diagnose unilateral illness, even when the RI is within normal limits[8].

The means of the RI's presented here still fall within the RI's for healthy patients [17] although they are closer to the RI's of patients with CKD, as the literature suggests an upper value of 0.70 for cats [8,16],which is the same proposed as a limit for normal mean intrarenal RI in man [12].

An increased RI is a non-specific finding and can be seen (although not invariably) in cases of acute obstruction, acute renal disease, acute tubular necrosis, glomerulopathy, perinephric or subcapsular fluid accumulation and severe hypotension[15].

A ROC curve was performed to determine a value cutoff forpossible diagnosis of CKD in cats [7]. Using an RI >0.63 to indicate CKD, a sensitivity and specificity of 100% was achieved. This is very close to the mean RI in this study (0.61 and 0.62), suggesting CKD may be developing in our population.

Extrarenal factors may influence both the increase in RI and sSDMA, since the cat with the highest RI value did not have an increase in sSDMA. In human medicine, factors which affect the RI include age, blood pressure, pulse and respiratory rate [6]. This may explain the lack of statistical difference between the groups with normal SDMA and increased SDMA. Certainly, the low number of samples in the increased SDMA group may have affected this result. Other underlying disease such as diabetes or hypothyroidism could result in increased sSDMA, researchers have been studying the SDMA biomarker and what influences it in diabetic cats which have lower SDMA than healthy cats [4].

In our study, there were more cats with an increased right RI compared to the contralateral kidney, even with a small group of cats with increased SDMA. The SDMA results had no influence on the RI results because the study was blind to the results of SDMA in the doppler evaluation. There was a significant correlation between the right kidney RI and the increase in sSDMA, but we are unable to explain this finding.

The indices were evaluated and compared with the biomarker creatinine in a previous study [7]. Although there was no statistical correlation with increased right kidney RI with increased of serum creatinine, our study showed a tendency to increased right kidney RI with increasing creatinine. It might be that this correlation is not statistical supported because the serum creatinine marker is later biomarker for detection of early signs of kidney disease. However, creatine shows a positive correlation with higher sSDMA.

Evaluation of RI is not recommended as a screening test for the presence of renal disease, but rather should be considered as an ancillary diagnostic test. Doppler ultrasonographic evaluation of one kidney is not sufficient to provide an estimate of RI for both kidneys in early disease. When the animal is non-cooperative and RIs cannot be obtained from both kidneys, the doppler interpretation has to be interpreted with more caution. A loss of normal kidney morphology on B-mode ultrasonography, made it difficult to find an optimal interlobar artery in color doppler to perform a quality waveform measure.

In summary, it is possible to measure the RI of interlobar renal arteries in cats. However, we observed some difficulties in performing the RI analyses particularly when there were concomitant morphological changes such as loss of corticomedullary differentiation. Moreover, assessment was also difficult in restless and aggressive cats. There was a statistically significant correlation between the increased RI values and increased sSDMA concentrations, although the precise explanation for that is unclear.

CONCLUSION

For analysis of the RI of interlobar renal arteries in cats a cooperative patient is essential. Our study showed a significant correlation between the values of the RI, specifically in the right kidney, with increased sSDMA. Further studies are needed to rule out other influences on the RI and sSDMA values.

MANUFACTURERS

[1]IDEXX Brasil Laboratórios Ltda. São Paulo, SP, Brazil.

[2]IBM Corporate. Armonk, NY, USA.

***Funding*.** The work presented in this study was partial funded by Idexx Brasil Laboratórios Ltda., São Paulo SP, Brazil.

***Ethical approval*.** This work involved the use of non-experimental animals only (including owned or unowned animals and data from prospective or retrospective studies). This work was approved by the Federal University of Paraná's Animal Ethics Committee (under protocol no. 043/2019).

***Declaration of interest*.** The authors declare no potential conflicts of interest in regard of this research, authorship, and/or publication of this article. The authors alone are responsible for the content and writing of the paper.

REFERENCES

1 **Bragato N., Borges N.C. & Fioravanti M.C.S. 2017.** B-mode and Doppler ultrasound of chronic kidney disease in dogs and cats. *Veterinary Research Communications*. 41: 307-315. DOI: 10.1007/s11259-017-9694-9

2 **Carvalho C.F. & Chammas M.C. 2011.** Normal Doppler velocimetry of renal vasculature in Persian cats. *Journal of Feline Medicine and Surgery*. 13(6): 399-404. DOI: 10.1016/j.jfms.2010.12.008

3 **Hall J.A., Yerramilli M., Obare E., Yerramilli M., Almes K. & Jewell D.E. 2014.** Comparison of serum concentrations of symmetric dimethylarginine and creatinine as kidney function biomarkers in cats with chronic kidney disease. *Journal of Veterinary Internal Medicine*. 28(6): 1676-1683. DOI: 10.1111/jvim.12445

4 **Langhorn R., Kieler I.N., Koch J., Christiansen L.B. & Jessen L.R. 2017.** Symmetric dimethylarginine in cats with hypertrophic cardiomyopathy and diabetes mellitus. *Journal of Veterinary Internal Medicine*. 32(1): 57-63. DOI: 10.1111/jvim.14902

5 **Lee H.Y. & Grant E.G. 2002.** Sonography in renovascular hypertension. *Journal of Ultrasound in Medicine*. 21: 431-441.

6 **Lin Z.Y., Wang L.Y., Yu M.L., Dai C.Y., Chen S.C., Chuang W.L., Hsieh M.Y., Tsai J.F. & Chang W.Y. 2003.** Influence of age on intrarenal resistive index measurement in normal subjects. *Abdominal Imaging*. 28: 230-232. DOI: 10.1007/s00261-002-0024-4

7 **Matos I., Azevedo P. & Carreira M.L. 2018.** Pilot study to evaluate the potential use of the renal resistive index as a preliminary diagnostic tool for chronic kidney disease in cats. *Journal of Feline Medicine and Surgery*. 20(3): 471-478.

8 **Novellas R., Espada Y. & Ruiz de Gopegui R. 2007.** Doppler ultrasonographic estimation of renal and ocular resistive and pulsatility indices in normal dogs and cats. *Veterinary Radiology & Ultrasound*. 48: 69-73.

9 **Nyland T.G., Mattoon J.S., Herrgesell E.J. & Wisner E.R. 1995.** Urinary tract. In: Nyland T.G. & Mattoon J.S. (Eds). *Veterinary Diagnostic Ultrasound*. Philadelphia: WB Saunders, pp.158-195.

10 **Paepe D. 2014.** Screening for early feline chronic kidney disease: limitations of currently available tests and possible solutions. PhD thesis, Faculty of Veterinary Medicine, Ghent University, Ghent.

11 **Park I.C., Lee H.S., Kim J.T., Nam S.J., Choi R., Oh K.S., Son C.H. & Hyun C. 2008.** Ultrasonographic evaluation of renal dimension and resistive index in clinically healthy Korean domestic short-hair cats. *Journal of Veterinary Science*. 9: 415-419. DOI: 10.4142/jvs.2008.9.4.415

12 **Platt J.F., Rubin J.M. & Ellis J.H. 1993.** Acute renal obstruction: evaluation with intrarenal duplex Doppler and conventional US. *Radiology*. 186: 685-688.

13 **Pourcelot L. 1974.** Applications clinique de l'examen Doppler transcutane. In: Peronneau P. (Ed). *Symposium: Velocimetric ultrasonnor Doppler*. Paris: Inserm, pp.213-240.

14 **Randermacher J., Ellis S. & Haller H. 2002.** Renal resistive index and progression of renal disease. *Hypertension*. 39: 699-703.

15 **Rivers B.J., Walter P.A., Polzin D.J. & King V.L. 1997.** Duplex Doppler estimation of intrarenal Pourcelot resistive index in dogs and cats with renal disease. *Journal of Veterinary Science*. 11: 250-260.

16 **Rivers B.J., Walter P.A., O'Brien T.D. & Polzin D.J. 1996.** Duplex Doppler estimation of Pourcelot resistive index in arcuate arteries of sedated normal cats. *Journal of Veterinary Internal Medicine*. 10(1): 28-33.

17 **Tipisca V., Murino C., Cortese L., De Rosa A., Luciani A. & Ciaramella P. 2015.** Resistive index for kidney evaluation in normal and diseased cats. *Journal of Feline Medicine and Surgery*. 18: 471-475. DOI: 10.1177/1098612X15588442.