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Association of renal ultrasonographic findings with elevated serum symmetric dimethylarginine in asymptomatic cats

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Abstract: This study aimed to compare renal ultrasonographic findings with serum symmetric dimethylarginine (sSDMA) in asymptomatic cats. A prospective blinded study evaluated qualitative and quantitative ultrasound parameters in 101 cats without clinical signs of chronic kidney disease (CKD). Cats were grouped based on sSDMA levels: normal (≤14 µg/dL) or elevated (>14 µg/dL). Ultrasonographic abnormalities were scored (1–10) for statistical comparison. Of the 101 cats, 86 (85.15%) had normal sSDMA, while 15 (14.85%) exhibited elevated levels. Cats with increased sSDMA were more likely to show reduced corticomedullary differentiation (p=0.029), pelvic dilation (p=0.036), and ureteral calculi (p=0.04). A positive correlation was found between sSDMA and corticomedullary loss, whereas renal length showed a negative correlation with sSDMA. The overall correlation between sSDMA and ultrasonographic score was weak (r = 0.190, p = 0.057). Ultrasonographic variability was greater in cats with elevated sSDMA. In conclusion, asymptomatic cats with reduced corticomedullary differentiation, pelvic dilation, or smaller kidneys on ultrasound are more likely to have elevated sSDMA, suggesting early renal changes. These findings highlight the potential role of ultrasonography alongside sSDMA in detecting subclinical kidney disease in cats.
Keywords: CKD, feline, ultrasound, kidney, SDMA.

1. Introduction

Chronic kidney disease (CKD) is a common disorder in geriatric cats (Lulich et al., 2017). Although it can occur at any age, the prevalence of CKD in the general feline population is reported to be approximately 0.5 to 1.5% (Polzin et al., 2011). CKD may be the result of incomplete recovery from single or multiple injuries to one or both kidneys (Cowgill et al., 2016), which can cause irreversible and progressive structural and functional impairment (Polzin, 2011; Bartges, 2010).

Early diagnosis and supportive treatment may slow disease progression (Debruyn et al., 2013), but management requires a combination of laboratory and imaging tests. The most helpful method of monitoring is the measurement of serum urea and creatinine concentrations, as well as urine specific gravity. Urinary tract ultrasound and measurement of symmetric dimethylarginine (SDMA) may provide useful adjuncts to diagnosis. SDMA has emerged as a potential serum biomarker for the early detection of CKD, offering potential advantages over serum urea nitrogen and creatinine assays (Hall et al., 2017).

SDMA is a byproduct of cellular protein metabolism, specifically the intranuclear methylation of L-arginine residues; after proteolysis, these free SDMA residues are released into the circulation. SDMA is not bound to plasma proteins and is primarily eliminated via renal excretion, where it is freely filtered by the glomerulus and neither secreted nor reabsorbed by the tubules (Schwedhelm et al., 2011).

Previous literature reports have described sSDMA as an indicator of compromised renal function in cats with CKD (Hall et al., 2017). A recent review on feline renal biomarkers stated that SDMA detects decreased glomerular filtration rate (GFR) earlier than creatinine, is unaffected by lean body mass, and is now included in the International Renal Interest Society (IRIS) guidelines for staging chronic kidney disease (Kongtasai et al., 2022). An investigation involving hyperthyroid cats treated with radioactive iodine showed that, although creatinine and urea increased after treatment, SDMA levels remained stable and did not consistently correlate with glomerular filtration rate (Wagner et al., 2023). Moreover, in another study, sSDMA was found to be increased above upper reference limits in 39 of 43 cats with kidney stones (Hall et al., 2017).

Ultrasound examination of the urinary tract enables a non-invasive assessment of the internal renal architecture, provides information on parenchymal morphology, and excludes certain pelvic and obstructive ureteral diseases (Nyland et al., 2002; Debruyn et al., 2012). Nevertheless, there is an overlap between normal and abnormal ultrasound findings in azotemic and non-azotemic cats, with one study reporting that 47% of ultrasound abnormalities were present in the kidneys of non-azotemic cats (Lamb et al., 2017).

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The aim of this study was to compare the subjective and quantitative renal ultrasonographic findings in cats with serum SDMA values within and above the normal range (> 14 µg/dL), but without clinical signs of kidney disease. We hypothesized that abnormalities in kidney ultrasonography would be associated with an increase in SDMA values, and the combination of ultrasonographic findings (by score) would predict elevated sSDMA in cats.

2. Materials e Methods

Patient selection

This prospective and cohort study was approved and conducted following the guidelines of the Animal Ethics Committee of the Federal University of Paraná (Protocol number 043/2019). Client-owned cats, hospital staff cats, and cats from students were recruited from August 2018 to September 2019.

Inclusion criteria were cats without signs of chronic renal disease. The sample population of cats was divided into two groups: 1. asymptomatic cats with sSDMA values in the normal range, and 2. asymptomatic cats with sSDMA values >14µg/dL. Information collected from medical records included: patient history, breed, sex, age, weight, and body condition. All cats were clinically evaluated, and blood and urine samples (collected by cystocentesis) were obtained. A B-mode abdominal ultrasound was performed to exclude concomitant illnesses. The commonly used renal biomarker values were reviewed (i.e., creatinine, urea, urine specific gravity, urine protein:creatinine ratio, urinary gamma-glutamyl transpeptidase (GGT).

Exclusion criteria were: I. had clinical signs of ureteral obstruction or active lower urinary tract infection during the previous year; II. dehydration or clinical signs of kidney disease that may contribute to decreased renal perfusion; III. pelvic dilation > 0.3 cm on ultrasonography; IV. reduced urinary density (urine specific gravity < 1.025) and/or presence of infection/inflammation in the bladder.

Ultrasonographic examination

For the examination, the cats were gently, manually restrained, with no sedation. Two-dimensional ultrasonographic evaluations were performed using high-resolution ultrasonographic equipment (GE Logic F6 GE Healthcare, Milwaukee, Wisconsin, USA) with a 7.5-12MHz linear multifrequency transducer. After examining the entire abdominal cavity, the kidneys were imaged in both transverse and dorsal planes.

A single radiologist (with five years of experience) performed all ultrasonographic examinations following a detailed predefined examination protocol that included recording of standard plane images, using video clips, and static images. The radiologist was blinded to the results of the laboratory examinations.

Ultrasonographic evaluation

To evaluate the kidneys for size (the longitudinal renal length between the poles was measured). The kidney shape, contour, echogenicity of the cortices and medulla, corticomedullary definition, and evaluation of the renal pelvis.

Cortical echogenicity (left kidney) was compared to the splenic parenchyma at the same gain and depth. It was usually slightly hypo- or isoechoic when compared with the liver parenchyma (right kidney) (Nyland et al., 2002). The echogenicity of the medulla was considered increased when hyperechoic speckles or lines were seen on a normal background echogenicity.

Ultrasound lesions were classified as present or absent, and echogenic lesions were further characterized as diffuse and/or focal. Focal lesions were classified as parenchymal or pelvic. Parenchymal (cortical or medullary) lesions include cysts and infarcts (seen as hyperechoic wedge-shaped or triangular lesions) specifically in the cortex (Debruyn et al., 2012).

Renal length was measured by positioning the medical calliper at the level of a line drawn between the medial surfaces of the cranial and caudal poles of the kidney on dorsal plane images. Normal renal length was considered to be 3.0 cm to 4.3 cm (Debruyn et al., 2012).

The pelvic diameter was measured on transverse planes, ensuring that the ureter was excluded from the measurement. The normal renal pelvis width was considered to be 0 to 2mm. However, if the pelvic diameter was greater than 3mm, the cat was excluded from the study. Nephroliths were classified as absent or present (Table 1). Nephroliths were defined as lesions with a curved hyperechoic interface, suggesting a structure that displaced surrounding kidney tissue or projected into the kidney pelvis, and were usually associated with an acoustic shadowing artifact (Cléroux et al., 2017).

The retroperitoneal space was examined, searching for alterations in perirenal fat or free fluid, as well as a careful examination of the ureters and bladder.

A score from 1 to 10 was given to each kidney based on the ultrasonographic findings. One point was awarded for each of the ten ultrasonographic findings, as shown in Table 1.

KIDNEY ULTRASONOGRAPHIC FEATURES	NORMAL OR ABNORMAL ULTRASONOGRAPHIC SIGNS	SCORE
Echogenicity of the cortex	*Normal*	0
	Increased	1
Echogenicity of the medulla	*Normal*	0
	Increased	1
Renal shape †	*Normal*	0
	Abnormal	1
Renal size +	*Normal range*	0
	Increased or reduced	1
Corticomedullary definition	*Present*	0
	Absent or partially absent	1
Pelvic diameter	*Normal range*	0
	*Dilatation**	1
Calcification in parenchyma	*Absent*	0
	Present	1
Infarcted areas	*Absent*	0
	Present	1
Cystic lesion	*Absent*	0
	Present	1
Pelvic lithiasis	*Absent*	0
	Present	1

Table 1 – Score based on renal ultrasonographic findings in all cats included in the study.
†cortical depression, flatted or irregular surface;+ cortical length <3.0cm or >4.3cm. * pelvic diameter >2.0mm.

Laboratory tests

Blood was collected from all cats for measurement of serum creatinine and urea, and abnormalities on blood or urinalysis were used as exclusion criteria. Serum concentrations of SDMA were determined using liquid chromatography-tandem mass spectrometry. Blood samples were centrifuged, and analysis was performed using IDEXX laboratory equipment (São Paulo, São Paulo, Brazil). Serum SDMA levels greater than 14 µg/dL were considered elevated, and these cats were included in the group with increased sSDMA for further statistical analysis.

Other laboratory analyses, such as the urine protein:creatinine ratio, urinary GGT, presence of bacteria in urine, and urinary density, were used as inclusion and exclusion criteria to provide a better understanding of the composition of the groups and to classify the animals according to the IRIS Staging of CKD.

Statistical analysis

All statistical analyses were conducted by one of the authors (R.C.D.G.) and a statistician (C.M.M.). Two observations were made for each animal, since the kidneys were counted individually. The data were investigated using mixed logistic models. A descriptive data analysis was carried out. For qualitative variables, relative and straightforward frequency estimates were made. Data distribution was tested using the Shapiro-Wilk test, and all non-normally distributed data were analyzed using a non-parametric approach. To assess the difference in sSDMA between groups (presence and absence of findings and parameters), a Mann-Whitney U test or non-parametric ANOVA (Kruskal-Wallis) with Dunn's post-hoc test was used. Spearman's correlation was used to analyze the relationship between the sSDMA serum values and the ultrasonographic kidney score (1-10). The tests were considered significant when $p < 0.05$. All analyses were performed using SPSS 21.0 (IBM, 2012).

3. Results

A total of 114 cats met the inclusion criteria and were recruited for this study. Of these, 101 cats met the exclusion criteria and were excluded from the study. Thirteen cats were excluded from the study: eight due to the presence of

bacteria in the urine, four had reduced urinary density (below the predetermined cut-off (<1.025), and another had significant unilateral hydronephrosis (Figure 1). Ultrasonographic imaging was performed on 202 kidneys.

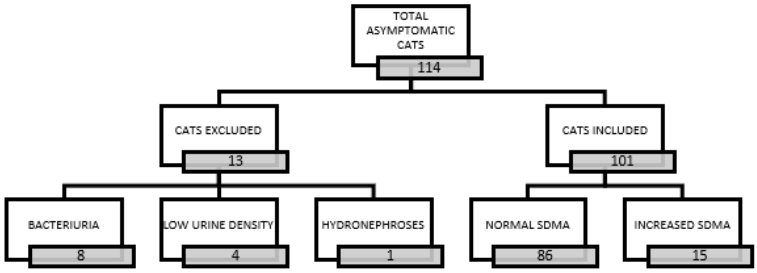

Figure1 – Flow chart of the included and excluded cats, showing grouping and division. Cut off for excluded and included cats were made using urine protein: creatinine ratio > 0.2; urinary GGT> 29.7 UI/L., SDMA > 14ug/dl was considered elevated.

Breeds represented were domestic short hair (87/101, 86.1%), Persian (5/101, 5.0%), Maine Coon (3/101, 3.0%), Siamese (2/101, 2.0%), and one each (1.0%) of Angora, British, Sphynx and Savannah. Forty-four (43.6%) were male and 57 (56.4%) were female. The median age was 6.1 years (range: <1 year – 18 years). The median weight was 4.7 kg (range, 1.98 kg – 11.3 kg), with body conditions recorded as obese (8/101, 7.9%), overweight (22/101, 21.8%), normal (61/101, 60.4%), and underweight (10/101, 9.9%). Eleven cats were not IRIS classified. CKD cats consisted of IRIS stage 1 (49/101, 48.5%), IRIS stage 2 (40/101, 39.6%), IRIS stage 3 (1/101, 0.99%), and no cats were in IRIS stage 4.

Normal sSDMA values were present in 86 cats (85.15%) and 15 cats (14.85 %) had increased sSDMA (>14µg/dL), six of which had normal creatinine (5.94%); creatinine values were increased (1.6 mg / dL) in 28 (27.7%); 65 (85.5%) had increased urinary GGT values.

Ultrasonographic evaluation of the kidneys showed that 162 out of 200 kidneys were within normal limits for length (81%), measuring between 3.0 cm and 4.3 cm. In the group with normal sSDMA, 150 kidneys were within normal limits (150/200). At least one abnormal subjective ultrasonographic finding was identified in 151 of 202 kidneys, regardless of the group (normal or abnormal sSDMA values).

Based on all cats, the average right kidney length was 3.46 cm (SD ± 0.48). The left kidney was 3.53 cm (SD ± 0.50). Renal length was decreased in 26/200 (13%), and kidney enlargement was present in 12/200 (6%). Renal pelvic diameter was normal in 190/198 (95.95% - < 0.2cm). Infarcted areas were present in at least 36 out of 202 kidneys. Prevalence of renal lithiasis was 32/202 (15.84%). Areas of renal parenchymal calcification were present in 77/202 (38.11%) kidneys. The corticomedullary definition was lost or decreased in 28/202 (13.86%) kidneys, and renal cysts were present in 9/202 (3.96%) (FIGURE 2). Perirenal fluid was present in one cat, 1/202 (0.49%), and no cat had subcapsular fluid.

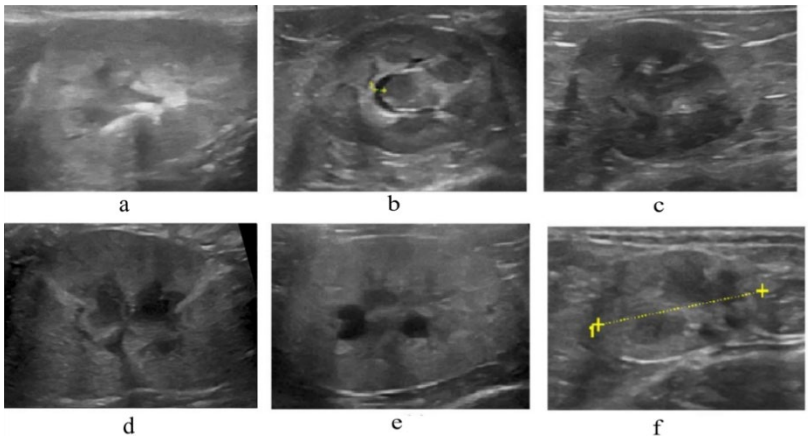

Figure 2 – Examples of different ultrasound findings. (a) Renal lithiasis associated with loss of corticomedullary definition; (b) cat with pelvic dilatation and increased medullary echogenicity; (c) infarcted areas in a kidney with an abnormal shape and decreased size; (d) multifocal renal infarcts ; (e) loss of corticomedullary definition with cystic lesions in the renal parenchyma and increased kidney size; (f) loss of corticomedullary definition, decreased kidney size, irregular contour and presence of microcalcification in parenchyma.

Inference statistics were performed to identify which specific ultrasonographic findings had a positive correlation with sSDMA values, showing that cats with pelvic dilation (p = 0.036) and cats with kidneys with decreased corticomedullary definition (p = 0.029) were more likely to have elevated sSDMA. Cats with ureteral calculi were also more likely (p = 0.04) to have elevated sSDMA.

Table 2 presents the relative frequencies of each ultrasonographic finding by group. The loss of corticomedullary differentiation was positively correlated with higher sSDMA values.

Kidney/ureter findings	Classification	Normal SDMA		Abnormal SDMA		Total		p-valor
		N	%	N	%	N	%	
Left Kidney length	*Reduced*	12	80.0%	3	20.0%	15	100%	0.816
	Normal size	69	86.2%	11	13.8%	80	100%	
	Increased	5	83.3%	1	16.7%	6	100%	
Right Kidney length	*Reduced*	7	63.6%	4	36.4%	11	100%	0.110
	Normal size	72	87.8%	10	12.2%	82	100%	
	Increased	5	83.3%	1	16.7%	6	100%	
Left pelvic diameter	*Normal size*	80	85.1%	14	14.9%	94	100%	0.568
	Increased size	4	80.0%	1	20.0%	5	100%	
Right pelvic diameter	*Normal size*	83	86.5%	13	13.5%	96	100%	0,059
	Increased size	1	33.3%	2	66.7%	3	100%	
Kidney shape	*Normal*	66	88.0%	9	12.0%	75	100%	0.147
	Abnormal	20	76.9%	6	23.1%	26	100%	
Infarcted areas	*Absent*	66	85.7%	11	14.3%	77	100%	0.500
	Present	20	83.3%	4	16.7%	24	100%	
Hyperechoic cortices	*Normal*	37	86.0%	6	14.0%	43	100%	0.530
	Abnormal	49	84.5%	9	15.5%	58	100%	
Increased medullary echogenicity	*Normal*	69	86.2%	11	13.8%	80	100%	0.715
	Abnormal	16	80.0%	4	20.0%	20	100%	
	Not rated	1	100.0%	0	0%	1	100%	
Parenchyma calcification	*Absent*	53	88.3%	7	11.7%	60	100%	0.474
	Present	32	80.0%	8	20.0%	40	100%	
	Not rated	1	100.0%	0	0%	1	100%	
Corticomedullary definition	*Absent*	3	42.9%	4	57.1%	7	100%	0.005
	Decreased	7	87.5%	1	12.5%	8	100%	
	Present	76	88.4%	10	11.6%	86	100%	
Presence of renal cysts	*Absent*	81	85.3%	14	14.7%	95	100%	0.629
	Present	5	83.3%	1	16.7%	6	100%	
Kidney lithiasis	*Multiple and bilateral*	9	75.0%	3	25.0%	12	100%	0.541
	Absent	70	87.5%	10	12.5%	80	100%	
	Only one	5	83.3%	1	16.7%	6	100%	
	One bilateral	2	66.7%	1	33.3%	3	100%	
Ureter lithiasis	*Absent*	86	86.0%	14	14.0%	100	100%	0.149
	Present	0	0.0%	1	100.0%	1	100%	
Cystolithiasis	*Multiple*	1	100.0%	0	0.0%	1	100%	0.837
	Absent	84	84.8%	15	15.2%	99	100%	
	Only one	1	100.0%	0	0.0%	1	100%	

Table 2 – Statistical values and summary of association of ultrasound findings with normal and abnormal SMDA values in two groups of cats (101)

Table 3 shows the statistical results of the correlation coefficient ("r) between SDMA and the proposed ultrasonographic score (1-10) (Table 1).

	Range	MD	Min	Max	25% Perc.	75% Perc.	SD	"r"	P
Ultrasonographic score*	3	2	0	8	2	3	2	0.190	0.057

Table 1 - Shows the range, medium, minimal, maximal, interquartile range, standard deviation and P-value of the correlation coefficient for ultrasonographic score (1-10), based on abnormal ultrasonographic findings in cat's kidneys and proximal ureter (202 kidneys)
* proposed ultrasonographic score correlated with abnormal ultrasonographic findings in kidney and ipsilateral ureter. P was calculated using the spearman's rank correlation coefficient. P<0.05

Table 4 presents the statistical results comparing the two cat groups, using the proposed ultrasonographic score (1-10) (Table 1). The Mann-Whitney U test was performed, and no statistically significant difference was found (p = 0.784).

	Range	MD	Min	Max	25% Perc.	75% Perc.	SD	P-value*
Ultrasonographic score								**0.185**
Group SDMA normal values	3	2	0	8	2	3	2	
Group SDMA increase values	3	3	1	7	2	6	2	

Table 4 – Shows the range, medium, minimal, maximal, interquartile range, and standard deviation of the ultrasonographic score (1-10) based on abnormal ultrasonographic findings in cat's kidneys and ureter; and compares whether there is a difference in the ultrasonographic score and the SDMA for the two group of cats
SDMA normal values correspond to 86 cats (172 ultrasonographic kidney evaluations). Increased SDMA values correspond to 15 cats (30 ultrasonographic kidney evaluation). P was calculated using the Mann-Whitney U test. P<0.05.

Figures 3 and 4 show sample scatterplots of the relations between sSDMA and proposed ultrasonographic score after ultrasound analyses of the kidneys, and a box plot graph of the sSDMA variable value and the proposed ultrasonographic score (0-10) (Table 1). This box plot graph shows that cats with elevated sSDMA usually have more variable ultrasonographic findings; however, this was not statistically significant.

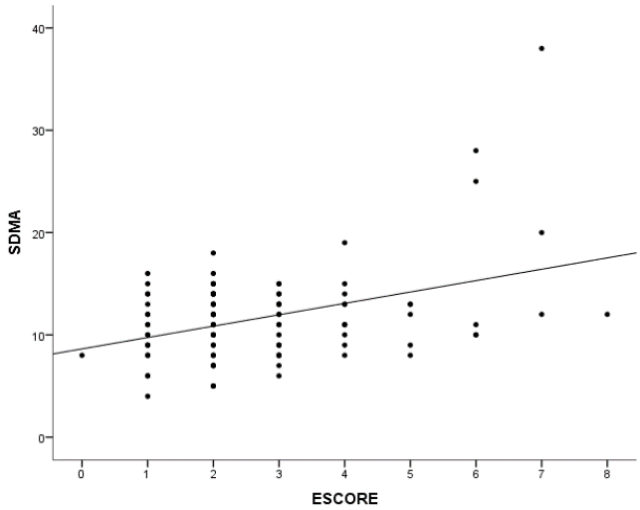

Figure 3 – Scatterplots of the relation between serum SDMA values of the 101 cats and proposed kidney and ipsilateral ureter ultrasonographic score.

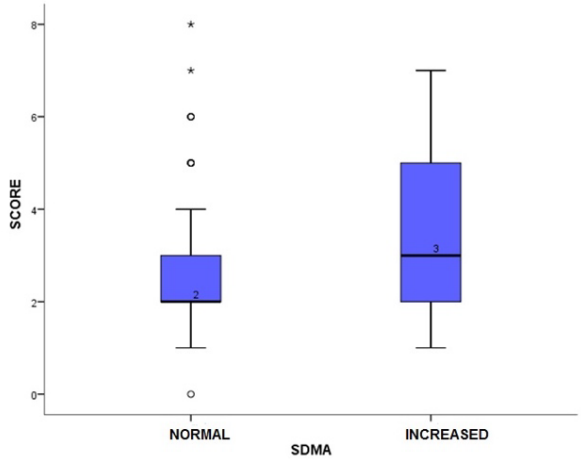

Figure 4 – Average ultrasonographic score of kidney and ureter findings in two groups of cats, with normal and increased sSDMA values. There is no statistically significant difference between groups. P<0.05

As previously stated, two ultrasonographic findings were correlated with increased sSDMA: reduced or loss of kidney corticomedullary definition and decreased kidney length. Figure 5 shows that when the kidney (left or right) was smaller, there was an increased likelihood of having raised sSDMA values. The correlation coefficient between left renal length and increased sSDMA was –0.214, with a p = 0.031. The correlation coefficient between right renal length and increased sSDMA was –0.215, with a p = 0.033.

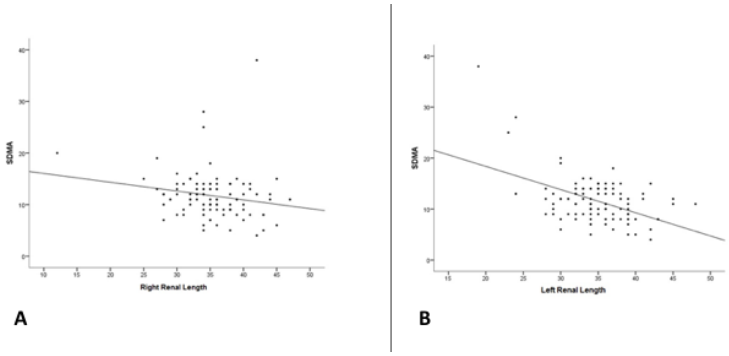

Figure 5 – Sample scatterplots showing the linear relationships between right renal length (centimeter) and serum SDMA (ug/dl) (A), and left renal length (centimeter) and serum SDMA (ug/dl) (B).

4. Discussion

This is the first research that compares the renal ultrasound findings of cats asymptomatic for CKD with sSDMA values. A total of 101 cats were studied. However, 11 cats were considered normal and were not classified as IRIS CKD. Cats were classified as IRIS CKD Stage 1, 49/101 cats (48.51%), IRIS CKD Stage 2, 40/101 cats (39.6%), and one patient IRIS CKD Stage 3. The cats represented a wide range of ages, breeds, and sexes. In total, 202 kidneys were examined ultrasonographically. It is interesting to note that in 89/101 cats (88.11%), at least one unilateral or bilateral abnormal ultrasound finding was detected in the kidney and/or ureter. The identification of only one ultrasound abnormality in the kidneys might be considered insignificant, which makes the correlation between imaging findings and laboratory data difficult.

However, the identification of a single renal ultrasound abnormality is one of the parameters for staging a cat in CKD IRIS stage 1. For some researchers, the signs of renal degeneration are related to renal functional and/or structural loss, and a single abnormal ultrasound finding results in the classification of cats as IRIS stage 1 (International, 2020). Abnormal ultrasound findings, especially single focal changes, such as the presence of a single cyst, slight cortical deformations, or hyperechoic cortices, can be incidental (Debruyn et al., 2012). Hyperechoic cortices were observed in 49/101 (48.51%) patients with normal sSDMA in this study. Thus, although they may be of no clinical relevance, we believe that even mild renal changes indicate the need for further monitoring.

Renal ultrasound is not recommended as a sole investigation in cats with CKD, and some investigators do not even recommend it as a screening technique, since there is a poor correlation between renal ultrasound findings and renal function due to the prevalence of abnormalities in non-azotemic cats (Cléroux et al., 2017).

To determine the relevance of information obtained during renal ultrasound, we attempted to correlate the ultrasound findings with sSDMA. A recent study compared ultrasound findings and glomerular filtration rates in dogs and demonstrated that specific ultrasound findings are associated with reduced glomerular filtration rates (Mattei et al., 2019).

Here, we identified the specific renal and ureteral ultrasound findings that have a positive correlation with increased serum sSDMA. These findings included pelvic dilatation, ureter calculus, loss of corticomedullary definition, and reduced renal size (pole-to-pole length).

Dilation of the renal pelvis is a finding common to not only CKD but also pyelonephritis and partial ureteral obstruction (Lamb et al., 2017). Additionally, any of these underlying pathologies may occur in isolation or concurrently. We believe that renal pelvic dilation is an indicator of kidney injury, even when only mild dilation (2.0-3.0 mm) is present, as small dilations are correlated with increases in sSDMA. Therefore, these patients should be followed up and baseline pelvic measurements should be determined at the time of initial diagnosis of chronic kidney disease (Griffin, 2020).

Another study showed that cats with kidney stones may exhibit early compromised renal function, characterized by increased sSDMA and non-azotemia, or more advanced renal dysfunction with azotemia (Hall et al., 2017). The authors of that study propose that cats with increased sSDMA should undergo imaging tests to identify kidney stones. We suggest that cats with ureteral stones, as identified on imaging examinations, should also undergo SDMA testing (Hall et al., 2017).

The other ultrasonographic finding that was positively correlated with increased sSDMA was the reduction in, or loss of, corticomedullary definition. This is a classical ultrasonographic abnormality frequently associated with CKD.[16] A previous study of 508 cats identified loss of corticomedullary definition in azotemic (26%) and non-azotemic cats (5%) (Lamb et al., 2017). These findings are further supported by a recent study that identified reduced corticomedullary definition as one of the strongest ultrasonographic predictors of decreased glomerular filtration rate in early-stage CKD cats, reinforcing its diagnostic value even before the onset of overt azotemia (Schaefer et al., 2023). Interestingly, while the same study found no significant association between point-of-care SDMA and GFR, our results showed a positive correlation between increased sSDMA and loss of corticomedullary definition, suggesting that laboratory-based SDMA may reflect early structural kidney changes more accurately in some clinical contexts.

We found a negative correlation of renal length with increased SDMA (Figure 5). Cats with reduced kidney length were more likely to have increased sSMDA. Although demonstrating statistical correlation, the interpretation of this finding is challenging because numerous other parameters influence this measurement, including body weight, kidney fat accumulation, age, sex, and breed. We specifically used strict guidelines for standard length (3.0 cm – 4.3 cm) that have been standardized for the Brazilian cat population.

There was no specific correlation between diffuse hyperechoic cortices and increased sSDMA. However, this finding had the highest sensitivity for low IKGFR/PV in dogs and human patients (Mattei et al., 2019). The histological changes responsible for increased parenchymal echogenicity include glomerulosclerosis, tubular atrophy, and interstitial fibrosis (Zotti et al., 2015). Intrinsic factors affecting parenchymal echogenicity are normal variation in fat deposition in cat kidneys, wide variability in the normal range of cortical echogenicity, and severe dehydration (Chien et al., 2012). Extrinsic factors influencing this finding include operator experience, variability in image interpretation, and ultrasound system settings. It is challenging to distinguish between normal and pathological kidneys based solely on this finding.

At least 24/101 cats (23.8%) in this study had renal infarcts, with four cats having increased sSDMA and 20 cats having normal sSDMA. In cats, chronic renal infarcts result in hyperechoic wedge-shaped tissue sections, caused by disruption of blood flow to a renal pyramid (Debruyn et al., 2012). There was no statistical correlation between the infarcts and increased sSDMA. This finding concurs with the results of other studies, which have shown no correlation between renal infarcts and kidney disease. However, there is a significant association between renal infarcts and hypertrophic cardiomyopathy and other prothrombotic diseases, including hyperthyroidism and neoplasia (Hickey et al., 2014).

There was no statistical correlation between the proposed ultrasound score and an increase in sSDMA (Tables 3 and 4; Fig. 4). However, the Spearman correlation coefficient results (Table 3) were borderline significant, which, for some statisticians, can be considered a positive correlation. Our methodology for scoring classification may be inadequate, as some findings that might be regarded as incidental were assigned the same value as potentially more critical findings.

There was a difference in the sample size of animals recruited for each group. If more asymptomatic cats with high sSDMA had been included, the score classifications would have had better sSDMA concentrations. One study in dogs showed a positive correlation between the scoring method and reduced glomerular filtration rate, although a different scoring method was used (Mattei et al., 2019).

The limitations of this research were related to the small number of cats in the asymptomatic group with elevated sSDMA. A further limitation is that inter-breed differences or sexual differences in the renal length weren't calculated. Nevertheless, only three large cats (Maine-coons) were included in the study, and there was no statistically significant difference between the sexual incidences (Debruyn et al., 2013).

5. Conclusion

Ultrasonography is an effective tool in the early assessment of CKD in asymptomatic cats. Our study showed that cats with loss of the kidney corticomedullary differentiation, small kidneys, and kidneys within pelvic dilation on ultrasound examination are more likely to have increased sSDMA.

Conflict of interest: The authors declared no potential conflicts of interest concerning the research, authorship, and/or publication of this article**.**

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Ethical approval: This work involved the use of non-experimental animals only (including owned or unowned animals and data from prospective or retrospective studies). Established internationally recognised high standards (‘best practice’) of individual veterinary clinical patient care were followed. Ethical approval from a committee, while not explicitly required for publication in JFMS, was nonetheless obtained, as stated in the manuscript.

Informed consent: Informed consent (either verbal or written) was obtained from the owner or legal custodian of all animal(s) described in this work (either experimental or non-experimental animals) for the procedure(s) undertaken (either prospective or retrospective studies). No animals or people are identifiable within this publication, and therefore, additional informed consent for publication was not required.

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