Comparison of sonographic and CT findings for the identification of renal nodules in dogs and cats

ULTRASONOGRAPHIC AND CT FINDINGS IN 39 CANINE AND FELINE KIDNEYS WITH RENAL NODULES

Key words: kidney, metastases, small animals

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Abstract:

Ultrasonography (US) and Computed Tomography (CT) are used to diagnose neoplastic and non-neoplastic focal renal lesions; however, comparative studies between these two diagnostic tools are lacking. The aim of this retrospective study was to evaluate evaluate and compare the US and CT features of confirmed focal renal nodules in a group of animals.

Imaging studies of animals with mono- or bilateral renal nodules smaller than 3 cm that underwent both US and CT were reviewed. Animals with renal cysts and infarcts were excluded. Recorded features included, for both modalities, shape, size, number, localization, margins, renal profile; for CT only, attenuation (HU) and pattern of enhancement; for US only echogenicity, echostructure and rate of visibility. Final diagnosis was obtained by cytology or histopathology.

Using CT, lesions were identified in 39/39 (100%) kidneys of 18 dogs and 7 cats. Most lesions were multiple, cortical, well defined, iso-attenuating (pre-contrast), hypo-attenuating and moderately enhancing (post-contrast).

Using US, lesions were identified in 29/39 (74%) kidneys. Overall, 9 (31%) lesions were

poorly visible; 10 (26%) kidneys appeared normal; in 17 (59%) organs, lesions' number was underestimated. Isoechoic, non-protruding lesions were difficult to identify by US.

Final diagnoses included metastatic disease (n=16), infiltration by feline lymphoma (n=4), primary neoplasia (n=3), and non-neoplastic benign lesions (n=2).

In the current case series, both US and CT showed renal nodules, however US failed to diagnose or underestimated the number of inflammatory and neoplastic nodules in a significant number of cases compared to CT.

1. Introduction:

Focal renal nodules are uncommonly reported in small animals, primary renal neoplasia being the most frequent cause of renal nodules or masses.[1-6] Renal metastases are rare in people, with a reported incidence ranging from 2.36 to 12.6%, with carcinomas being the most common tumors (80%) spreading to the kidneys.[7,8] Little information is available in veterinary medicine regarding renal metastases. A single case report describes renal metastases in a dog with nasal condrosarcoma[9], whereas in cats with lymphoma the kidneys can be infiltrated and a nodular pattern is commonly described.[10,11]

Benign nodules are even more rare in small animals. Renal adenomas have been described; however, there is a grey zone in the differentiation with well-differentiated carcinomas.[4] Finally, non-neoplastic lesions like granulomas, abscesses or haemorrhage are occasionally diagnosed.[3]

Diagnostic imaging plays a fundamental role in investigating kidney diseases: ultrasonography (US) is the first approach in clinical practice, however Computed Tomography (CT) is becoming more and more popular especially in large dogs and in patients where the sonographic window is suboptimal. A diagnostic multimodal approach is also preferred in human beings, where CT, MRI and PET-CT have shown a higher diagnostic accuracy in demonstrating renal disease compared to US.[8,12,13,14]

In veterinary medicine, comparative studies are lacking; in a single investigation including different abdominal conditions, CT was superior in lesion detection compared to US in dogs over 25 Kg; however, renal nodules were not included.[15]

The aim of this descriptive cross-sectional retrospective study was to evaluate and compare the US and CT features of focal renal nodules confirmed by cytology or histopathology in dogs and cats.

2. Material and Methods

Study population and imaging analysis

Dogs and cats with a final diagnosis of uni- or bilateral, single or multiple renal nodules, undergoing both abdominal US and a pre- and post-contrast CT study of the abdomen at the Clinica Veterinaria dell'Orologio between 2012 and 2021, were identified from the database from one of the authors (XX).

Approval by an institutional animal care and use committee or institutional review board was not required.

Inclusion criteria were: 1. At least one renal nodule visible in US or CT, defined as a round to oval, vascularized cortical or medullary lesion with any type of echogenicity or CT perfusion pattern focally disrupting the normal renal parenchyma 2. Abdominal US and CT examination performed within one week 3. A complete set of diagnostic quality ultrasound images and videos representing all parts of one or both kidneys available for review and 4. Final diagnosis of the renal lesion/lesions obtained by conclusive cytology or histopathology. Animals with renal masses with a diameter over 3 cm, simple renal cysts and renal infarctions were excluded from the study. Nodules were defined as single solid focal lesions of any echogenicity or CT perfusion pattern. According to the Bosniak classification used in human radiology, simple renal cysts were diagnosed in CT as well-marginated, fluid-attenuating (0-20 Hounsfield Units, HU), non-enhancing homogeneous lesions with a

hairline-thin wall and confirmed in US as round to oval, anechoic, homogeneous, smooth and sharply demarcated thin wall structures associated with distal acoustic enhancement and surrounded by normal renal parenchyma.[16,17] Renal infarctions were recognized as wedge-shaped, cortical broad-based, hyperechoic bands in US and as wedge-shaped parenchyma perfusion defect, with or without a cortical rim sign, without mass effect, or major peri-renal fat stranding lesions in CT, eventually associated with irregular shape and focal cortical atrophy in the chronic phase.[18,19]

Signalment information including age, breed, sex, and body weight were obtained from the medical records.

Decisions regarding case selection and the review of the CT and US studies were made by a second year ECVDI resident (XX). The same author and an European College of Veterinary Diagnostic Imaging (ECVDI) board-certified radiologist (XX) recorded the US and CT findings independently. US images and videos were analysed first, followed by the CT studies, A consensus was found in case of initial disagreement. The CT images were evaluated using an open-source dedicated DICOM viewer software (Horos version 3.3.6, Horosproject.com) and displayed using soft tissue window (window level 50 HU, window width 350 HU) for medium frequency and bone window (window level 300 HU, window width 1500 HU) for high frequency reconstruction algorithm. The second algorithm was used to identify the site of lesion's mineralization. Multiplanar reconstructions (dorsal, sagittal, and transverse) were used to evaluate all studies.

For both modalities and for each kidney, recorded images features were: lesions' number (divided in 3 groups: single, between 2-6 and over 6 lesions), size (nodule largest diameter, <1 cm or ≥1), shape (round or oval), margins (well-defined or irregular), location (cortical, medullary or both) and renal profile (normal or deformed).

Only for CT, the minimum, maximum, median (± SD) attenuation of the largest lesion, expressed in HU was measured in the pre- and post-contrast series including the entire

lesion; moreover, the enhancement pattern (homogeneous, heterogeneous, rim) was evaluated.

Only for US, the B-mode echogenicity (iso-, hypo or hyperechoic compared to the surrounding renal cortex or medulla), the echo-structure (homogeneous or heterogeneous) and, if available, the Color or Power Doppler pattern (hypo- or hypervascular lesions) were evaluated. If Doppler was used, the lesion and part of the surrounding normal kidney were included in the Color Doppler box, and the two regions were subjectively compared. Lesions were considered hypervascular if with similar or higher vessel conspicuity to the kidney was present and hypovascular if lower vessel density was observed. Finally, the visibility of all renal lesions recognized in CT were compared with the sonographic appearance and classified in 3 categories: 1. clearly visible (immediate, excellent visualization in US because of evident altered echogenicity or evident renal profile deformation), 2. poorly visible (unclear lesion, with mild changes of cortical/medullary echogenicity or echostructure and poor renal profile deformation) and 3. not visible (normal cortical/medullary echogenicity and echostructure, no deformation of the renal profile).

Other additional relevant CT findings, including abdominal lymphadenopathy, presence of lesions in other abdominal organs or in any additional examined body parts were annotated. The final diagnosis was recorded. In case of renal metastasis, information on the primary extra-renal cancer (type, location, presence of other sites of metastases) was registered.

The study hypotheses were that a higher number of lesions was visible in CT and that lesions' US features (especially size, echogenicity, deformation of the renal profile) and location (right versus left kidney) influence their visibility in US.

Statistical analysis

The statistical analysis was performed by a veterinary researcher with experience in medical data analysis (SS). Descriptive statistics were used to summarize demographic information and lesion characteristics. When appropriate, data sets were tested for normality by use of

the D'Agostino and Pearson omnibus normality test. No data had normal distribution and were therefore expressed as median (range).

The difference on the number of nodules detected in US compared with CT for each kidney was assessed with Wilcoxon matched pairs signed rank test.

The effects of species, sex, kidney side (right vs left), nodule location (cortical vs medullary), number of nodules (single vs multiple), nodule largest diameter (≥1 vs <1 cm), nodule shape (round vs oval) and final histologic diagnosis (non-neoplastic lesion, primary renal tumor, metastatic tumor) on the possibility to detect renal nodular lesions were evaluated with Fisher's exact test. The effects of dogs' body weight on the possibility to obtain a correct US diagnosis was evaluated with Mann-Whitney U test.

Data were analyzed by use of commercial software programs (SPSS Statistics v. 26, IBM, Somers, NY). P values ≤ 0.05 were considered significant.

3. Results

3.1 Clinical demographic data

Fifty-three animals with renal nodules that underwent both CT and US were initially identified. Twenty-eight cases were excluded because the renal lesions were not sampled (n=23) or cytology was inconclusive (n=5). Finally, the study population included 39 kidneys (22 right and 17 left) from 25 animals (18 dogs and 7 cats).

All cats were domestic shorthair; 2 of them were castrated males and 5 spayed females. Median age was 15 years (range 5-21.2), and median weight was 5 Kg (range 3.1-6.7).

Mixed-breed dogs represented the majority (n=7), whereas purebred dogs included one each of the following: German Shepherd, Boxer, Dalmatian, Epagneul Breton, Chihuahua, English Setter, Cocker Spaniel, Labrador Retriever, Maltese, Beagle and Giant Schnauzer. Median age was 11.2 years (range 6-18), and median weight 19.5 kg (range 3.3-40). There were 8 spayed females, 4 intact females, 4 intact males and 2 castrated males.

Final diagnoses were obtained in 23 cases by cytology (in 19 cases by US-guided fine needle aspiration and in 4 cases by combined CT/US guidance) and in 2 cases by histopathology (by US-guided tru-cut biopsy in one case and after nephrectomy in the second case). The combined CT/US approach was performed in 4 animals where US failed to visualize the nodules, by sampling the area where the lesion was visualized in CT.

Following diseases were diagnosed: 2 (8%) non-neoplastic benign lesions (1 inflammatory granulomatous nodule, 1 nodular hyperplasia), 2 (8%) primary renal neoplasia (1 adenoma, 1 primary canine lymphoma), 5 (20%) feline lymphoma (1 bilateral renal lymphoma, 2 nasal and 2 multicentric lymphomas with renal involvement), and 16 (64%) metastatic lesions. Among the latter, there were 12 carcinomas (4 canine pulmonary, 3 canine thyroid, 1 canine mediastinal neuroendocrine, 1 canine adrenal, 1 feline retrobulbar, 1 canine apocrine, 1 canine metastatic cancer of unknown primary (MCUP), 2 sarcomas (1 canine histiocytic sarcoma, 1 canine hemangiosarcoma) and 2 melanomas (1 canine digital and 1 canine pharyngeal). Metastases were solitary (n=5/16, 31%) or multiple (n=11/16, 69%), bilateral (n=9/16, 56%) or unilateral (n=7/16, 44%). In 7/16 (44%) of these patients, the kidney was the only metastatic site, whereas in the remaining 9 cases metastases were found also in the lung, pleura, liver, subcutis, muscles, lymph nodes and bones.

3.2 Imaging techniques

US of the kidneys was performed with one of the following units: Esaote My Lab 30 Vet, Esaote Megas CVX, Esaote My Lab 70Vet, Esaote MyLab^{TM} X8 paltform, using either a electronic microconvex 5-7,5 MHz or a linear 5-13 MHz probe. In 10/26 cases (38,5%), a first abdominal US examination was performed by the referral veterinarian before the CT study: in 6/10 of them the kidneys were evaluated as normal, whereas single (n=2) or multiple (n=2) renal lesions were recognized in the other 4 animals; all lesions were confirmed in CT. In all animals, the kidneys were scanned by US under general anaesthesia immediately following the CT study, with the further aim of sampling the renal lesions found

in CT. Each kidney was scanned in longitudinal and transverse plane after clipping the area of interest, with the patient in lateral or dorsal recumbency. Grey-scale images were obtained in all cases, Color and/or Power Doppler was performed in 13 animals.

CT studies were performed in sternal recumbency under general anaesthesia. In all animals, a total-body CT was acquired, the scan including cranially the entire head and caudally the proximal half of the hind limbs. Two different CT units were used: a 16-slice multidetector CT (Brightspeed S, GE Healthcare, Medical Systems, Milan, Italy) and a 64-128 multidetector CT (Optima 660, GE Healthcare, Medical Systems, Milan, Italy). Technique settings for the scans were: slice thickness range from 0.65 to 2.5 mm, matrix size of 512 x 512, field of view ranging between 200-500 mm, kVp 100-120, mAs 99-400, and pitch 0.9375-1.75.

A pre-contrast and a post-contrast study was always performed, after the administration of a water-soluble iodinated contrast medium (Ioversol, Optiray 300, Guerbet S.p.A, Milan), injected intravenously using a power injector (OptiVantage®DH, Guerbet S.p.A, Milan), at a dose range of 450-600 mg/l/kg.

3.3 Imaging characteristics of renal nodules

Table 1 summarizes US and CT findings of renal nodules.

US identified lesions in 21/25 (84%) animals and 29/39 (74%) kidneys, 12 on the left kidney and 17 on the right kidney. Renal lesions were bilateral in 8/21 (38%) animals and unilateral in 13/21 (62%); nodules were single in 18/29 cases (62%, 6 left and 12 right), between 2-6 in 6 cases (21%, 4 left and 2 right) and over 6 in 5 cases (17%, 2 left and 3 right).

The median maximum diameter was 1.2 cm (range 0.4-2.9). In 18/29 (62%) cases, the biggest lesion visualized in US was over 1 cm, whereas in 11/29 (38%) was smaller than 1 cm.

The shape was round in 25 (86%) nodules and oval in 4 (14%). Margins were well-defined (n=19, 66%) or ill defined (n=10, 34%). The nodules were located in the cortex in 24 kidneys (83%) and in the medulla in 5 (17%).

Lesions were mostly hypoechoic (n=18, 62%), less frequently hyperechoic (n=8, 28%) or isoechoic (n=3, 10%); the echotexture was mostly heterogeneous (n=20, 69%), less frequently homogeneous (n=9, 31%), deforming (n=18, 62%) and non-deforming (n=11, 38%) the renal capsule.

The sonographically detectable nodules were most frequently single (62%), hypoechoic (62%), heterogeneous (69%), deforming (62%) and well-defined (66%).

Color-Doppler was available for 13 animals, in 2 of them Power-Doppler was also used. In the cases where the lesion was already clearly visible in grey-scale (n=9), Doppler was considered useful to evaluate lesion's vascularisation. Overall, nodules were mostly hypovascular (n=6, 46%) except for 3 hypervascular metasases (23%) from thyroid carcinomas, where a net of thin uniformly distributed vessels was visible in the lesion. In the 4 cases (30.8%) with poorly visible nodules, Color Doppler did not improve their visualization.

CT identified focal renal lesions in 25/25 animals (100%) and 39/39 kidneys (100%). Lesions were distributed almost equally in the two kidneys, 22 (56%) on the right side and 17 (44%) on the left side. In 12/39 (31%) cases, lesions were single, in 16/39 (41%) cases 2-6 nodules were identified, and in 11 cases (28%) there were more than 6 lesions.

Lesions' shape was mostly round (n=32, 82%) and less frequently oval (n=7, 18%).

Mean maximum diameter was 1.5 cm, with 14/39 (36%) kidneys having nodules smaller than 1 cm, 14/39 (36%) over 1 cm and 11/39 (28%) nodules of both categories.

The nodules had mostly well-defined margins (n=36, 92%), cortical location (n=36, 92%) and deformed the renal profile in 18 (46%) cases. The mean attenuation was 35.8 HU in the native scan and 78.24 HU after contrast administration. Compared to the surrounding cortex,

all nodules were markedly hypoattenuating post contrast. The enhancement was homogeneous in 24/39 kidneys (62%), heterogeneous in 13/39 (33%) and ring-type in 2 (5%).

3.4 Comparison of sonographic and CT findings

In CT, renal nodules were clearly visible in all kidneys; in the post-contrast scan they were strongly hypoattenuating to the surrounding cortex. There were no cases where US identified renal lesions and CT did not.

US identified renal nodules in 29/39 kidneys (74%) and 21/25 patients (84%). Within the 29 kidneys with sonographically detected lesions, the number of visualized lesions was the same as in CT for 12 (41%) cases and underestimated in 17 (59%) ($P < 0.001$). Among identified nodules, lesions were considered poorly visible in 9 (31%) kidneys and 7 (33%) patients, and clearly detectable in 20 (69%) kidneys and 14 (67%) patients. The distribution of the identified nodules between right and left side was not significantly different in both the total group and the dogs group.

Compared to CT, lesions were not detected by US in 10/39 kidneys (26%). In one dog, bilateral nodules were missed, whereas in 3 cases (2 dogs and 1 cat) one kidney was normal but the contralateral was affected; all these 4 animals had a primary neoplasia (3 carcinomas and 1 melanoma) and were staged negative with US. In other 5 dogs, one kidney was considered normal but nodules in the contralateral kidney were identified. Table 2 summarizes the CT features of the 10 nodules undetected in US.

The median weight of dogs with visible renal lesions (either clearly or poorly visible) in US was significantly lower compared with that of dogs with undetected renal lesions (16.0 kg vs 29.5 kg, respectively; $P = 0.032$).

No significant effect of species, sex, kidney side, nodule location, number of nodules, nodule size, nodule shape and final histologic diagnosis on the possibility to detect renal nodular lesions was identified. Isoechoic, non-protruding lesions were difficult to identify by US.

Discussion

This study first describes the US and CT features and prevalence in a group of dogs and cats with confirmed renal nodules. In clinical practice, both techniques are used to scan the abdomen in oncologic patients, with the aim of identifying parenchymal lesions compatible with metastases.

In the current study, 16% of animals with renal lesions were staged negative with US and, among patients with sonographically identified lesions, there was a significant underestimation of the number of nodules compared with CT. Renal lesions were clearly identified by contrast CT, regardless of their size, because of the evident hypoattenuating appearance compared to the surrounding cortex. The strong cortical enhancement in CT is produced by the sum of the vascular component (contrast medium in the renal vascular bed) and the filtration process (contrast medium filtered from the renal glomeruli to the tubules); the distortion of the vascular pattern and of the filtrating structures in the nodule can explain the marked hypoattenuating aspect.[8]

The second study hypothesis was also confirmed. In US, the hypo- or hyperechogenicity, the heterogeneous echostructure and the deformation of the renal profile were the most useful features to visualize the nodules, whereas isoechoic, non-protruding nodules were undetectable, even if multiple. In the category of poorly visualized nodules, the majority of them were non-protruding and their presence was suspected because of the subtle changes in echogenicity compared to the homogeneous surrounding cortex. This result suggests that cortical renal lesions may be difficult to visualize by US and that a complete and accurate evaluation of the entire cortex is necessary, especially when renal lesions are suspected.

It is interesting to note that the number of nodules did not increase the US performance. Among the 10 cases with sonographically undetectable lesions, 7 had multiple nodules identified by CT.

Surprisingly, the location of the nodules (right versus left kidney) did not affect the US performance; our hypothesis was that the more cranial location of the right kidney could increase the risk of missing renal lesions, however this was not confirmed in both the total group, and the dogs group. On the contrary, the weight of the animals significantly influenced the nodules visibility, since the median weight was significantly lower in the group of dogs with visible nodules (16 kg vs 29.5 kg). The dog size is recognized to be a limitation in ultrasound, since the increased skin-organ distance requires lower frequencies to be used, leading to a decreased image quality.[15] This might have affected the possibility to visualize ill-defined cortical nodules. By contrast, CT is not influenced by dog size and this could be one of the reasons explaining the better performance.

In this study, renal nodules always showed some enhancement, and this is an important feature to distinguish vascularized nodules from renal cysts.[14,20] The CT enhancement pattern was mostly homogeneous (61.5%); however, heterogeneous/ring type nodules were likewise well represented (38.5%), without any significant correlation with the histologic type. The small number of primary neoplasia and inflammatory lesions makes the comparison between different types of nodules not reliable. Indeed, this was not the goal of this study, and the exclusion of renal lesions bigger then 3 cm represents a bias and explains why primary cancer was under-represented here. Our goal was to compare the performance of US and CT in the challenging situation of small cortical renal lesions. Sampling the nodules remains the only way to obtain a definitive diagnosis.

In this study, a high number of renal nodules were represented by renal metastases (17/25 animals, 68%). The majority of primary tumours were carcinomas followed by melanomas and sarcomas; lung and thyroid carcinomas were over-represented. Metastatic nodules

were most commonly cortical, multiple and bilateral. In 7 patients, kidneys were the only metastatic sites; therefore, the detection of these lesions was crucial for a correct staging. In 4 cases, renal nodules were missed in US and the abdomen was considered normal, whereas CT showed them clearly.

In human medicine, renal metastases are considered a rare entity with a reported incidence variable between 2.36% and 12,6% in autopsies studies of cancer patients.[7,8,21-22] Similarly to our study, the most common primary location is the lung (43.7%), followed by colorectal region (10.6%), small intestine (6%), breast (5.3%), soft tissue (5.3%), thyroid (5.3%), and unknown primary (5.3%).[7,8,14] The kidney cortex is a common site for haematogenous metastases from highly vascularized tumours. Because of the high vessel density of the glomeruli, the cortex is an ideal area for entrapment and proliferation of tumour emboli.[23] CT is the preferred modality for the diagnostic work-up, even though pathognomonic imaging characteristics for renal metastases versus primary neoplasia have not been recognized, rather the suspected diagnosis is based on the history of a known primary and the knowledge about the disease biology and behaviour.[7,8,14,20,,23,24,26] Fine-needle aspiration or, less frequently, tissue core biopsy is used to confirm the suspected diagnosis.[7,8] Detection of renal metastases is often incidental without symptoms referable to the kidneys, therefore very important since it influences treatment and survival.[7,14] In veterinary medicine, there is lack of information about the prevalence, clinical presentation and prognosis of animals with renal metastases. This study shows that in the presence of a primary tumour and multiple renal nodules, this scenario should be considered very likely, especially if the primary tumour is a lung or thyroid carcinoma. In these patients, CT is indicated for staging purposes, followed by sampling by FNA or biopsy. If the abdominal staging is performed by ultrasound, every subtle change in the renal cortex must be identified and the clinician must be aware of a possible false-negative result.

There are some limitations, mainly due to the retrospective nature of this study.

A Doppler study of the kidney was available only for about half of the cases (13/25 animals). With nodules already clearly identified by grey-scale ultrasound, Doppler enabled to evaluate the abnormal vascular pattern; on the contrary, Doppler did not help to increase the visualization of poorly detected nodules. Moreover, if the kidneys were considered normal, this technique was not consistently used, therefore it is not possible to draw definitive conclusions regarding Doppler examination performance. Both Power Doppler and Contrast Ultrasound are used in humans to study focal renal lesions, with improved visualization of the vascular pattern and some utility in the differential diagnosis[26,27]. However, these techniques are used to investigate lesions already identified by grey-scale US, and a complete screening of both kidneys in each cancer patients would be time-consuming and not realistically possible. In cancer patients, CT combines the advantages to investigate the primary lesion and to perform a complete staging; renal metastases are quickly suspected in all vascular phases; in 12 of our 25 patients, bilateral, multiple vascularized renal nodules were detected; therefore, the diagnosis of metastatic diseases was already likely even before sampling.

The two authors were blinded to CT when analysing the US images but not vice versa. However, lesions in CT were always obvious, whereas more difficult to detect in US in part of the cases, therefore this was not considered a bias.

Other limitations are the limited numbers of primary neoplasia and inflammatory lesions, compared to the metastatic group, therefore a comparison between these categories was not possible. Finally, histopathology was available only for 2 cases and necropsy was not performed to confirm the CT findings. It is possible that also CT fails to diagnose renal lesions and that these are detectable only with histopathology after necropsy; a study having this method as gold standard is needed to evaluate and compare US and CT accuracy.

In conclusion, both US and CT are useful for the detection of renal nodules. Compared to CT, US failed to diagnose or underestimated the number of inflammatory and neoplastic nodules in a significant number of cases. Renal nodules were frequently represented by metastases, especially from lung and thyroid carcinomas, therefore CT can be considered an indicated tool for the abdominal staging.

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Renal nodules		**CT (n=39)**	**US (n=29)**
Accuracy US vs CT			74%
Number	single	12 (30.8%)	18 (62.1%)
	>2 and < 6	16 (41%)	6 (20.7)
	>6	11 (28.2%)	5 (17.2%)
Size	mean	1,45	1,3
	< 1 cm	14 (35.9%)	11 (38%)

	> 1 cm	14 (35.9%)	18 (62%)
	< 1 cm and > 1 cm	11 (28.2%)	0 (0%)
Shape	round	32 (82%)	25 (86.2%)
	oval	7 (18%)	4 (13,8%)
Margins	well defined	36 (92%)	19 (65.5%)
	irregular	3 (8%)	10 (34.5%)
Location	cortical	36 (92%)	24 (82.8%)
	medullary	0 (0%)	5 (17.2%)
	cortical and medullary	3 - (8%)	0 (0%)
Renal profile	deformed	18 (46%)	18 (62%)
	not deformed	21 (54%)	11 (38%)
Attenuation	mean HU	Pre-contrast 35,8 Post-contrast 78,24	
	compared to the cortex	Pre-contrast isoattenuating – 32 (82%) Post-contrast hypoattenuating – 39 (100%)	
Enhancement pattern	homogeneous	24 (61,5%)	
	heterogeneous	13 (33.3)	
	ring	2 (5.2%)	
Echogenicity	Isoechoic		3 (10.4%)
	Hypoechoic		18 (62%)
	Hyperechoic		8 (27.6%)
Echostructure	Homogeneous		9 (31%)
	Heterogeneous		20 (69%)
Color/Power Doppler (n=13)	Hypovascular		6 (46%)
	Hypervascular		3 (23%)
	Non useful		4 (31%)

Table 1. CT and US feature of renal nodules. In CT (39 kidneys), renal nodules were mostly multiple, cortical, round, well marginated, not deforming the renal profile, isoattenuating in the native scan and hypoattenuating after contrast administration, homogeneously enhancing. US feature of 29/39 kidneys, showed that renal nodules were mostly cortical, single, round, with well-defined margins, deforming the renal profile, hypoechoic and heterogeneous.

CT features of renal nodules non visible in US (total 10)	
Number	
Single	3 (30%)
>2 and <6	5 (50%)
> 6	2 (20%)

Size	
> 1 cm	7 (70%)
< 1 cm	3 (30%)
Shape	
Round	9 (90%)
Oval	1 (10%)
Margins	
Well-defined	10 (100%)
Location	
Cortex	10 (100%)
Profile	
Non deforming	10 (100%)

Table 2: Features of the nodules visible in CT and undetected in US. They were mostly multiple, over 1 cm in size, round, cortical, with well-defined margins and non-deforming the renal cortex.

		CT	**US**
Accuracy		100% (kidneys)	74% (kidneys)
		100% (patients)	84% (patients)
Lesion's visibility	Clearly visible	39 (100%)	20 (69%)
	Poorly visible		9 (31%)

	Not visible		10 (25,6%)
Side	Right	22 (all patients) 17 (dogs)	17 (all patients) 13 (dogs)
	Left	17 (all patients) 13 (dogs)	12 (all patients) 8 (dogs)
Median weight of dogs with visible lesions		29.5*	16*
Number of visualized lesions – US versus CT	Same number		12 (41%)^
	Less number		17 (59%)^

***P = 0.032**

^P = 0.001

Table 3. Comparison between US and CT.

US accuracy was 74% considering the kidneys and 84% the patients. In US, 31% of the lesions were poorly visible and 25,6% not visible. There was not significant difference between right and left side, however the median weight of dogs with visible lesions was higher in CT (29.5 versus 16 Kg; P=0.032). US underestimated renal lesions compared to CT in 59% of the kidneys (P=0.001)

Figures Legends.

Fig. 1. Example of a single renal nodule imaged with grey-scale US (A), Power Doppler (B) and CT (C, post-contrast, sagittal reformatted image). All images modality clearly showed

the nodule, with a high flow with Power Doppler and a moderate heterogeneous enhancement in CT. Final diagnosis was a metastasis arising fa rom thyroid carcinoma.

Fig. 2 Mixed breed dog with multiple bilateral metastases arising from a mediastinal neuroendocrine carcinoma. A,B: right kidney. C,D: left kidney. A,C: post-contrast CT images, sagittal reconstruction. B,D: US focused on the region where the nodules were visible in CT. On the right (A,B), renal nodules were clearly visible in CT and poorly visible in US. The nodule at the cranial pole of the left kidney was not visualized in US (C,D).