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Evaluation of the Impact of Intravenous Contrast Medium Injection on Kidney Length in Clinically Healthy Dogs Using Computed Tomography

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Abstract

This study aims to evaluate the effect of intravenous contrast medium injection on kidney length using computed tomography (CT) in clinically healthy dogs. A retrospective analysis was conducted on CT examinations of the abdomen performed in 113 dogs (43 females, 70 males). Kidney lengths (K) were measured on precontrast and post contrast images. They were normalized using the length of the body of the second lumbar vertebra (L2), expressed as K/L2 ratio, and compared using paired t-tests. Precontrast normalized kidney length was 3.03±0.28 for the right kidney (PrRK) and 2.97±0.31 for the left kidney (PrLK). Post contrast normalized length was 3.06±0.30 for the right kidney (PcRK) and 3.0±0.31 for the left kidney (PcLK). On both precontrast and post contrast acquisitions, the right kidney was significantly longer than the left one (P <0.05) for a given dog. The mean increase in kidney length on post contrast images was 0.03 K/L2 for both kidneys compared to precontrast measurements. Males had significantly longer normalized kidney lengths than females in both precontrast and post contrast images (P <0.05). Intravenous contrast medium injection results in a slight but significant increase in kidney length in dogs on CT. This increase is consistent between the right and left kidneys. This study also found inherent anatomical variations, with males having longer normalized kidneys than females and the right kidney being longer than the left. These findings suggest that kidney length measurements can be reliably performed before or after intravenous contrast medium injection in clinical settings.

Keywords: Dogs; Kidneys; Computed Tomography; Contrast Medium

Introduction

Renal size is an important factor in assessing renal health in veterinary medicine. Several canine diseases can cause changes in renal size. Renomegaly may be observed in portosystemic shunt, renal cysts, renal tumors, pyelectasia, renolithiasis, amyloidosis, glomerulonephritis and pyelonephritis, while a decrease in renal size can be observed in congenital or acquired atrophy and chronic renal failure [1]. Kidney size is also related to glomerular filtration rate (GFR) [2]. Thus, kidney size provides useful clinical information and is commonly performed with measurement of kidney length. This measurement is simple and convenient for a routine clinical use and is commonly performed with radiograph, ultrasonography or computed tomography (CT). In human medicine, renal size measurement is more accurate using helical CT multiplanar reformation than radiography or ultrasonography [3,4]. On radiography, kidney size may be misestimated secondary to magnification and distortion [5,6]. On ultrasonography, kidney size can be altered by transducer compression, the cranial pole of the right kidney is usually difficult to visualize and measurement is subject to intra- and inter-observer variations.[3,6,7] Computed tomography overcomes these limitations and can provide precise kidney measurements using multiplanar reconstructions.[3,6,8] Moreover, CT provides an excellent visualization of the kidney anatomy, offers excellent tissue contrast, and intravenous contrast medium injection permits to detect more precisely kidney changes like parenchymal nodule, irregular margins or infarti [9–11]. However, in dogs and humans, intravenous nephrography showed to cause an enlargement of the kidney on survey radiograph and Darawiroj et al. showed that intravenous contrast injection alters the size of cat's kidney on CT, mostly on the right side, causing a slight enlargement of the kidneys [4,6,12]. To the authors' knowledge, there is no information in the veterinary literature regarding the effect of intravenous contrast medium injection on renal size in dogs on CT. The purpose of this study is to evaluate the effect of intravenous contrast medium injection on kidney length using CT in clinically healthy dogs. The authors postulate that intravenous contrast medium injection will slightly increase kidney length compared to precontrast length, but with a non-significant statistical result.

Material and Methods

Case Selection

The study design was retrospective. Computed tomography examination of the abdomen performed in the Olliolis referral veterinary clinic between January 2018 and January 2024 were reviewed. Images were acquired using a multidetector 16-slice CT scanner (SOMATOM Scope; SIEMENS, Forchheim, Germany) in helical scan mode. Dogs were enrolled in the study if they were judged clinically healthy, with no previous urinary clinical signs reported, and if their hematology and serum biochemistry test results were normal. Moreover, the other inclusion criteria were:

- A full CT examination of the abdomen must have been acquired in sternal recumbency, under general anesthesia, from the diaphragm to the pelvic cavity and with no lesions detected.
- Precontrast and post contrast CT images were acquired and available, with post contrast acquisition performed 30 seconds after a 2ml/kg intravenous injection of nonionic iodinated contrast medium

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(Iobitridol, iodine concentration 300 mg/mL, Xenetix 300®, Guerbet, France).

- Patient information such as gender, age, breed, and body weight of the dogs, were recorded in the database.

Dogs were excluded from the study if the quality of CT images was poor (due to motion artifact or for any other reason).

Computed Tomography Measurements

Patient DICOM data were reviewed on a computer workstation using Osirix software. The length of both kidneys was measured on CT precontrast and post contrast acquisitions displayed with a window width (WW) of 350 Hounsfield units (HU) and a window level (WL) of 40 HU. Kidney length measurements were performed with the digital ruler of the software as the maximal longitudinal length measured on a dorsal multiplanar reconstruction [Figure 1]. The length of the body of the second lumbar vertebra (L2) was measured using the digital ruler on dorsal multiplanar reformatted images displayed with a WW of 1,500 HU and a WL of 300 HU [Figure 2]. Each measurement of the kidney length (K) and L2 body length was performed 5 times for each case, and final measurement was considered as the mean of the five measurements.

Statistics

Standardization of Dimensional Values

- Precontrast right kidney length (PrRK), precontrast left kidney length (PrLK), post contrast right kidney length (PcRK), and post contrast left kidney length (PcLK) were measured for each dog.

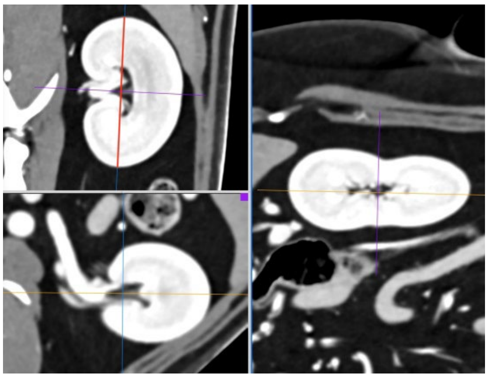

Figure 1: Multiplanar computed tomography of the abdomen of a clinically healthy dog after intravenous contrast medium injection showing the measurement of the left kidney length on dorsal plane (red line).

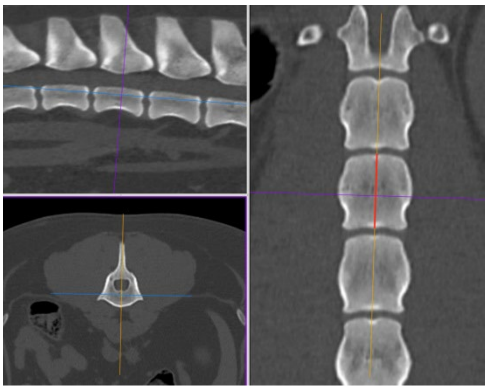

Figure 2: Multiplanar computed tomographic image of the spine showing the measurement of the second lumbar vertebra performed on dorsal plane (red line).

- These measurements were normalized using the length of the body of L2, expressed as K/L2 ratio.

Right and Left Kidney Length Comparison

- Normalized PrRK and PcRK were compared to normalized PrLK and PcLK, respectively, using paired t-tests.
- This comparison aimed to evaluate differences in renal length between the right and left kidneys, both on precontrast and post contrast acquisitions.

Precontrast and Post contrast Kidney Length Comparison

- Normalized PrRK and normalized PrLK were compared to normalized PcRK and PcLK, respectively, using paired t-tests.
- This comparison assessed differences in renal length before and after contrast medium administration, for both kidneys.

Male and Female Kidney Length Comparison

- Cases were grouped based on sex.
- Normalized PrRK, normalized PrLK, normalized PcRK, and normalized PcLK were calculated for each group.
- The same comparisons described for pre/post contrast and left/right kidney length differences were performed between male and female groups using independent t-tests.

Degree of length variation

- The degree of length variation was calculated by subtracting precontrast normalized length from post contrast normalized length for each kidney size and sex.
- Comparisons of the quantity of length variation between the right and left kidneys were analyzed using paired t-tests.
- Comparisons of the quantity of length variation between male and female groups were analyzed using independent t-tests for both right and left kidneys.

Verification of Normal Distribution

- The normal distribution of each normalized group was verified using QQ-plots.

Statistical Analysis

- All statistical analyses were performed using XLSTAT software.
- Statistical significance was defined as a p-value < 0.05.

Results

One hundred thirteen dogs met the study inclusion criteria, with 43 females (35 spayed and 8 sexually intact) and 70 males (28 castrated and 42 sexually intact). Represented breeds were French bulldog (n=18), Dachshund (14), Maltese (7), Jack Russell (7), Beagle (7), Border Collie (6), Shih Tzu (5), Golden Retriever (5), Yorkshire Terrier (4), Belgian Malinois (3), Pug (3), Labrador (3), Beauceron (3), Braque (3 dogs), Griffon (3), Brittany Spaniel (3), German Shepherd (3), Chihuahua (2), Irish Setter (2), Staffordshire Bull Terrier (2), Springer Spaniel (2), Bobtail (1), Boxer (1), Shar Pei (1), Fauve de Bretagne (1), Doberman (1), Cairn Terrier (1), Papillon Spaniel (1) and Leonberger (1). Mean age of dogs in this study was 7.0 years (median, 7 years; range, 1 to 12 years) and the mean weight was 17.3 kg (median, 13 kg; range, 2.6 to 48 kg). The average length of L2 was 2.02 ± 0.5 cm. All groups had a normal distribution based on the QQ-plots analysis. The normalized mean precontrast value of right and left kidney length was 3.0±0.3. Normalized PrRK was 3.03±0.28 whereas normalized PrLK was 2.97±0.31 [Table 1]. On precontrast images, normalized right kidneys were significantly longer (P-value $=2.2\times10^{-6}$) than normalized left kidneys [Figure 3]. Normalized PcRK was 3.06 ± 0.30 and normalized PcLK was 3.0±0.31 [Table 1]. On post contrast images, normalized right kidneys were significantly longer (P-value = 7.9×10^{-6}) than normalized left kidneys [Figure 3]. The mean difference between right and left kidneys was of 0.06 in both precontrast and post contrast images. Comparing precontrast and post contrast measurements, normalized PcRK and normalized PcLK were significantly longer than normalized PrRK and normalized PrLK (respectively, P-value = 3.62×10^{-8} and P-value = 5.5×10^{-7}). The mean difference between normalized PrRK and normalized PcRK and between normalized PrLK and normalized PcLK was 0.03. There were no significant differences in this length increase between right and left kidneys (P-value >0.05). For males, normalized PrRK was 3.08±0.28, normalized PrLK was 3.03±0.29, normalized PcRK was 3.12±0.29 and normalized PcLK was 3.06±0.30 [Table 1]. For females, normalized PrRK was 2.95±0.28, normalized PrLK was 2.86±0.30, normalized PcRK 2.97±0.29 and normalized PcLK was 2.91±0.31 [Table 1]. Males had significantly longer normalized kidneys (right and left) than females when comparing in both precontrast and post contrast images (P-value for PrRK comparison= 0.015; P-value for PrLK comparison = 0.003; P-value for PcRK comparison = 0.009; P-value for PcLK comparison = 0.015). There were no significant differences in this length increase between males and females (P-value >0.05).

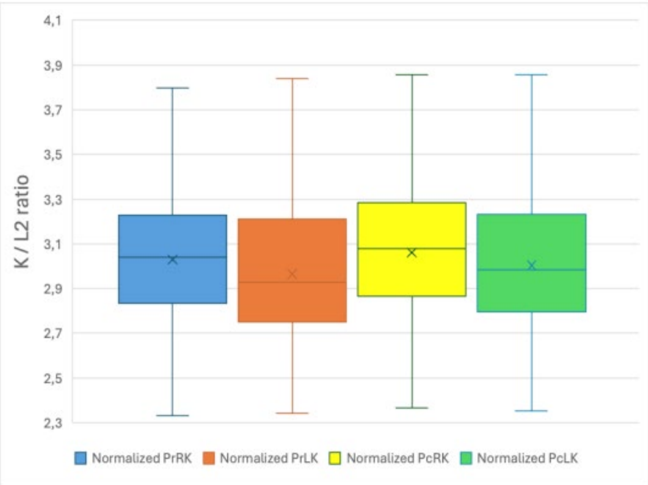

Figure 3: Normalized kidney length by L2 length in clinically healthy dogs on precontrast and post contrast computed tomography. Abbreviations: PrRK, precontrast right kidney length; PrLK, precontrast left kidney length; PcRK, post contrast right kidney length; PcLK, post contrast left kidney length; K / L2 ratio, ratio between kidney length and the length of the body of the second lumbar vertebra. Normalization of kidney length performed by dividing kidney length by L2 body length.

Discussion

Systemic or renal diseases can impact renal size [1,13-17]. Studies have shown that kidney volume is associated with renal function, and glomerular filtration rate [2,18-21]. Kidney volume measurement can be performed on CT using voxel count method; however, this method is laborious and time-consuming [22,23]. It has been proved in human that there is a significant correlation between measured kidney length on ultrasound and kidney volume using CT [21]. Moreover, in cats, it had been shown that feline renal length correlates well with renal volume [22]. For routine use, kidney measurement in veterinary medicine should be convenient, fast to perform, and is usually done using ultrasonography, radiography or CT. Computed tomography has been proved to have very low inter- and intra-observer variation for kidney length measurements in dogs and is recognized as the most reliable technique for kidney measurements in humans [3,4,8].

Body weight of healthy dog has a significant relationship with kidney length [7,24-26]. Due to the large variation in body size among dog's breeds, kidney length should be normalized to suppress the effect of this parameter. In radiography and CT, the dog kidney length normalization is usually performed using the length of the body of L2 [5,8,27]. Normalization by the diameter of the aorta has been previously used on ultrasonography and CT [8,28]. However, it has been shown that vessel diameter can be affected by hydration status, anesthesia, cardiac cycle or systemic arterial pressure, that is why the authors decided not to use this parameter for normalization [8,29,30]. Our precontrast K/L2 ratio is in agreement with previously obtained K/L2 ratio from radiographs without intravenous injection of contrast medium [12,24]. However, we observed a slight difference with the only study using CT in dogs. Hoey et al. studied the K/L2 ratio on CT of dogs without intravenous injection [8]. Our mean K/L2 ratio on precontrast images is slightly higher, with a mean ratio of 3±0.3 compared to their ratio of 2.7. This discrepancy is unclear. It could be due to the lower number of cases and the lower proportion of castrated and sexually intact males in their study. Indeed, we observed in our study that males had a significantly higher K/L2 ratio than females. The effect of sex on kidney size is inconsistently observed in veterinary medicine. Some studies have observed larger kidneys in males, while others did not find a significant difference [5,6,12,27,28]. It has been demonstrated in humans that men have longer kidneys than women [31]. Moreover, a study on mice showed that exogeneous injection of testosterone induces a cellular hypertrophy, causing an increase in renal size [32].

In this article, a significant difference was observed between the right and the left kidney lengths, with the right kidneys being slightly longer than the left ones. To the authors' knowledge, no other studies in dog using CT have investigated this difference. Only other studies using ultrasonography have evaluated it and did not observe the same difference [7,28,33]. This could be related to the fact that ultrasonography is less accurate compared to CT for measuring kidneys due to the difficulty of visualizing the cranial pole of the right

Table 1 : Precontrast and postcontrast computed tomographic normalized kidney measurements in clinically healthy dogs and differentiated by sex (males and females).

	All dogs (113 dogs)	Males (70 dogs)	Females (43 dogs)
Normalized PrRK (mean ± SD)	3.03 ± 0.28	3.08 ± 0.28	2.95 ± 0.28
Normalized PrLK (mean ± SD)	2.97 ± 0.31	3.03 ± 0.29	2.86 ± 0.30
Normalized PcRK (mean ± SD)	3.06 ± 0.30	3.12 ± 0.29	2.97 ± 0.29
Normalized PcLK (mean ± SD)	3.00 ± 0.31	3.06 ± 0.30	2.91 ± 0.31

PrRK : precontrast right kidney length; **PrLK :** precontrast left kidney length; **PcRK:** postcontrast right kidney length; **PcLK:** postcontrast left kidney length. Normalization of kidney length performed by dividing kidney length by L2 body length.

kidney owing to its deepest and subcostal location [28].

This study is the first to evaluate renal length variation on CT after intravenous contrast medium injection in dogs. Results suggest that intravenous contrast medium injection significantly increases renal length in dogs. However, this increase is slight, with a mean increase of 0.03 K/L2 ratio for both the right and the left kidneys. Similar information has been published in cats. Darawiroj et al. showed that intravenous contrast medium injection slightly but non-significantly increases the length of both right and left kidneys in cats [6]. Moreover, in this study, the increase was more pronounced for the right kidney [6]. We did not observe such a difference as, for a given dog, the increase in kidney length induced by the intravenous injection of contrast medium was of the same level for both the right and the left kidneys. A direct comparison between species is difficult, and disparities may be explained by anatomical specificities, various effects of contrast medium injection between species, or studies protocol differences.

The cause of kidney size increase in our study is unclear. In human medicine, it has been shown that contrast medium injection has a significant impact on liver volume measurement [34]. Moreover, the CT measurement of liver volume varies depending on the phase after contrast medium injection in which the measurement was taken, with the largest mean liver volume observed with venous CT phase [34]. So, contrast medium may be suspected to have the same effect on kidneys. Contrast medium used in CT is suspected to modify the volume of intra-organ vessels and can lead to artifacts such as blooming, beam hardening, and volume distortion artifacts [35-37]. These artifacts may contribute to inaccuracies in length or volume measurements comparing precontrast and post contrast CT images.

Even if a significant difference was observed between kidney length measurements in this study, the difference was only 0.03 point of the K/L2 ratio, which may be considered unimportant. This kind of variation does not lead to increase the renal length outside the normal range reported in previous studies. Based on this observation, the authors suggest that renal length measurement can be performed before or after contrast medium injection. However, it has been shown that intravenous injection of contrast medium may cause contrast-induced nephropathy, ranging from mild and temporarily to severe [38]. The mechanism of contrast-induced nephropathy is not well known but is suspected to be due to direct damage to renal tubular cells, vasoconstriction causing renal ischemia, oxidative damage, and other factors [39-42]. Even if contrast-induced nephropathy remains rare, with an incidence of 7.6%, with only 2.2% considered to be clinically relevant, patients who need a kidney assessment often already have renal dysfunction which is likely to get worse after intravenous contrast medium injection [38]. Based on our results, kidney length measurements do not need contrast medium injection to be reliably measured. Nevertheless, CT soft tissue contrast is poor without contrast medium injection [43]. Moreover, contrast-enhanced CT helps for observation of non-detected renal lesions on nonenhanced CT, such as kidney infarctions, nodules or cysts which can lead to length or volume variations [11,44,45].

This study has several limitations. Firstly, the retrospective nature of our study may introduce various biases related to data collection and patient selection. Additionally, health status of dogs enrolled is based on their clinical examination and their blood tests, which cannot definitively exclude underlying diseases such as kidney disease. The absence of renal biopsy may have left some kidney diseases undetected, potentially affecting the study's results. In conclusion, this study demonstrates a significant but minute effect of intravenous contrast medium injection on kidney length measurement, with this effect being equally present in both the left and right kidneys. Additionally, the study found a significant difference in kidney size between the two kidneys, with the right kidney being longer compared to the left. Furthermore, the study highlights a significant difference in kidney size between sexes, with male dogs having larger kidneys compared to females. These findings underscore the subtle yet measurable impact of contrast medium on renal imaging and the inherent anatomical variations influenced by laterality and sex.

Acknowledgement

None

Conflict of Interest

None

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