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MEASURING KIDNEY TO ABDOMINAL AORTA RATIO USING ULTRASONOGRAPHY TO DETERMINE KIDNEY SIZE IN HEALTHY DOMESTIC SHORTHAIR CATS

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ABSTRACT

Renal diseases are among the most common diseases in cats. Understanding the size of the kidney is important in evaluating kidney disease. Researches have shown that measurements of kidney length are possible using ultrasonography with high repeatability. The objective of this study was to measure kidney to abdominal aorta ratio using ultrasonography to determine kidney size in healthy domestic shorthair cats. The study population included 35 domestic cats referred to a private animal hospital in Tehran for a yearly checkup. Healthy cats based on biochemical factors were selected regardless of age and sex and were positioned on the back. Ultrasonography was conducted using a linear or sector transducer through skin contact and ultrasound gel. Quantitative data from the study were analyzed using SPSS® version 21 software by paired t-test. The correlation coefficient was analyzed based on a significance level 0.05. The results showed that there was no significant difference between the average length of the right kidney and the left one. The ratio of the right kidney's length to aorta was 9.12, and it was 8.88 for the left kidney. In addition, the ratios of right and left kidneys' width to the aorta were 5.25 and 5.24, respectively. The result found that the ratio of the length of the kidneys (both left and right) to the average diameter of the aorta in the cats was 7.12-11.35, and this ratio was about 4.25-7.05 for the width of the kidneys to the diameter of the aorta. It was necessary to compare the size of the kidney with a different structure separate from the spinal cord. Therefore, the ratio of kidney size to the diameter of the abdominal aorta was used in this study.

1. INTRODUCTION

Measuring the kidneys is an important factor in diagnosing renal diseases in dogs and cats. Since there is a variation in the size of animals, measuring the kidney alone cannot confirm the evaluation during ultrasound imaging. In order to achieve this purpose, the ratio of the kidney to aorta size and

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length of the kidney in the parietal view have been measured. In the next stage, the diameter of the aorta has been measured in the abdominal aorta area and their ratio has been compared. This index is independent of weight and size in most feline cases. Another reason for using this method is the difficulty of finding the vertebra in ultrasound imaging.

Before conducting the ultrasonography, the hair of the area is shaved, and in order to achieve better resolution of renal images, ultrasound gels are rubbed on the skin. The animal is positioned on its back or sleeping on the left or right side, and the kidneys in both sides are examined. In order to simplify the procedure, the examination should be started from the transverse view and be continued with ultrasonography from the longitudinal view. Correct pressure of the probe is important for achieving the best display in kidneys in different views and preventing the blockage of the intestinal loops [1, 9].

The left kidney is generally viewed better in the lateral abdominal approach, however, the presence of gas or feces in the descending colon limits the ability for evaluation. Imaging of the right kidney is more difficult in large chested cats because of the deeper position of the right kidney in the anterior abdominal area. Imaging of the right kidney can also be affected by intestinal contents, especially in the duodenum, ascending colon or cecum [2]. The kidneys have a particular diversity in depth, which is due to the diversity in the body structure of the animals. In small cats, high-frequency ultrasonography probes (7.5 MHz or more) are recommended. However, the evaluation of larger cats needs probes with more penetration ability (5 MHz or less).

If necessary, higher frequencies can be used to complete the examination of the left kidney. It is more common to use sector and convex probes due to their ability to create a perfect image of the kidneys. In addition, these probes have less contact with the skin and can be easily used in intervertebral spaces. The kidneys should be scanned cranio-caudal and latero-medial in several cross-sectional and longitudinal sections for the examination of all parts, including the cortex, medulla, and collecting ducts [2].

In many cats, the complete evaluation of the left kidney is easier due to its posterior location to the right kidney and the creation of an ultrasonic window by the spleen. The right kidney is located in the anterior of the left kidney and in close proximity with the caudate lobe of the liver. Examination of the right kidney is more difficult due to its location inside the thoracic area or in the dorsal area of the intestinal loops. Both kidneys are bean-shaped and symmetrical in shape and size in cats. The kidneys are measurable at different sections and their size is measurable as well. The accurate measurements in cats should be made considering the overall body weight because of the large diversity in cat races. Recently, a new technique is being used to measure kidneys, in which, the ratio of renal length to the aorta thickness is measured [3].

Renal cortex, medulla, and collecting ducts are subject to be investigated using ultrasonography in cats [4]. The echogenicity of the cortex is more than medulla, however, it is less compared to the liver and spleen. A longitudinal sonogram of the kidney divides it into three distinct regions including a bright central area which is related to the renal sinus and fat surrounding bassinet, and a hypoechoic region [dark color] around the bassinet, which is related to the kidney medulla. The renal medulla is more hypoechoic compared to the cortex. The medulla is also more hypoechoic or isoechoic

compared to the liver, and it is clearly more hypoechoic than the spleen. In cats, the accumulation of fat vacuoles in the kidney cortex leads to a hyperechoic image in this part. The inner margin of the kidney has serrated shape and forms an oval valve which opens to the renal sinus. This area is called renal hilum or renal pedicle.

During the medio-lateral scan of kidney in the longitudinal view, the middle bright area in parts of the sonogram representing the renal sinus disappears, which leads to the appearance of a central hypoechoic area are enclosed by two parallel lines with high echogenicity. The central hypoechoic represents the renal ridge [also known as renal pyramid or renal papilla], and the parallel lines with high echogenicity represent the dorsal and ventral bassinet diverticulum, which are the interlobular arteries and veins. Diverticulum and veins of the kidney can be distinguished by their small, linear, and high echogenic structure that moves transversely from the medulla area to the cortex using the same pattern as the anterior areas. Interlobular vessels and diverticulum divide the hyperechoic medulla into several sections. Cat kidney is single-pyramid and without calyx, and sections of the medulla are drained entirely into one pyramid. Diverticulum and vessels are cut transversely in the longitudinal section, and a short length of them is displayed in each plan. Arched and intralobular arteries are sometimes seen as short and echogenic lines and in pairs at the junction of cortex and medulla, as well as inside the kidney cortex.

Evaluating kidney by dorsal views from the lateral wall of the body, or using transverse views allow the veterinarian to see more length of the arteries and renal diverticula. The reason for this is that the images obtained in these views are in the direction of the longitudinal axis of these structures. Although the output beams pass through the dorso-ventral border of the diverticulum in the medio-dorsal view, they cannot be seen in the images. Therefore, it seems that views parallel to the dorso-ventral border of the renal diverticulum -which is called the oblique dorsal plan- can be more suitable for this purpose [5].

Using an appropriate tool with high image resolution, evaluation of the renal bassinet, the surrounding adipose tissue, proximal urethra, renal diverticulum, medulla, and cortex are possible in the transverse view of the ventral surface or lateral abdominal wall. The echogenic lines forming the dorsal and ventral kidney diverticulum and the interlobular vessels originate from the bassinet and radially pass along the cortex. In the whole lateral renal scan, the medulla is seen as a distinct area throughout the entire kidney. Renal ridge is seen easily in the mid-sectional view along with the kidney diverticulum. No urine is seen in the bassinet and renal diverticulum of healthy cats. Viewing the renal bassinet is facilitated using the new ultrasonography devices that have the high-resolution ability. The length of the bassinet should be measured less than 2 mm. Generally, no urine is seen in the urethra except for when the animal is under medications. Therefore, the objective of this study was to measure kidney to abdominal aorta ratio using ultrasonography to evaluate the size of the kidney in healthy domesticated short hair cats.

2. RESEARCH METHOD

Among domestic short hair cats referred to a private hospital in Tehran, about 35 were selected. The cats were verified as healthy animals based on biochemical factors regardless of gender and age.

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After selecting the samples, if the animal was calm, it was only restrained without using sedation. First, the animal's hair was shaved to facilitate the contact of the transducer with the skin. In the next step, the animal was positioned on the back and sonography was performed using linear or sector transducer with a frequency of 7.5 to 10 MHz through skin contact and ultrasound gel. Then, the kidneys were located from outside the vertebral arch and lateral of the spines. The largest diameter of the kidney in the parietal view, in which the kidney wall was plain was measured, and then the small diameter of the kidney perpendicular to the large diameter was measured. In order to measure the diameter of the aorta, the abdominal aortic walls were measured in transverse and longitudinal views. All images were recorded by a veterinary radiologist. Quantitative data from the study were analyzed using SPSS® software version 21 by paired t-test and correlation coefficient was analyzed based on a significance level of less than 0.05.

3. FINDING

Based on the data from (Table 1), the studied cats were healthy based on clinical examination and ultrasonography. The average length of the left and right kidneys, as well as the maximum and minimum values, were presented based on the data obtained from ultrasonography in centimeters. Statistical analysis of paired t-test showed that there was no significant difference between the length and width of left and right kidneys, and the diameter of the aorta in the domesticated short hair cats of the study (p> 0.05).

Table 1: Average, maximum, minimum, and other measured variables in 35 domesticated cats (in centimeters)

Kidney		Average	SD	Maximum	Minimum
Right	Length	3.65	0.40	4.51	2.87
	Width	2.15	0.26	2.90	1.69
Left	Length	3.56	0.43	4.57	2.83
	Width	2.10	0.03	2.784	1.71
Aorta	Diameter	0.40	0.04	0.48	0.32

Based on (Table 2), there was a significant relationship between the length of the kidney and the diameter of aorta in cats based on the correlation coefficient. The average ratio of the length of the right kidney to the aorta was 9.12 and the ratio of the left kidney's length to the aorta was 8.88. In addition, it was found that the average ratio of the width of the right kidney to the aorta was 5.25 and the ratio of the width of the left kidney to the aorta was 5.24. These findings showed that the width of the kidneys and diameter of the aorta in the tested cats had a very significant correlation and relationship. This means that the diameter of the aorta had a direct significant relationship with the width and length of both kidneys (P <0.05).

Table 2: The ratio of kidneys to the diameter of the aorta

Comparison of the examined indexes	Average	SD	Maximum	Minimum	Correlation coefficient	P-value
Right kidney length to the diameter of aorta	9.12	0.07	12.4	6.9	0.55	0.01
Right kidney width to the diameter of aorta	5.25	0.41	8.5	4.1	0.64	0.05
Left kidney length to the diameter of aorta	8.88	0.12	12.2	6.1	0.61	0.04
Left kidney width to the diameter of aorta	5.24	0.29	8.7	4	0.79	0.001

Based on (Table 3), the results from the measurement of the ratio of the length to the width of the kidneys in the study cats showed that the length of the left and right kidneys in the cats were different in some cases. However, they had a direct correlation and were statistically significant in the study of cats ($P < 0.05$).

Table 3. Findings from the measurement of the kidney length ratio.

Cat #	Right kidney length (cm)	Left kidney length (cm)	Ratio
1	3.89	3.98	0.98
2	3.89	3.77	1.03
3	3.31	3.11	1.05
4	3.57	4.73	1.32
5	4.10	4.10	1.00
6	3.92	3.42	1.14
7	3.74	3.71	1.01
8	3.83	4.1	0.82
9	3.37	3.39	0.99
10	3.74	3.94	0.95
11	4.03	4.57	0.88
12	3.3	3.17	1.04
13	4.51	4.28	1.05
14	3.4	3.22	1.06
15	3.8	3.71	1.00
16	3.17	3.14	1.01
17	3.6	3.7	0.97
18	2.99	2.94	1.03
19	2.9	2.83	1.02
20	3.9	3.65	1.02
21	3.98	3.56	1.11
22	3.49	3.38	1.03
23	3.41	3.27	1.04
24	3.8	3.77	1.01
25	3.53	3.27	1.08
26	4.16	4.40	0.95
27	4.01	3.96	1.02
28	2.87	2.92	0.02
29	3.71	3.08	1.2
30	3.72	3.43	1.09
31	3.41	3.52	0.97
32	3.01	2.95	1.02
33	3.65	3.76	0.97
34	3.35	3.61	0.92
35	3.40	3.51	1.01
Minimum	2.71	2.83	Total ratio
Maximum	4.51	4.57	1.01
Correlation coefficient			0.89
P-value			0.001

Table 4: Average maximum length of the left and right kidneys.

The average maximum length of left and right kidneys	4.54
Average aorta	0.40
Ratio	11.35

Table 5: Average maximum width of left and right kidneys.

Average maximum width of left and right kidneys	**2.82**
Average aorta	0.40
Ratio	7.05

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Table 6: Average minimum length of left and right kidneys.

Average minimum length of left and right kidneys	2.85
Average aorta	0.40
Ratio	7.12

Table 7: Average minimum width of left and right kidneys

Average minimum width of left and right kidneys	1.7
Average aorta	0.40
Ratio	4.25

Based on Tables 4-7, the ratio of the width of the right and left kidneys to the aorta was 5.25 and 5.24, respectively. In addition, the ratio of the length of the kidneys (left and right) to the average diameter of the aorta in cats was 7.12 to 11.35, and this ratio was between 4.25 and 7.05 for the width of the kidneys to the diameter of the aorta.

4. DISCUSSION

Two studies have measured the thickness of the cortex and medulla in the kidneys. Walter et al. evaluated the thickness of the cortex to be 0.82 ± 0.14 centimeters and the thickness of the medulla to be 0.59 ± 0.06 centimeters. Park et al. stated that the size of the cortex was 0.47 ± 0.08, which was less than Walter's study and the size of the medulla in their study was similar to Walter et al. (0.55 ± 0.07 centimeters). The healthy kidney is bean-shaped or oval in cats with a smooth surface. Renal capsule is detectable as an echogenic line, and occasionally artifacts are seen on the edges. Two regions of the kidney are detectable in ultrasound images, which include the cortex and medulla. The renal bassinets are not usually seen in the image. While in radiology the size of the kidneys is measured using the length of L2 or L3, it is not easy to locate them during ultrasonography. Therefore, it was necessary to compare the size of the kidney with a different structure separate from the spinal cord, so the ratio of kidney size to the diameter of the abdominal aorta was used in this study. The method used in this study was similar to the method of the other researches conducted in this field.

Park In-Chul, et al. (2008) examined renal dimensions including the thickness of cortex and medulla in short hair Korean cats. They showed that the length of the kidney in the panoramic view was 3.83 ± 0.51 centimeters. They concluded that no significant difference was seen between the dimensions of the right and left kidneys [6].

Stocco et al. (2016) studied the size of the left and right kidneys in 40 Brazilian shorthair cats. They concluded that the length, width, and the thickness of kidney in male cats was 2.3, 2.83, and 22.42, respectively. In addition, the values in female cats were 2.3, 2.61, and 37.48 cm, respectively. They stated that the size of the left kidney in male cats was larger than female cats [7].

Debruyn, K., et al. (2012) compared kidney size in three cat breeds including Raddoll, British short hair, and sphynx using ultrasound. They showed that the sphynx cats had the largest kidney size (a length of 4.09 ± 0.33 centimeters), however, this value was not significant. British shorthair cats had kidneys with a length of 3.77 ± 0.43 centimeters, and Raddoll cats had kidneys with a length of 3.87 ± 0.41 centimeters. In addition, in British shorted hair cats, the size of the cortex and medulla was thinner than the other two breeds. They showed that the size of the left kidney was significantly

smaller than the right kidney and the medulla was also thicker. However, the difference between the thickness of the cortex between breeds was not statistically significant (3). Mareschal et al. (2007) examined the size of the kidney size in dogs using the ratio of renal size to the aorta. They showed that the ratio of the kidney to the diameter of the aorta in the right and left kidneys was the same, and the number obtained for the ratio of the kidney to the aorta was between 1.9 to 5.5 [8].

It should be noted that the size of the kidney increases along with aging, and the castrated cats have larger kidneys. In addition, the kidney in male cats is larger than female cats. In humans, no significant difference has been reported between the thickness of the cortex and the medulla. However, the results of the present study showed that the left renal cortex was significantly thicker than the medulla.

The results of this study also showed that the average length of the right kidney was 3.63 ± 0.36 centimeters and the length of the left kidney was 3.56 ± 0.95 centimeters, which indicated that there was no significant difference between the length of the right and left kidneys. The maximum size of the right kidney was 4.51 cm and the left kidney was 4.57 cm. Furthermore, the minimum size was 2.87 cm in the right kidney and 2.83 cm in the left kidney. The average size of the diameter of the aorta was 0.40 ± 0.24 cm. The maximum diameter was 0.48 cm and the minimum was 0.32 cm. The ratio of the length of the right kidney to the aorta was 9.12 cm, and it was 8.88 for the left kidney. In addition, the ratio of left and right kidneys to aorta was 5.25 and 5.24, respectively. In the present study, the ratio of the length of the kidneys (left and right) to the average diameter of the aorta in cats was 7.12 to 11.35, and the ratio between the width of the kidneys to the diameter of the aorta was 4.25 and 7.05, respectively.

5. CONCLUSION

In this study, it was tried to use the ratio of the kidney to the aorta as a reference for measuring kidney size in cats. The size of the kidneys in cats had a range of 2.4 to 3 cm and reached 3.5 cm in some cases. Left and right kidneys were relatively similar in terms of size. The size of the kidneys varies according to the animal's gender and stage of sexual activity. Female cats have smaller kidneys compared to males, and castrated cats have larger kidneys compared to normal cats.

The results found no significant difference between the length of the right and left kidneys. The ratio of the length of the kidneys (left and right) to the average diameter of the aorta in cats and the ratio between the width of the kidneys to the diameter of the aorta have been examined.

6. DATA AVAILABILITY STATEMENT

The used or generated data and the result of this study are available upon request to the corresponding author.

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