

The Dog Kidney as Experimental Model in Endourology: Anatomic Contribution

Marco A. Pereira-Sampaio, D.V.M., Ph.D.,^{1,2} Beatriz P.S. Marques-Sampaio, D.V.M., M.S.,¹
Robert W. Henry, D.V.M., Ph.D.,³ Luciano A. Favorito, M.D., Ph.D.,¹
and Francisco J.B. Sampaio, M.D., Ph.D.¹

Abstract

A systematic study of the morphometry and the collecting system of the canine kidney is presented and compared with previous findings in humans. Renal measurements (kidney length, width, and thickness) were recorded. In addition, 110 three-dimensional endocasts of the kidney collecting system were produced and studied. Anatomic details, important to research and surgical training in endourology, were observed and recorded in canine kidneys. Dogs whose height was more than 70 cm at the withers presented similar kidney measurements to those found in the adult human. The collecting system consisted only of a renal pelvis with a variable number of recesses around its perimeter. The dog kidney is not a good model for experimental studies that consider the morphology of the collecting system. Kidneys from dogs taller than 70 cm, however, might be useful as a model in experimental studies in which renal volume is an important aspect, such as shockwave lithotripsy and endourology.

Introduction

THE RELEVANT APPLICATIONS of less invasive procedures, such as laparoscopy, endourology, extracorporeal shockwave lithotripsy (SWL), and conservative renal surgery, as well as other techniques to manage renal pathologic conditions require experiments in appropriate animal models.^{1–3}

In recent years, the pig kidney has been considered the best urologic experimental model because of its anatomic resemblance to the human kidney.^{4,5} For many institutions, however, swine procurement and their maintenance as well as management in the laboratory setting are difficult, so that other animals have been used in research on the urinary system.

In many countries and many institutions, the dog is often used in research because it is easy to obtain and handle, and its size is appropriate. Nevertheless, studies on the anatomy of the canine kidney are scant in the literature. No specific renal anatomic studies on the canine were found in the literature, and available anatomic data are generic and do not assist in urologic investigation. Therefore, a detailed morphologic analysis of the canine kidney was performed to validate its possible use in experimental urologic studies.

The objective of this work was to obtain and record detailed measurements of the dog kidney and document a comprehensive description of the collecting system. These results were compared with previous findings in humans.

Materials and Methods

Kidneys were taken from 55 adult mongrel dogs (19 females and 36 males) after euthanasia. The dogs were weighed, and their height was measured at the withers (the highest point of the vertebral column of the thoracic segment) and recorded.

Collecting system

One hundred ten (55 right and 55 left) three-dimensional endocasts of the kidney collecting system were produced, using a previously described technique.^{4,6} Briefly, yellow polyester resin (approximate volume 3 mL) mixed with 3% methyl ethyl peroxide (catalyst for the resin) was injected into the ureter to fill the kidney collecting system. Perirenal fat was removed and the kidneys were morphometrically evaluated. The kidneys were stored overnight at room temperature.

After setting of the resin (around 24 hours), the specimens were immersed in a bath of concentrated commercial

¹Urogenital Research Unit, State University of Rio de Janeiro, Rio de Janeiro, Brazil.

²Department of Morphology, Fluminense Federal University, Niteroi, RJ, Brazil.

³Department of Comparative Medicine, University of Tennessee, Knoxville, Tennessee.

hydrochloric acid for 48 hours to remove the organic matter, leaving only the three-dimensional endocasts of the collecting system. The cleaned, dried casts were weighed, and their morphology was recorded. The number of recesses in the dog kidneys were observed and recorded.

Morphometric analysis

Measurements of the 110 kidneys included the greatest longitudinal length, greatest cranial pole width (cranial to the hilus), smallest hilar width, greatest caudal pole width (caudal to the hilus), greatest thickness, and weight. The same observer made all measurements using a 0.01-mm precision digital caliper ruler. Kidneys were weighed after injection of the resin on a digital balance with a precision of 0.01 g. To obtain the net kidney weight, the weight of the corresponding endocast was subtracted from the recorded weight. A statistical evaluation of the renal measurements and dog height, weight, and sex were made determining the mean, the standard deviation, the coefficient of variation, and minimum and maximum values. The correlation coefficient of Pearson (r) and the Student t test were calculated to compare all measurements.

Results

Collecting system

In the 110 kidney collecting system endocasts that were produced, no calices were found. The collecting system had only a renal pelvis with a variable number of recesses on its margin. The number of recesses, U-shaped projections of the renal pelvis (Fig. 1), varied from 9 to 17 (median 14) in the 90 casts evaluated for recess number. Only the best casts were used for recess analysis. One kidney had 9 (1.1%) recesses, 4 had 11 (4.2%) recesses, 11 had 12 (11.6%) recesses, 24 had 13 (25.3%) recesses, 33 had 14 (34.7%) recesses, 15 had 16 (5.3%) recesses, and 2 had 17 (2.1%) recesses. The same number of recesses in both kidneys of the same animal were observed in 11 of the 40 (27.5%) analyzed pairs of kidneys.

Morphometric analysis

Table 1 records the results from the measurements and weight of the kidneys and dog weight and height. No statistically significant differences were found between left or right kidneys or between male and female dogs.

Table 2 shows the results of several statistical correlations performed among the kidney measurements and between them and the dog height and weight.

Discussion

The dog kidneys presented a mean of 5.87 cm for length, which is significantly shorter than the mean of 11.1 cm found in humans.⁷ The length of dog kidneys in this study was similar to those found by some authors, who found 5 to 6 cm⁸ and 6.5 cm.⁹ Nevertheless, Evans and Christensen¹⁰ recorded the dog kidney length between 6 and 9 cm and Motwani and Harneja¹¹ around 8 cm. Furthermore, Mierzwa⁹ reported the right dog kidney length longer than that of the left kidney. No statistically significant difference was found between right and left kidneys in our study.

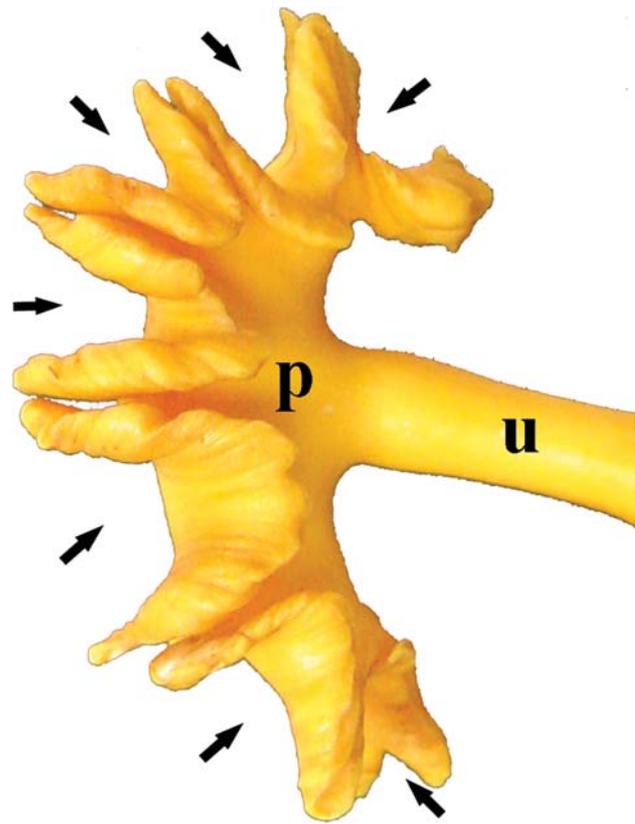


FIG. 1. Dorsal view of a dog kidney's collecting system endocast, showing the ureter (u) and the renal pelvis (p). Arrows point to the recesses of the renal pelvis.

Dog kidney width varied from 3.01 cm in the hilar zone to 3.25 cm and 3.26 cm in the caudal and cranial poles, respectively. These results on renal width are similar to those reported by Schwarze and Schroder⁸ and Mierzwa,⁹ who found widths of 3 cm and 3 to 4 cm, respectively. Evans and Christensen¹⁰ recorded different results, because they found kidneys that were 4 to 5 cm in width.

Textbooks present general descriptions and do not consider the differences between cranial and caudal pole widths in the same kidney. We could not compare our individual values of the cranial pole, caudal pole, or hilar region width with others studies, because no record exists on these measurements. In previous morphometric work performed in humans and pigs, cranial pole, caudal pole, and hilar region widths were studied separately. In these cases, the width of the cranial pole was greater than the width of the caudal pole, and this difference was statistically significant.^{4,7} In the present work, there was no statistically significant difference between cranial pole and caudal pole widths in dogs. The relationship between the renal width and the length was about 6:11 (5.99:10.80), similar to that of the human kidney (5.97:11.09).⁷ This information is important because it demonstrates that kidney proportion (width:length) is equivalent in humans and dogs.

Concerning the dog kidney thickness, the minimum value found was 1.72 cm and the maximum was 4.07 cm. Motwani and Harneja¹¹ found thickness ranging from 4 to 6.8 cm.

TABLE 1. RENAL MORPHOMETRIC DATA IN DOGS

	<i>Kidney length (cm)</i>	<i>Cranial pole width (cm)</i>	<i>Hilar width (cm)</i>	<i>Caudal pole width (cm)</i>	<i>Thickness (cm)</i>	<i>Weight (g)</i>	<i>Dog Height (cm)</i>	<i>Dog weight (g)</i>
Mean	5.87	3.26	3.01	3.25	2.53	38.64	54.25	13.97
SD	0.97	0.51	0.42	0.51	0.39	17.2	7.56	5.93
CV%	16.52	15.64	13.95	15.69	15.42	44.51	13.94	42.45
SDM	0.09	0.05	0.04	0.05	0.04	1.64	0.72	0.57
Maximum	9.02	4.84	4.19	4.64	4.07	110.32	73	32.7
Minimum	4.06	2.35	2.06	2.08	1.72	15.32	41.5	4.6

SD = standard deviation; CV = coefficient of variation; SDM = standard deviation of the mean.

The renal weight mean was 38.64 g, even though the majority of the authors found means between 30 and 80 g.^{8,9,12} Furthermore, Evans and Christensen¹⁰ found values of only 25 to 30 g. All found weights were within our range (15.32 g to 100.32 g), except the results shown by Motwani and Harneja,¹¹ who found weights that varied from 106 to 120 g. Although there was no statistical difference between left and right kidneys in our results, Nickel and associates¹² record that right kidneys are heavier than left kidneys.

Our study was made on mongrel dogs; however, the breed used by other authors was not mentioned. Therefore, differences found in morphometric data might be a result of different racial aspects. Also, no statistically significant difference was found between sexes in our study.

Morphometric data of the canine kidney presented several statistical correlations with dog height and weight. The ones associated with height were stronger than width correlations (Table 2). Dogs taller than 70 cm (measured at the withers) had renal length of 9 cm, which is similar to adult human data.⁷ Therefore, kidneys from this size dog might be useful as a model in experimental studies in which renal volume is an important aspect.

We agree with Nickel and associates¹² and Evans and Christensen¹⁰ that the dog kidney is unipapillary. Once produced, urine drains into the renal pelvis from a single linear region, the renal crest, which is positioned along the center of the renal pelvis (Fig. 2). On the other hand, we disagree with these authors when they define the dog kidney as unipyramidal. The renal parenchyma in the dog has several pyramidal-like structures that are made of a base in the cortex and an apex that is fused with other apices to form the renal crest. Therefore, it would be more suitable to define the dog kidney as unipapillary and multipyramidal, because it presents several pyramidal-like structures, separated by the recesses of the renal pelvis. Arnautovic¹³ reported the presence of renal pyramids, although he described only seven pyramids while our median number of recesses was 14. Mierzwa⁹ found that the number of renal recesses varied from 14 to 16, while we found that the number varied from 9 to 17.

Fitzpatrick and colleagues¹⁴ compared the effects of renal function and morphology after intrarenal access by the extended sinus approach, the radial paravascular approach, the anatomic intersegmental approach, and the bivalve approach. They showed that access by the extended sinus approach was associated with no functional or parenchymal

loss. Gahring and associates¹⁵ reported that sutureless nephrotomy closure minimized renal function impairment from nephrolithotomy. Stone and coworkers³ determined that bisection nephrotomy caused more intrarenal hemorrhage and cortical infarction and inflammation than intersegmental nephrotomy.

Greenwood and Rawlings¹⁶ described three selected cases of pyelolithotomy and concluded that it may be a better technique than nephrolithotomy for the removal of renal calculi in patients that have an enlarged renal pelvis and proximal ureter outside the renal parenchyma. The results found by these authors concerning a variety of intrarenal access in dogs, however, cannot be associated and transferred to the clinical human setting, because of the great difference between the collecting systems in dog and human kidneys.

The laser¹⁷ and the jet scalpel² were used experimentally in canine kidneys. Dogs are not useful models to determine intraoperative blood loss, postoperative bleeding, and urinary leakage in these techniques because of the difference between the dog and human collecting systems. A large constant renal pelvis and lack of renal calices in the dog kidney collecting system makes its identification and closure easy during surgery, decreasing urinary leakage. Also, in dogs shorter than 70 cm at the withers, kidney volume

TABLE 2. STATISTICAL CORRELATIONS BETWEEN RENAL MORPHOMETRIC DATA IN DOGS

<i>Correlations</i>	<i>t</i>	<i>r</i>	<i>P</i>	<i>N</i>	<i>Equations</i>
L×RW	8.91	0.85	<i>P</i> < 0.01	110	<i>y</i> = 16.16 <i>x</i> - 56.22
L×H	6.72	0.64	<i>P</i> < 0.01	110	<i>y</i> = 6.00 <i>x</i> + 19.00
CRPW×RW	8.38	0.80	<i>P</i> < 0.01	110	<i>y</i> = 28.92 <i>x</i> - 55.62
CRPW×H	6.37	0.61	<i>P</i> < 0.01	110	<i>y</i> = 10.84 <i>x</i> + 18.90
HW×RW	7.78	0.74	<i>P</i> < 0.01	110	<i>y</i> = 32.31 <i>x</i> - 58.63
HW×H	5.66	0.54	<i>P</i> < 0.01	110	<i>y</i> = 11.60 <i>x</i> + 19.35
CDPW×RW	8.31	0.79	<i>P</i> < 0.01	110	<i>y</i> = 28.97 <i>x</i> - 55.50
CDPW×H	5.99	0.57	<i>P</i> < 0.01	110	<i>y</i> = 10.30 <i>x</i> - 20.77
T×RW	8.39	0.80	<i>P</i> < 0.01	110	<i>y</i> = 38.11 <i>x</i> - 57.77
T×H	5.41	0.52	<i>P</i> < 0.01	110	<i>y</i> = 12.12 <i>x</i> + 23.58
RW×H	6.61	0.63	<i>P</i> < 0.01	110	<i>y</i> = 0.33 <i>x</i> + 41.35

t = Student test; *r* = Pearson correlation coefficient; *P* = significance index; *N* = sample; *L* = renal length; *RW* = renal weight; *H* = dog height; *CRPW* = cranial pole width; *HW* = hilar width; *CDPW* = caudal pole width; *T* = renal thickness.

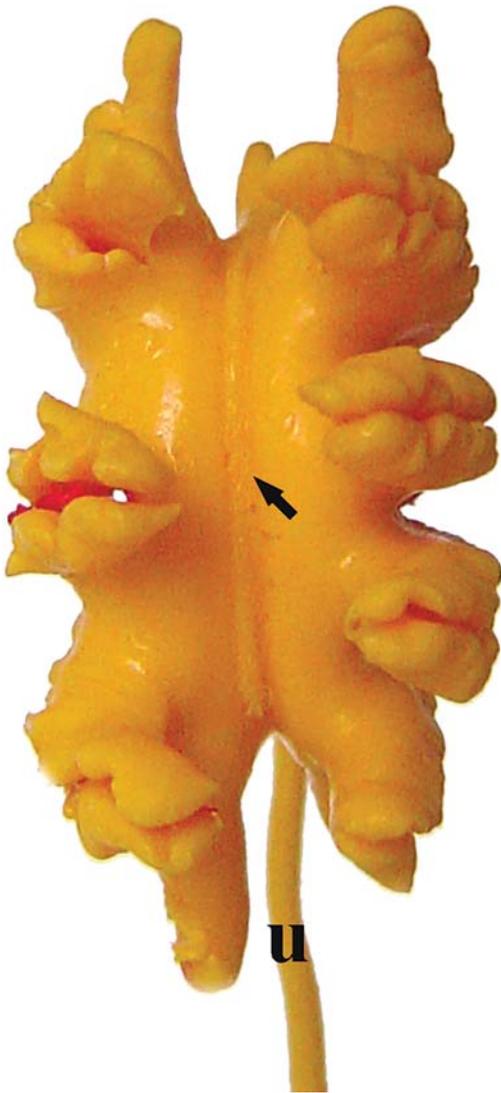


FIG. 2. Lateral view of a dog kidney's collecting system endocast, showing the ureter (u). Arrow points to the groove made by the renal crest in the renal pelvis cast.

cannot be compared with that of humans because of the size discrepancy.

Rassweiler and Alken¹⁸ revised extracorporeal SWL by showing its limitations and using collecting system anatomy as one of the criteria for patient selection. They related that the stone-free rate does not exceed 60% for calculi in the lower calix. This is because of the infundibulum-pelvic angle of the lower caliceal group in the human kidney.¹⁹ Barcellos Sampaio and Mandarim-de-Lacerda⁶ determined by studies of the human collecting system the variability in position, shape, and number of minor calices. This is different from the dog collecting system, where a constant position and shape of the renal pelvis and its recesses were found. Therefore, the canine kidney must not be used as a model in extracorporeal SWL experimental studies in which the collecting system is the focus of interest.

Conclusion

The dog kidney is not a good model for experimental studies in which collecting system morphology is an important factor to be considered. Kidneys of dogs that are taller than 70 cm at the withers, however, might be useful as a model in experimental studies in which renal volume is an important aspect.

Acknowledgments

This work was supported by grants from the National Council of Scientific and Technological Development (CNPq) and Foundation for Research Support of Rio de Janeiro (FAPERJ), Brazil.

Mr. Roberto Barreto Sacramento provided technical assistance.

Disclosure Statement

No competing financial interests exist.

References

1. Karlsen SJ, Smevik B, Hovig T. Acute morphological changes in canine kidneys after exposure to extracorporeal shock waves. A light and electron microscopic study. *Urol Res* 1991;19:105-115.
2. Pentchev R, Damyanov CH, Kavardjikova V. Application expérimentale du scalpel à jet d'eau dans la chirurgie rénale chez le chien. *Ann Urol* 1993;27:84-86.
3. Stone EA, Robertson JL, Metcalf MR. The effect of nephrotomy on renal function and morphology in dogs. *Vet Surg* 2002;31:391-397.
4. Sampaio FJ, Pereira-Sampaio MA, Favorito LA. The pig kidney as an endourologic model: Anatomic contribution. *J Endourol* 1998;12:45-50.
5. Pereira-Sampaio MA, Favorito LA, Sampaio FJ. Pig kidney: Anatomical relationships between the intrarenal arteries and the kidney collecting system. Applied study for urological research and surgical training. *J Urol* 2004;172:2077-2081.
6. Barcellos Sampaio FJ, Mandarim-de-Lacerda CA. 3-Dimensional and radiological pelvicaliceal anatomy for endourology. *J Urol* 1988;140:1352-1355.
7. Sampaio FJ, Mandarim-de-Lacerda CA. Morphométrie du rein. Étude appliquée à l'urologie et à l'imagerie. *J Urol [Paris]* 1989;95:77-80.
8. Schwarze E, Schroder L. Compendio de Anatomia Veterinaria. El Sistema Visceral. Acribia, Zaragoza, 1970.
9. Mierzwa J. The renal pelvis and selected measurements of the dog kidney. *Folia Morph (Warsz)* 1977;36:217-223.
10. Evans HE, Christensen GC. The urogenital system. In: Evans HE, ed. *Miller's Anatomy of the Dog*. 3rd ed. Philadelphia: WB Saunders, 1993, pp 494-558.
11. Motwani K, Harneja NK. A comparative anatomy of renal arterial segments in common mammals and man. *Indian J Vet Surg* 1982;3:27-31.
12. Nickel R, Schummer A, Seiferle E, Sack WO. *The Viscera of the Domestic Mammals*. New York: Springer-Verlag, 1979.
13. Arnautovic I. The distribution of the renal artery in the kidney of the dog. *Brit Vet J* 1959;115:446-448.
14. Fitzpatrick JM, Sleight MW, Braack A, Marberger M, Wickham JE. Intrarenal access: Effects on renal function and morphology. *Br J Urol* 1980;52:409-414.
15. Gahring DR, Crowe DT Jr, Powers TE, Powers JD, Krakowka S, Wilson GP III. Comparative renal function studies

- of nephrotomy closure with and without sutures in dogs. *J Am Vet Med Assoc* 1977;171:537-541.
16. Greenwood KM, Rawlings CA. Removal of canine renal calculi by pyelolithomy. *Vet Surg* 1981;10:12-21.
 17. Johnson DE, Cromeens DM, Price RE. Use of the holmium:YAG laser in urology. *Lasers Surg Med* 1992;12:353-363.
 18. Rassweiler J, Alken P. ESWL'90—state of art. Limitations and future trends of shock-wave lithotripsy. *Urol Res* 1990; 18(suppl 1):S13-23.
 19. Sampaio FJ, D'Anunção AL, Silva EC. Comparative follow-up of patients with acute and obtuse infundibulum-pelvic angle submitted to extracorporeal shockwave lithotripsy for lower caliceal stones: Preliminary report and proposed study design. *J Endourol* 1997;11:157-161.

Address reprint requests to:
Francisco J.B. Sampaio, M.D., Ph.D.
Urogenital Research Unit
State University of Rio de Janeiro
Av 28 de Setembro, 87, fundos, FCM
Rio de Janeiro, RJ, 20562-030
Brazil

E-mail: sampaio@urogenitalresearch.org

Abbreviation Used

SWL = shockwave lithotripsy

