

# Dog Kidney: Anatomical Relationships Between Intrarenal Arteries and Kidney Collecting System

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## ABSTRACT

The detailed findings of canine intrarenal anatomy (collecting system and arteries) are presented. Ninety-five three-dimensional endocasts of the kidney collecting system together with the intrarenal arteries were prepared using standard injection–corrosion techniques and were studied. A single renal artery was observed in 88.4% of the casts. The renal artery divided into a dorsal and a ventral branch. Using the branching pattern of the ventral and dorsal divisions of the renal artery, the vessels were classified in type I or type II. Type I presented a cranial and a caudal artery, whereas type II presented a mesorenal and a caudal artery. Cranial branches of dorsal and ventral arteries supplied the cranial pole in 90.5% of the specimens. Caudal branches of the dorsal and the ventral divisions of the renal artery irrigated both the caudal pole and the mid-zone of the kidney in 95.8% and 98.9% of the cases, respectively. In all casts, caudal branches of both dorsal and ventral arteries supplied the caudal pole. Therefore, the caudal branches of the ventral and dorsal divisions of the renal artery are of utmost importance in the kidney arterial supply. Although many results of renal and intrarenal anatomy in dogs may not be completely transposed to humans, the anatomical relationship between arteries and the collecting system in the cranial pole of the dog kidney is similar to those in man. This fact supports the use of the dog as an animal model for urologic procedures at the cranial pole. *Anat Rec*, 290:1017–1022, 2007. © 2007 Wiley-Liss, Inc.

**Key words:** kidney; artery; dog; models; animal; laparoscopy; training

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Many animals have been used as experimental models for urologic procedures. The pig is used more often because its kidney most closely resembles the structural features of the human kidney (Sampaio et al., 1998; Pereira-Sampaio et al., 2004). On the other hand, dogs have been used as urologic models in many studies (Rawlings et al., 2003; Bakir et al., 2004; Groman et al., 2004).

The knowledge of intrarenal artery anatomy is important for performing intrarenal surgeries, which provide minimal blood loss and minimal injury to adjacent pa-

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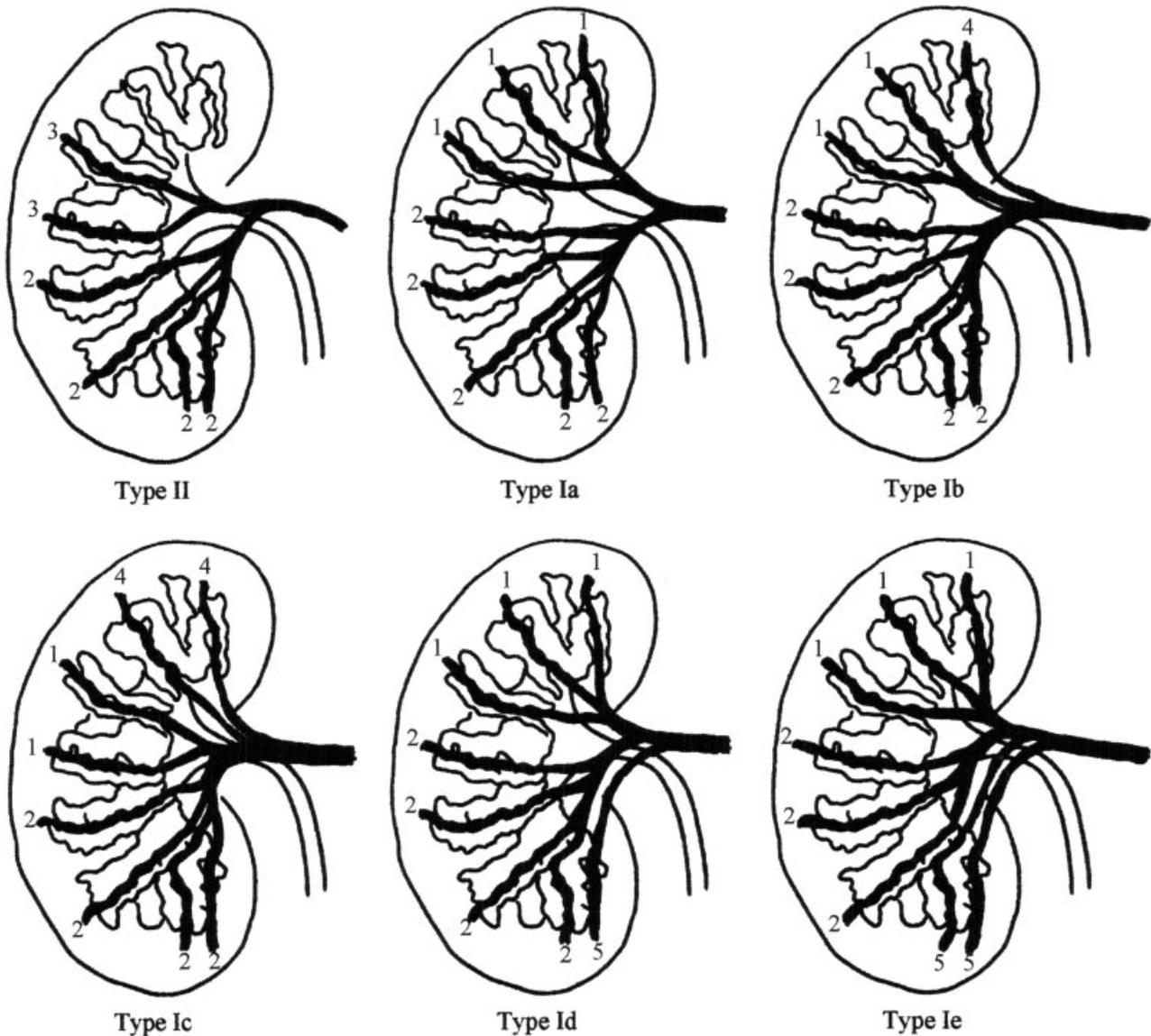


Fig. 1. Schematic drawings of arterial and collecting system casts of canine kidney, illustrating the branching patterns of the different types of either the dorsal or ventral divisions of the renal artery. (1) Interlobar branches from the cranial division of the renal artery, (2)

interlobar branches from the caudal division of the renal artery, (3) interlobar branches from the mesorenal division of the renal artery, (4) Extra-interlobar branches from the renal artery for the cranial pole, (5) extra-interlobar branches from the renal artery for the caudal pole.

renchyma (Novick, 1987). The arterial intrarenal anatomy in the human kidney (Graves, 1954; Sampaio and Aragão, 1990; Sampaio, 1992; Sampaio and Passos, 1992; Sampaio and Favorito, 1993; Sampaio et al., 1993; Satyapal et al., 2001) and the pig kidney (Evan et al., 1996; Pereira-Sampaio et al., 2004, 2007) have been thoroughly studied over the years.

Although few studies were published on dog kidney arterial anatomy (Fuller and Huelke, 1973; Jain et al., 1985), the urologic literature still lacks a thorough analysis of intrarenal vascular and pelvicaliceal anatomy in dogs. The aim of this article was to present detailed anatomical findings on the intrarenal anatomy (collecting system and arteries) in the dog.

## MATERIALS AND METHODS

Ninety-eight kidneys, without renal pathology, were taken during necropsies from 49 adult mongrel dogs (17 females and 32 males), each weighing from 4.6 to 32.7 kg (mean, 13.97 kg). The institutional animal review committee of the State University of Rio de Janeiro approved the research protocol for the use of canine kidneys from dead animals.

The intrarenal anatomy (collecting system and arteries) was studied in three-dimensional endocasts of the kidney collecting system together with the intrarenal arteries. For technical reason, tree casts were discharged and, therefore, 95 endocasts (46 pairs, 2 left

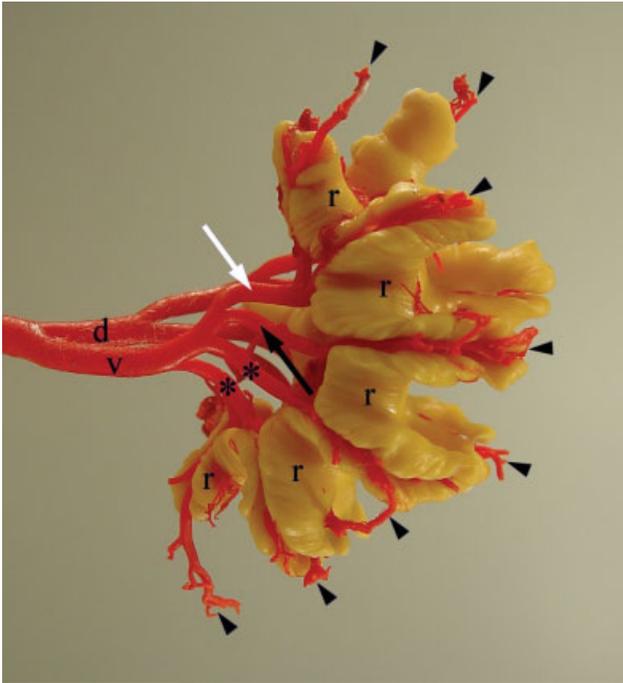


Fig. 2. Ventral view of an arterial and collecting system cast of dog kidney, type 1e. The ventral division of the renal artery (v) with a cranial branch (white arrow), caudal branch (black arrow), and two extra branches to caudal pole (\*). Interlobar arteries (arrowhead) between the pelvic recesses (r). Dorsal division (d) of the renal artery.

and 1 right kidneys) were analyzed. The casts were obtained by using a previously described injection-corrosion technique (Sampaio and Aragão, 1990; Pereira-Sampaio et al., 2004). Briefly, a yellow polyester resin was injected into the ureter to fill in the kidney collecting system and a red resin was injected into the main trunk of the renal artery to fill in the arterial tree. Three percent of methyl ethyl peroxide was added to the resin as a catalyst. After injection, the kidneys were stored at room temperature to allow the resin to set (24 hr). The next day, the perirenal fat was removed and the kidneys were immersed in a bath of concentrated commercial hydrochloric acid for 48 hr to remove the organic matter. To preserve the relationships as existed *in vivo*, one or two arterial branches were fixed with glue to the collecting system. The branching pattern of each kidney was recorded as well as its relationship to the collecting system was determined after preliminary inspection of several casts looking for similarities and differences by which the casts could be categorized. Hence, casts with similar anatomical arrangement of the branching patterns of the dorsal and ventral divisions of the renal artery were categorized into two major subsets: I and II. As well, similarities in subset I were grouped into five subgroups based on the presence of extra branches for the cranial and caudal poles (Fig. 1).

## RESULTS

A single renal artery (Fig. 2) was observed in 84 kidneys (88.4%) and two renal arteries, a dorsal and a ven-



Fig. 3. Ventral view of an arterial and collecting system cast of dog kidney, type 1a. Two renal arteries: ventral (v) and dorsal (d). The ventral renal artery (v) divided in a cranial (white arrow) and caudal branch (black arrow). Ureter (u).

tral branches (Fig. 3), were found in 11 kidneys (11.6%). The frequency of a double renal artery was not statistically different between left and right kidneys. In all cases, the single renal artery divided into dorsal and ventral branches (Fig. 2). These secondary branches (dorsal and ventral) sent interlobar arteries (tertiary branches). Interlobar arteries reached the cortex of the cranial and caudal pole and mid-zone of the kidney through the renal columns, which are located between the recesses of the renal pelvis (Fig. 2).

The dorsal and ventral divisions of the renal artery were classified as type I or II, according to their branching pattern and their relationship to the collecting system. In type I, they presented two branches: one to the cranial portion and another one to the caudal portion of the collecting system. Type II casts also presented two branches of the dorsal or ventral division of the renal artery; one to the caudal portion of the collecting system and the other to the middle portion of the collecting system (mesorenal; Fig. 4). Type I was divided into five subtypes according to the occurrence of small extra branches of either the dorsal or ventral divisions of the renal artery directed to the renal poles. Type Ia did not present extra branches (Fig. 3). Type Ib presented an extra branch to the cranial pole (Fig. 5). Type Ic presented two extra branches to the cranial pole (Fig. 6). The casts presenting one extra branch to the caudal pole formed Type Id



Fig. 4. Dorsal view of an arterial and collecting system cast of canine kidney, type II. The dorsal division of the renal artery (d) divided into a mesorenal (black arrow) and caudal branch (white arrow). The cranial pole was irrigated only by a dorsal (\*) and ventral (arrowhead) branch of the ventral division of the renal artery. Ureter (u).



Fig. 5. Ventral view of an arterial and collecting system cast of canine kidney, type Ib. The ventral division of the renal artery (v) gave a caudal branch (black arrow), cranial branch (\*), and an extra branch to the cranial pole (arrowhead). The cranial pole was involved by dorsal (d) and ventral (v) divisions of the renal artery. Ureter (u).

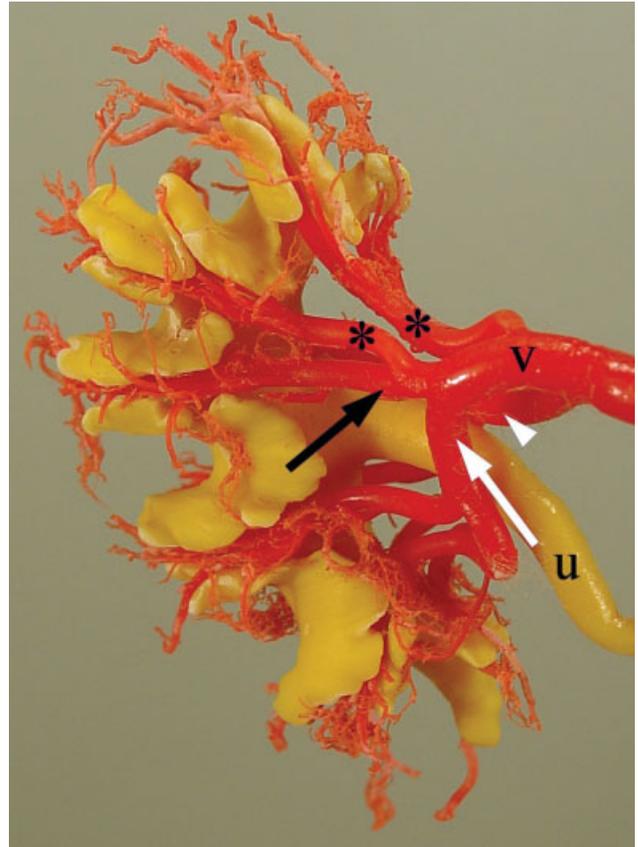


Fig. 6. Ventral view of an arterial and collecting system cast of dog kidney, type Ic. The ventral division of the renal artery (v) gave a cranial branch (black arrow), caudal branch (white arrow), and two extra branches to the cranial pole (\*). Important arteries were observed on both sides of the ureteropelvic junction (arrowhead, and white arrow). Caudal branch of the dorsal division of the renal artery (arrowhead), ureter (u).

(Fig. 7), and casts that presented two extra branches to the caudal pole formed Type Ie (Fig. 2).

The most frequent pattern of distribution of the dorsal and ventral divisions of the renal artery is presented in Table 1. The most frequent branching pattern was Type I in 93.7%. In the type I group, the type Ia subtype was the most frequently occurring in 67.3% in the ventral division and occurring in 64.2% in the dorsal division of the renal artery.

Cranial branches of the dorsal and ventral divisions of the renal artery supplied the cranial pole in 86 casts (90.5%). However, in three casts (3.2%) only branches from the dorsal division supplied the cranial pole, and in six casts (6.3%) only branches of the ventral division supplied the cranial pole (Fig. 4).

The dorsal mid-zone was irrigated from both cranial and caudal branches in 57 casts (60.0%). In 32 kidneys (33.7%), the dorsal mid-zone region presented only a caudal branch of the dorsal division. In four cases (4.2%), this region was supplied by a branch to the cranial pole, which originated from the ventral division of the renal artery, associated with a mesorenal dorsal branch. Finally, in two casts (2.1%), a mesorenal dorsal

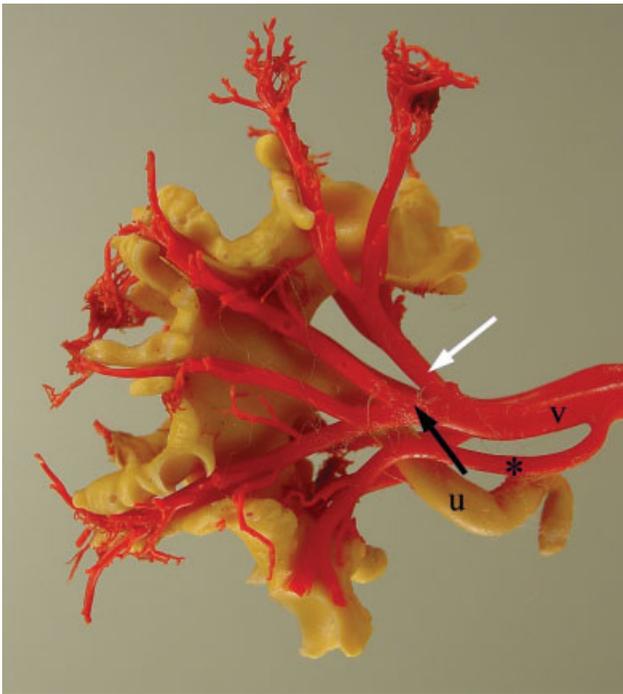


Fig. 7. Ventral view of an arterial and collecting system cast of canine kidney, type Id. The ventral division of the renal artery (v) giving a caudal branch (black arrow), cranial branch (white arrow) and an extra branch to the caudal pole (\*). Ureter (u).

branch supplied this region together with a caudal dorsal branch.

Cranial and caudal branches of the ventral division of the renal artery supplied the ventral mid-zone region in 55 casts (57.9%). In 37 kidneys (38.9%), only the caudal branch of the ventral division was found in this region. In two cases (2.1%), a mesorenal ventral branch and a caudal ventral branch supplied this region. In one cast (1.1%), the mesorenal region was irrigated by a ventral branch from the mesorenal division and by a cranial branch from the dorsal division of the renal artery.

Caudal branches of both dorsal and ventral divisions of the renal artery supplied the caudal pole in all casts. The ureteropelvic junction in dogs was related to two important arteries, from the caudal branches of the ventral and dorsal divisions of the renal artery, on both its ventral and dorsal sides (Fig. 6).

## DISCUSSION

A single renal artery was found in 88.4% of evaluated dog kidneys, whereas in 11.6% of the cases, two renal arteries were observed, a dorsal and a ventral. It is different from the finding of Jain and colleagues (1985), who reported three renal arteries in dog kidneys. On the other hand, only a single renal artery has been reported in pigs (Pereira-Sampaio et al., 2004), whereas multiple renal arteries were found in human kidneys (Sampaio and Passos, 1992; Satyapal et al., 2001). This fact is important because, when performing laparoscopic training in dogs, surgeons could face a situation that is quite common in laparoscopic donor nephrectomy in humans,

**TABLE 1. Arterial pattern of the dorsal and ventral divisions of the renal artery as related to the collecting system<sup>a</sup>**

Classification	Dorsal division		Ventral division	
Type I	Ia	64.2%	Ia	67.3%
	Ib	25.2%	Ib	21%
	Ic	3.2%	Ic	6.3%
	Id	1.1%	Id	1.1%
	Ie	0%	Ie	1.1%
Type II	6.3%		3.2%	

<sup>a</sup>Type I, cranial and caudal branches; Type Ia, without extra branches; Type Ib, one extra branch to the cranial pole; Type Ic, two extra branches to the cranial pole; Type Id, one extra branch to the caudal pole; Type Ie, two extra branches to the caudal pole; Type II, mesorenal and caudal branches.

that is multiple renal arteries (Johnston et al., 2001; Oh et al., 2003), different from pigs (Pereira-Sampaio et al., 2004).

The number of branches arising from the ventral and the dorsal divisions of the renal artery, within the renal parenchyma has been described in several species (Fuller and Huelke, 1973; Motwani and Harneja, 1982; Jain et al., 1985). However, the renal artery distribution was not presented and, therefore, no comparison can be made concerning the arterial branching pattern and its relationship to the kidney collecting system. The most frequent branching of the primary divisions of the renal artery was type I, found in 93.7% of the dorsal division and in 96.8% of the ventral. This pattern of arterial distribution in the dog kidney is quite similar in humans, if the relationship between intrarenal arteries and the collecting system is considered (Sampaio and Aragao, 1990). Furthermore, the primary division of the renal artery is important to determine the main arterial segments (Pereira-Sampaio et al., 2007). Hence, the arrangement of dog kidney arterial segments (ventral and dorsal) is more similar to those of man than to those of pigs (Sampaio et al., 1993; Pereira-Sampaio et al., 2007).

Two main arteries, cranial branches of the dorsal and ventral division of the renal artery, involved the dog kidney cranial pole in 86 cases (90.5%). This relationship between intrarenal arteries and the collecting system of the cranial pole is similar to that in humans and pigs (Sampaio and Aragao, 1990; Pereira-Sampaio et al., 2004). Therefore, this similarity would support the use of the dog as an animal model for urologic procedures in the cranial pole (Fig. 5).

Either cranial and caudal branches (60.0%) or only the caudal branch (33.7%) of the dorsal division of the renal artery supplied the dorsal mid-zone. However, the ventral mid-zone region was irrigated from both cranial and caudal branches (57.9%) or only from the caudal branch (38.9%) of the ventral division of the renal artery. It is important to emphasize that the mid-zone region of the dog presented the most varied arterial supply as happens in man and pig (Sampaio and Aragao, 1990; Sampaio, 1992; Pereira-Sampaio et al., 2004). Therefore, it was difficult to establish a typical arterial distribution for this region.

The caudal pole received caudal branches from both dorsal and ventral divisions of the renal artery in all cases (100%), and the collecting system of the caudal

pole was supplied by branches of these two arteries. This finding differs from man, where the inferior pole is irrigated only by the inferior segmental artery of the ventral division of renal artery in 62% of kidneys (Sampaio and Aragao, 1990). Furthermore, the ureteropelvic junction in dogs presented two important arteries, from the caudal branches of the ventral and dorsal divisions of the renal artery, on both its ventral and dorsal sides (Fig. 6). This is different from humans, where this artery at the ureteropelvic junction posterior surface is found in only 3.8% and on the anterior surface in only 20.5% of cases (Sampaio and Favorito, 1993). Therefore, the dog kidney would not be a good model for urologic procedures in the ureteropelvic junction and in the caudal pole.

The caudal branches of both dorsal and ventral divisions of the renal artery irrigated the kidney's mid-zone and the caudal pole in 95.8% and 98.9% of casts, respectively. This finding demonstrates that these arteries are of utmost importance in the caudal pole and mid-zone arterial supply of the dog kidney. This finding is in contrast to human and pig kidneys, where the posterior segmental artery and the cranial segmental artery may supply up to 50% of the parenchyma, respectively, and are, therefore, the main arterial trunks (Sampaio et al., 1993; Pereira-Sampaio et al., 2007).

In conclusion, although the results of renal and intrarenal anatomy in dogs cannot be completely transposed to humans, the anatomical relationships between arteries and the collecting system in the cranial pole of the dog kidney is very similar to those in humans, supporting its utilization as an animal model for urologic procedures in this region.

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