ORIGINAL ARTICLE

Eur. J. Anat. 21 (2): 141-147 (2017)

Morphological characterization of the renal vein in pigs (Sus domesticus). Differential analysis with the human renal veins

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SUMMARY

Despite its importance as an experimental model, information about the morphology of the renal vein (RV) is scarce and limited to qualitative descriptions. The objective of this investigation was to determine the morphological characteristics of the RV and its tributaries in pigs (*Sus domesticus*). We studied 93 pairs of kidneys of pigs destined to slaughter. This descriptive study evaluated the RV and its tributaries, which were perfused with polyester resin (85% Palatal and 15% styrene). Subsequently for full corrosion pieces were subjected to infusion of KOH (potassium hydroxide) for 10 days. The RV and their tributaries were assessed for shape, trajectory and morphometry. The level of significance was set at p<0.05. A single RV was found in 93% of the specimens. The caliber of the RV was 12.8±3.05 mm. It was significantly higher on the left side (p=0.043). Length was 26.54±12.81 mm for the right RV and 37.64±13.62 mm for the left RV. The position of the RV in relation with the renal artery was cranial-ventral in 46.2% of the specimens, whereas its origin was hilar in 61.9% of the cases. The emergence of the RV from two tributary veins (pattern Ia) was the most common (76.9%). The morphological characteristics of the VR observed in this study are similar to those reported in humans, so the usefulness of this animal model in procedural applications and hemodynamics is evident.

Key words: Renal vein – Renal tributaries – Pig kidney – Anatomical variation – Additional renal veins

INTRODUCTION

The information about the morphological characterization of the renal vein (RV) in pigs (*Sus domesticus*) is scarce, and has been limited to basic qualitative descriptions and morphometric (Poisel and Sirang, 1972; Vodenicharov and Cirnuchanov, 1995; Vodenicharov and Gulubova, 1995). The RVs are voluminous, run obliquely forward, and join the caudal vena cava at an acute angle. The left RV is much longer than the right RV (Vodenicharov and Gulubova, 1995).

The RV of the pig is formed at the level of the renal sinus of the anastomosis of tributary veins, which in turn derive from the union of the interlobar veins. The RV is mainly formed from tributaries cranial and caudal; and lower incidence (11.5%) of tributaries cranial, middle and caudal (Sampaio, 1992; Bagetti et al., 2008).

In humans, the left renal vein (LRV) is longer than the right one (Anson and Daseler, 1961; Ballesteros et al., 2014). The configuration of the RV tributaries has not been subject to classification in previous studies in pigs. In humans, it is classified as Type Ia (one superior and one inferior tributaries), Type Ib (same as Type Ia, plus one posterior tributary); Type IIa (more than two tributaries, for example, superior, intermediate and inferior); Type

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Submitted: 13 September, 2016. *Accepted:* 26 January, 2017.

IIb (same as Type IIa, plus one posterior tributary); Type III (any of the above classifications, plus another additional vein) (Satyapal, 1995; Ballesteros et al., 2014).

Single right and left RV are a usual finding, as well as variant expressions reported as additional RV with one draining separately into the inferior cava vein (ICV) (Ross et al., 1961; Beckmann and Abrams, 1980; Satyapal et al., 1999; Ballesteros et al., 2014). The presence of additional veins is considerably common on the right side (7-38%), in comparison with the left side (1-3%) (Ross et al., 1961; Beckmann and Abrams, 1980; Satyapal, 1995; Satyapal et al., 1995; Satyapal et al., 1999; Dukes et al., 2002; Janschek et al., 2004; Aristotle et al., 2013; Ballesteros et al., 2014). This type of characterization has not been reported in studies of pigs' kidneys (Bagetti et al., 2008).

The confluence of two or three tributaries at extra - or intrarenal level gives rise to both RVs in humans and pigs (Dukes et al., 2002; Janschek et al., 2004; Bagetti et al., 2008; Ballesteros et al., 2014). In pigs, the formation of the RV from two tributaries is reported in 88.5%, while in humans it is reported in a range of 36-61.6%. (Satyapal, 2003; Bagetti et al., 2008; Ballesteros et al., 2014) In humans, the location of RV anterior and inferior has been reported predominantly, relative to the ipsilateral renal artery. The right renal vein (RRV) is 24-28 mm in length, similar to the length between the origin of the LRV and drainage on this ipsilateral gonadal vein (proximal segment) (Beckmann and Abrams, 1980; Satyapal, 2003; Ballesteros et al., 2014). Given the great similarity between the human and the pig's kidney, and the scarce information available on the characteristics of the RV and its tributaries in this species, this work seeks to generate meaningful information on this venous structure that allows for proposing this animal model for procedural and hemodynamic applications (Earp, 2003; Kaouk et al., 2003; Hammond et al., 2004; Bagetti et al., 2008).

MATERIALS AND METHODS

This descriptive study evaluated the qualitative and morphometrical characteristics of the RV and its tributaries in 93 pairs of male kidneys of commercial pigs bred (breeds of Pietrain, Belgian Landrace, and Large White varieties) (*Sus domesticus*) for slaughter with a mean age of 5 months and a mean weight of 85-90 kg, obtained from Vijagual Refrigerating Plant in Bucaramanga, Colombia. The organs were subjected to an exsanguination process for 6 hours in a water source.

A catheter number 14 was passed through the anterior end of the caudal vein cava to perfuse it with a semi-synthetic polyester resin (85% Palatal GP40L; 15% styrene) dyed with mineral blue. The renal specimens were left in water for 24 hours, and then they were immersed into a 15% potassium hydroxide (KOH) solution for ten days for the total corrosion of the specimen and detailed observation of the venous structures and their tributaries. Subsequently, the calibers and lengths of the RV and its tributaries were measured with a digital calibrator (Mitutoyo®) at 0.5 cm of their respective origins. The morphological characteristics of the

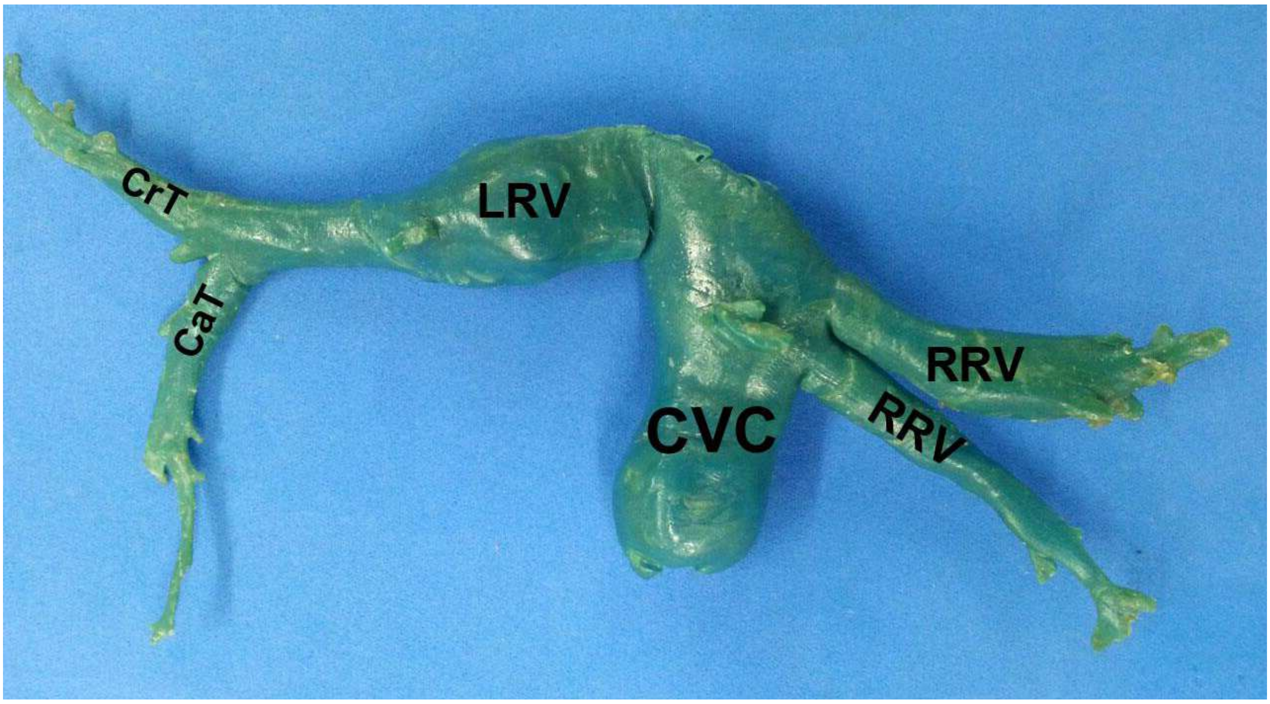

Fig 1. Dorsal view of the vascular renal specimen. Double right and single left renal veins. CVC: caudal vena cava; RRV: right renal vein; LRV: left renal vein; CrT: cranial tributary; CaT: caudal tributary.

RV were typified according to Satyapal's criteria (1995), performing the modification of anterior superior in humans by cranial ventral to the quadrupedal disposition of the studied animals.

The continuous variables (length and calibers) were analyzed using Student's t test, and the discrete variables (percentages and distribution patterns) were analysed using Pearson's Chi square test. The results were evaluated with the "Epi-Info 3.5.4" statistical program. The significance level used was $p<0.05$. Photographic records were taken with a digital camera of each of the specimens evaluated.

RESULTS

The RV was simple in 93% of samples; in 81 cases (87.1%) in the right kidney and in 92 specimens (98.9%) in the left. Double RV were found in 12 cases (12.9%) in the right kidney and in one case (1.1%) in the left kidney (Fig. 1), with significant differences in side (p=0.002).

The caliber of the RV was 11.06±2.65 mm for the right side, and 1455±3.44 mm for the left side. The length of the right RV was 26.54±12.81 mm and 37.64±13.62 mm for the left RV, without significant side differences (p=0.23).

In the majority of the cases, the RV had a cranial -ventral position with respect to the ipsilateral renal artery (46.2%) (Table 1) (Fig. 2). The origin of the RV was hilar in 58 pairs of kidneys (61.9%), corresponding to the right kidney 53 cases (57%) and left 62 samples (66.7%), while the extrahiliar origin was observed in 35 pairs of kidneys (38.2%) (Fig. 3) with statistically significant differences (p=0.000).

Type Ia distribution pattern of the tributary veins of the RV (cranial and caudal) was observed in 143 specimens (76.9%), while Type IIa was found in 25 cases (13.4%), without significant differences (p=0.351) (Table 2) (Figs. 4 and 5). The cranial, caudal, intermediate, and posterior tributaries of the RV were characterized taking into account their caliber, length and the number of tributaries forming them (Table 3).

DISCUSSION

There are no previous reports on the morphometric characterization of the RV in pigs, nor on the distribution patterns of their tributary branches. The few studies conducted on the morphology and irrigation of the kidney are limited to some basic qualitative descriptions (Poisel and Sirang, 1972; Vodenicharov and Cirnuchanov, 1995; Vodenicharov and Gulubova, 1995).

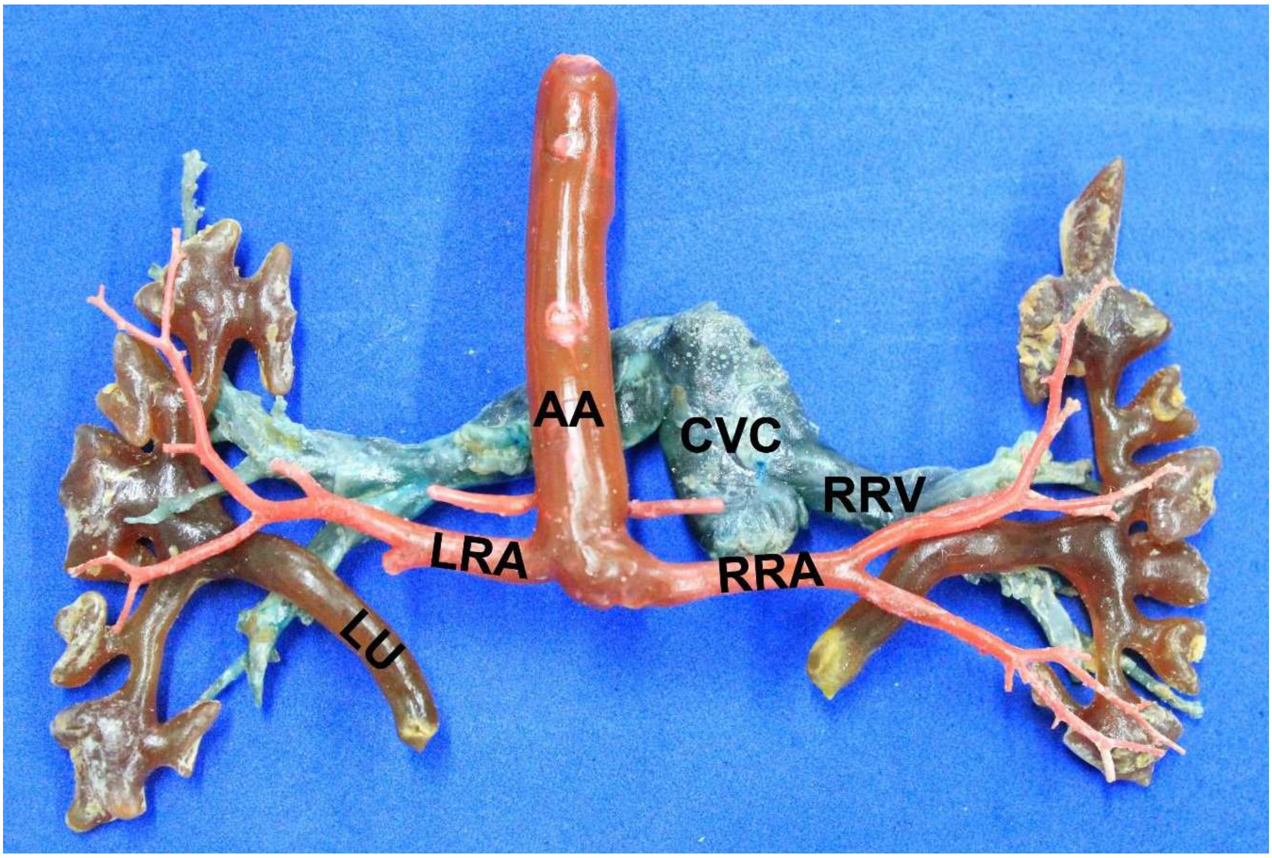

Fig 2. Dorsal view of the vascular renal specimen. Cranial-ventral renal veins, in relation to renal arteries. CVC: caudal vena cava; RRV: right renal vein; AA: abdominal aorta; RRA: right renal artery; LRA: left renal artery; LU: left ureter.

Our series found a single RV in 93% of the specimens, whereas this finding has been reported within a range of 74-82% in humans (Satyapal et al., 1999; Kavamoto et al., 2005; Ballesteros et al., 2014). The incidence of a double RV in our work was less than what has been reported in the majority of the prior studies in humans, but is consistent with the observation of this morphological variation with a greater frequency in the right side (Ross et al., 1961; Beckmann and Abrams, 1980; Satyapal, 1995; Satyapal et al., 1995; Satyapal et al., 1999; Dukes et al., 2002; Janschek et al., 2004; Ballesteros et al., 2014). Double RVs in humans are asymptomatic, being discovered during surgical procedures or as necropsy findings. This morphologic expression becomes increasingly important for kidney transplants, because they can determine or influence the technical feasibility of the procedure (Satyapal, 1999)

The origin of the RV at the renal hilum in humans has been reported within a frequency similar to what we found in the present study (61.9%) (Abrams et al., 1964; Beckmann and Abrams, 1980; Holden et al., 2005), although the considerably lower figure (22.1%) reported by Ballesteros et al. (2014) is of note. The extra-hilar origin of the RV in humans can result in a greater vulnerability of this vascular structure for surgical procedures, and for retroperitoneal trauma, because the tributary veins of the RV are scattered in an area medial to the kidney (Ballesteros et al., 2014).

Similarly, the predominant antero-posterior position of the RV with respect to the renal artery has been reported within a range of 40-57.8% in hu-

Table 1. Renal vein position with respect to the renal artery.

	Ventral	Ventral-caudal	Cranial	Caudal	Cranial-ventral	Cranial-dorsal	Dorsal
Right kidney	30 (32.3%)	0	15 (16.1%)	3 (3.2 %)	39 (41.9%)	5 (5.4%)	1 (1.1%)
Left kidney	9 (9.7%)	1 (1.1%)	32 (34.4%)	3 (3.2%)	47 (50.5%)	1 (1.1%)	0
Total (pairs of kidneys)	19.5 (21%)	1 (0.6%)	23.5 (25.3%)	3 (3.2%)	43 (46.2%)	3 (3.3%)	1 (0.6%)

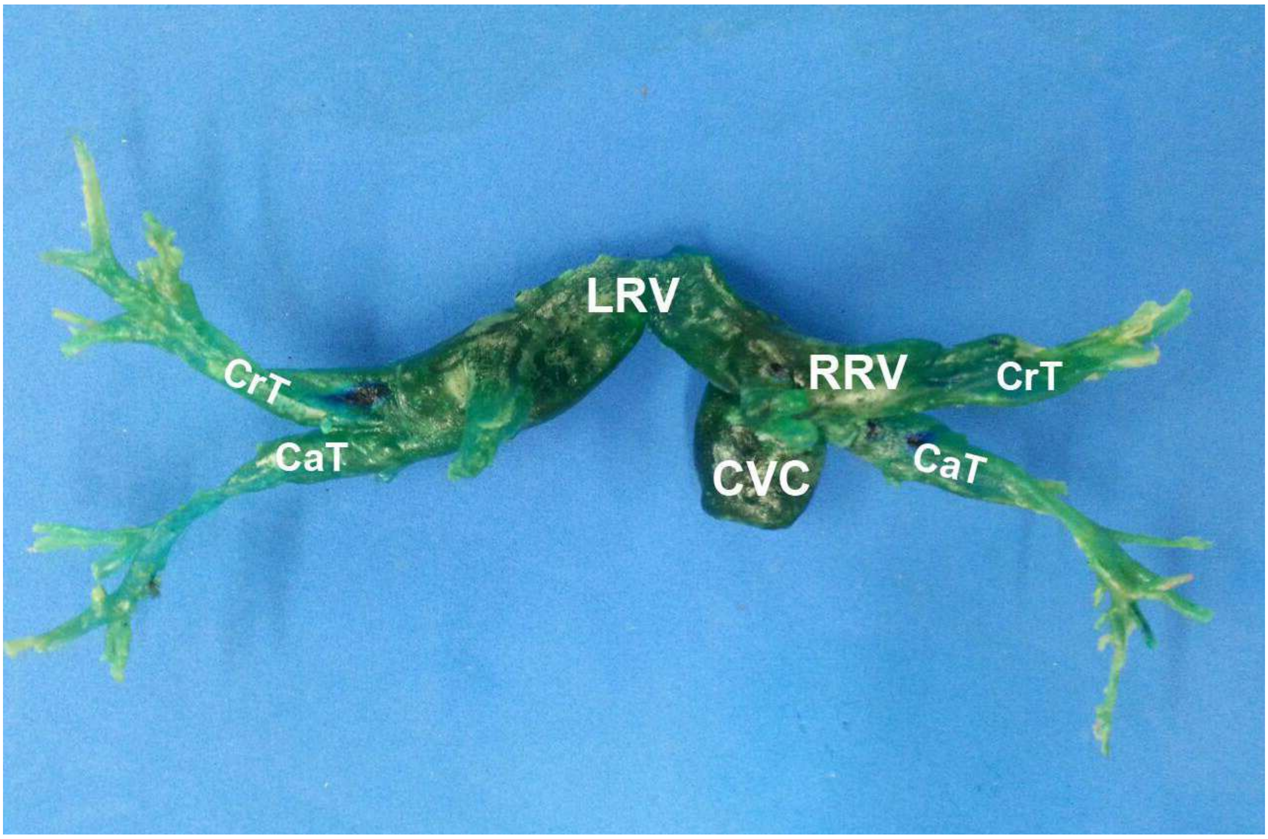

Fig. 3.- Dorsal view of the vascular renal specimen. Hilar and extra-hilar origin of the renal veins. CVC: caudal vein cava; RRV: right renal vein; LRV: left renal vein; CrT: cranial tributary; CaT: caudal tributary

mans, whereas in the present study it was observed more frequently in a cranial-ventral position (46.2%), which would correspond to an antero-superior position in humans, reported in 25% of the cases (Holden et al., 2005; Ballesteros et al., 2014). The ventro-caudal position of the RV in animals, analogous to the antero-inferior position in humans, was observed in a few specimens in our series (1.1%), so it this feature could be regarded as a difference in the topographic location of the RV in pigs and humans, within the context of comparative anatomy.

The mean caliber of the RV recorded in the present work (12.8 mm) is consistent with what has been reported in humans (Beckmann and Abrams, 1980; Ballesteros et al., 2014). The length of the RRV (26.54 mm) is within the mean range in relation to the measurements made in humans (24-28 mm), whereas the length of the LRV (37.64 mm) is slightly shorter than what has been reported for this dimension in humans (Beckmann and Abrams, 1980; Ballesteros et al., 2014).

The occurrence of the RV formation pattern as emerging from the convergence of two tributaries (Type Ia) in humans has been reported as the most frequent pattern within a range of 36-61.6% (Satyapal et al., 1995; Sampaio, 1992; Ballesteros et al., 2014). This feature is consistent with our study, although we observed it in a greater number of cases (76.9%). Similarly, the presence of three tributary branches, cranial, intermediate, and caudal (Type II) has second order incidence in RV

Table 2. Distribution patterns of tributaries renal vein.

	Type I		Total Type	Type II		Total Type II	Type III
	Ia	Ib		IIa	IIb		
Right kidney	70 (98.6%)	1 (1.4%)	71 (76.3%)	9 (90%)	1 (10%)	10 (10.8%)	12 (12.9%)
Left kidney	73 (96.1%)	3 (3.9%)	76 (81.7%)	16 (100%)	0	16 (17.2%)	1 (1.1%)
Total	143 (76.9%)	4 (2.2%)	147 (79.1%)	25 (13.4%)	1 (0.5%)	26 (13.9%)	13 (7%)

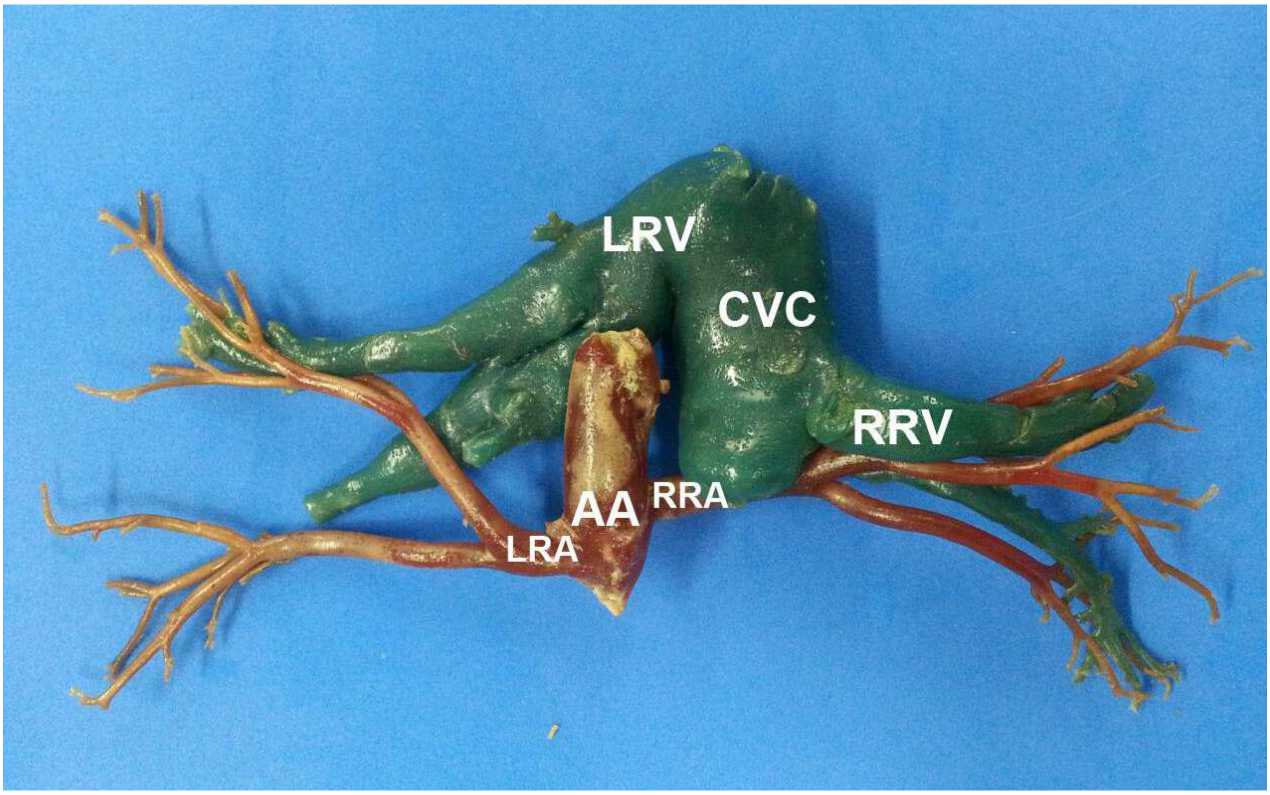

Fig 4. Dorsal view of the vascular renal specimen. Bilateral Type Ia distribution pattern. CVC: caudal vein cava; RRV: right renal vein; LRV: left renal vein; AA: abdominal aorta; RRA: right renal artery; LRA: left renal artery.

studies in both humans and in our work.

In humans, given the varied morphologic expression of the RV and their tributary branches, a proper understanding of these vessels is required to meet surgical, physiological, and clinical requirements. To comply with these aspects a refined dexterity is needed that allows for the performance of different procedures such as vascular sutures, kidney transplants, pathophysiological and venous phase tests of catheterizations, which must rest on the knowledge of the anatomy of these structures. In this regard, due to the similarity of its venous drainage to that of humans, the pig kidney is an excellent procedural model that allows for the development of the said techniques (Kaouk et al., 2003; Hammond et al., 2004).

CONCLUSIONS

The findings of this study enrich the knowledge of the anatomy of the pig kidney with the characterization of the RV and the distribution patterns of its tributary systems. These findings are in clear agreement with previous reports on the anatomy of the RV in humans, which allows for proposing the pig model for procedural and hemodynamic applications.

ACKNOWLEDGEMENTS

To the Vijagual Refrigerating Plant in the city of Bucaramanga, Colombia, for the donation of speci-

Table 3. Characterization of tributaries renal veins.

	Cranial tributary			Caudal tributary			Intermediate tributary			Posterior tributary		
	Cal - mm	Length (mm)	# tri	Cal - mm	Length (mm)	# tri	Cal - mm	Length (mm)	# tri	Cal - mm	Length (mm)	# tri
RK	6.7 ± 1.4	24.4 ± 8.4	3	6.7 ± 1.5	27.8 ± 10.4	2	5.1 ± 1.4	15.4 ± 10.7	3	4.6 ± 0.3	28.6 ± 1.7	2
LK	7 ± 1.8	25.7 ± 10.3	3	6.5 ± 1.9	29.5 ± 12.3	2	4.8 ± 1.3	16.9 ± 11.2	2	6 ± 1.6	27.3 ± 9	3

RK: right kidney; LK: left kidney; Cal: caliber

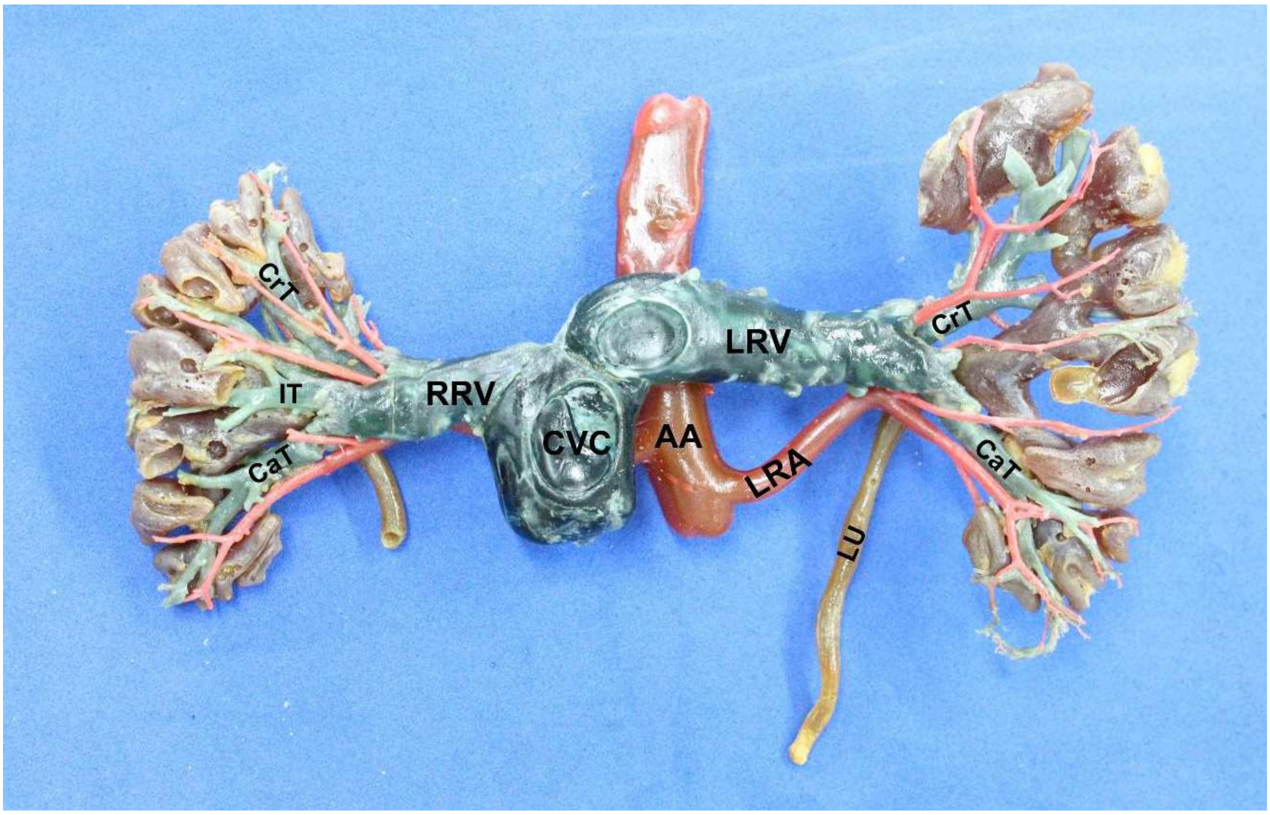

Fig 5. Ventral view of the vascular renal specimen. Type IIa distribution pattern, right kidney. Type Ia distribution pattern, left kidney. Ventral view. CVC: caudal vena cava; RRV: right renal vein; LRV: left renal vein; AA: abdominal aorta; LRA: left renal artery; LU: left ureter; CrT: cranial tributary; CaT: caudal tributary; IT: intermediate tributary.

mens for the conduction of this research, and to undergraduate students Fausto Arenas, Josimar Sneider Rincón and Juan Camilo Álvarez for their participation in the preparation of the study specimens.

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