Rom J Morphol Embryol 2014, 55(1):77–81

ORIGINAL PAPER

RJME Romanian Journal of Morphology & Embryology http://www.rjme.ro/

Morphologic evaluation of the renal veins: a study with autopsy material from Colombian subjects

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Abstract

Renal venous drainage presents a large degree of variability. The purpose of this study was to determine the morphological expression of the renal veins. Renal vein formation patterns, their morphometry, and frequency of additional veins were studied in a sample of 156 pairs of kidneys, the vascular beds of which were subjected to an injection-corrosion technique, taken from cadaver specimens autopsied at National Institute of Legal Medicine and Forensics Sciences in Bucaramanga, Colombia. A single renal vein (RV) was found bilaterally in 122 (78.2%) samples, whereas 34 (21.8%) kidneys had additional RVs (left side 33 cases, right side one case). Of the specimens with multiple right renal veins (RRV), 28 (17.9%) had two RVs and five (3.2%) had three RVs. Of the left kidneys, 99.4% had one LRV and 0.6% had two LRVs. The lengths of the left and right renal veins were 56.5±12.7 mm and 23.6±8.21 mm, respectively; the caliber of the left renal vein (LRV) was 12.3±1.41 mm, whereas the caliber of the RRV was 10.9±1.56 mm, a statistically non-significant difference (p=0.262). 82.7% of the LRVs and the 73.1% of the RRVs (p=0.768) originated at the extra-hilum level. Renal vein formation pattern characterized by the confluence of upper and lower tributaries was found in 61.6% of the cases, whereas 16.3% of the specimens had upper, medium, and lower tributaries. Variation patterns found in this study point towards a wide morphological expression of these vessels that needs to be taken into account for both imaging and surgical procedures.

Keywords: renal veins, additional renal veins, renal hilum, tributary veins, anatomical variations.

Introduction

Kidney venous drainage proceeds through the renal veins (RV), which, given the presence of two kidneys, include a right renal vein (RRV) and a left renal vein (LRV). Each renal vein originates from the confluence of a variable number of primary tributaries that emerge from the kidney, and drains into the lower vena cava (IVC). Since the lower vena cava is situated at the right side of the aorta, the left renal vein is longer than the right one [1, 2].

Single right and left RVs are usually found as well as a variant expression reported as an additional RV with a separate drainage into the IVC [3–5]. The frequency of an additional RV is considerably higher at the right side (7–38%) in comparison with the left side (1–3%) [3–10].

The LRV may have either an intra-renal or extra-renal origin due to the contribution of two or three tributaries (70%) [7, 9]. Its location inside the elements of the renal pedicle is either anterior or inferior to the renal artery or running obliquely towards the lower vena cava [10]. The RRV presents an anterior and inferior course with respect to the ipsilateral artery and is 24–28 mm in length, *i.e.*, similar to the length of the proximal segment of the LRV [1, 3].

RVs are asymmetrical with respect to the configuration of their tributaries and to their confluence level [7, 11, 12]. The complexity of the embryological development of the LRV determines the presence of variable expressions such as a circumaortic course or renal collar, characterized in that the renal vein emits two branches as it approaches the aorta, one projected in front and one behind it, which flow separately into the IVC. Similarly, 1–5% of the cases show a retro aortic course for the LRV [13–15].

The identification of variations in the RVs may be useful for diagnostic imaging, as well as for surgical retroperitoneal approaches, abdominal surgery, urological procedures, determination of the adrenal function, and renal transplantation [16–19].

The anatomical characteristics of the RV have been described using vascular bed injection, imaging studies, and classic dissection techniques in diverse population groups [3, 7, 20, 21]. Taking into account that the ethnic origin is decisive for the occurrence of different morphological expressions, and the absence of this type of information from the Mestizo population, which is predominant in Latin America, this study in fresh cadaver material is highly relevant to obtain our own reference information.

Materials and Methods

This descriptive crossover non-probabilistic analysis studied 156 renal blocks extracted from unclaimed cadavers of adult subjects who underwent necropsy at National Institute of Legal Medicine and Forensics Sciences in Bucaramanga, Colombia. The sample included both male and female Mestizo subjects, with ages ranging between 20–75 years, and with no evidence of their death having been caused by direct trauma or conditions involving the retroperitoneum. This investigation was approved by the Ethics Committee of Universidad Industrial de Santander.

ISSN (print) 1220–0522 ISSN (on-line) 2066–8279

Each specimen was subjected to proximal ligature and channeling of the distal segment of the IVC. This vessel was used to treat the RV with an injection of semi-synthetic resin 40 cc (a mixture of Palatal E210® BASF 80 cc; Styrene 20 cc) dyed with mineral blue at a pressure that depended on the vessel's filling status; the perfused renal blocks were left to polymerize at room temperature for 24 hours. Then, the anatomical pieces were subjected to a cleaning and corrosion process by immersion in 20% potassium hydroxide solution for 72 hours.

The different renal vein formation patterns are recorded per gender, number of RVs, side, lengths, calibers, and point of entry into the lower vena cava. The external diameter of the RV was also measured both at its origin and at its end. A digital calibrator (Mitotuyo®) was used for all morphometric evaluations.

According to the criteria of Satyapal *et al.* (1995), the LRV was divided into a proximal segment, which corresponds to the distance between the point of confluence of the tributaries and the lateral edge of the outlet of the left capsular vein (LCaV); and a distal segment comprised between the medial edge of the drainage of the capsular vein and the point of entry into the IVC [6].

The configuration patterns of the RV tributaries were classified as type IA (one upper and one lower tributary), type IB (type IA plus a posterior tributary); type IIA (more than two tributaries, for example, upper, medium, and lower); type IIB (type IIA plus a posterior tributary); type III (any of the above classifications plus another additional vein [9].

Digital photographs were taken from all pieces (Canon T2i Camera). The data obtained were recorded in Excel spreadsheets. Statistical analyses were carried out using STATA 8 software. For data analysis, the continuous variables were described using means and dispersions; similarly, the nominal variables were described using ratios. Statistical tests included chi-square (χ^2) and Student's *t*-test, accepting an alpha error of up to 5%.

Results

The veins of 156 renal blocks, corresponding to 129 (82.7%) male subjects and 27 (17.3%) female subjects, were evaluated. The mean age of the subjects was 41.6±21.6 years. A single RV was described bilaterally in 122 (78.2%) samples, whereas 34 (21.8%) kidneys had additional RVs (33 right side; left side, one case). There were additional veins in 27 (20.9%) men and seven (25.9%) women, a non-significant difference (p=0.452). Of the specimens with multiple RRVs, 28 (17.9%) had two RVs and five (3.2%) had three RVs (Figure 1).

At its distal segment, proximal to its point of entry into the IVC, LRV was 12.3±1.41 mm in caliber, whereas the RRV was 10.9±1.56 mm in caliber, a statistically non-significant difference (p=0.262). The first additional vein was 6.4±1.38 mm in caliber and the second additional vein was 4.95±1.4 mm in caliber. The RRV was 23.6±8.21 mm in length; the first additional vein was 30.7±10.19 mm in length, and the second additional vein was 31.2±7.93 mm in length; whereas the LRV was 56.5±12.7 mm in length, with 27.5±10.26 mm corresponding to its proximal segment. The distance from its distal segment was 25.6±7.79 mm. The distal caliber of the LCaV vein was 3.4±1.05 mm.

Concerning the point of origin of the RVs, the confluence of the tributaries was found at the extra-hilum level in 243 (77.9%) kidneys and at the hilum level in 66 samples (21.2%), with this difference being statistically significant (p=0.000) (Figure 2). An extra-hilum origin was observed in 82.7% of the cases for the LRV, and in 73.1% of the cases for the RRV (p=0.768) (Table 1).

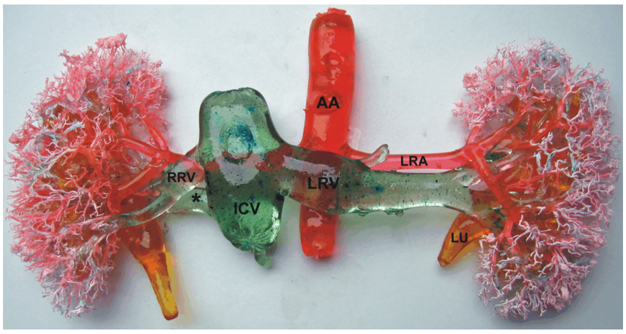

Figure 1 – ***Additional right renal vein. AA – Aortic artery, ICV – Lower vena cava, LRV – Left renal vein, RRS – Right renal vein, LRA – Left renal artery, LU – Left ureter, (*) Additional renal vein.***

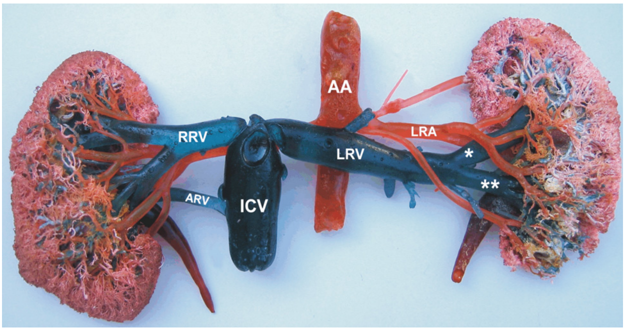

Figure 2 – ***Extra-hilum origin of the renal veins. AA – Aortic artery, ICV – Inferior vena cava, LRV – Left renal vein, RRV – Right renal vein, ARV – Additional renal vein, LRA – Left renal artery, (*) Upper tributary branch, (**) Lower tributary branch.***

Table 1 – ***Point of origin of the right and left renal veins***

Point of origin	Left side *n* (%)	Right side *n* (%)	Overall *n* (%)
Intra-renal	0 (0)	3 (1.9)	3 (0.9)
Hilar	27 (17.3)	39 (25)	66 (21.2)
Extrahilar	129 (82.7)	114 (73.1)	243 (77.9)

In 153 (98.1%) cases, the LRV had a preaortic course, which flowed into the side surface of the IVC; in two (1.3%) specimens, the course was retro-aortic and flowed into the postero-lateral surface of the IVC (Figure 3); in one case (0.6%), the course was circumaortic (Figure 4). The point of entry of the LRV into the IVC with respect to the contralateral vein was symmetrical in 86 (59.7%) cases; rostral in 50 (34.7%), and caudal in eight (5.6%). In the cases of an asymmetrical point of entry of the RVs, the distance from the point of entry into the IVC to the contralateral vein was 13.2±7.76 mm.

Inside the renal pedicles the veins had an anterior-inferior location with respect to the ipsilateral arteries in 178 (57.8%) kidneys followed by an anterior relation in 110 (35.3%) cases, with the difference between these two morphological expressions being non-significant (p=0.034) (Table 2).

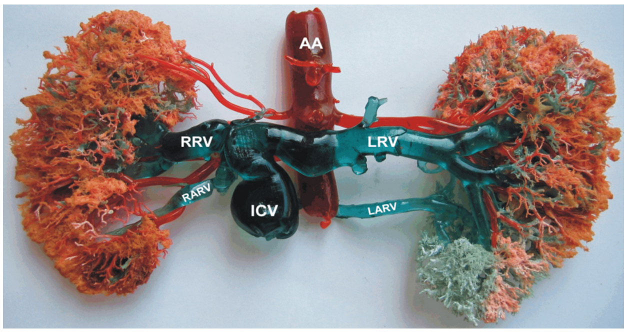

Figure 3 – ***Additional renal vein retro aortic course. AA – Aortic artery, ICV – Inferior vena cava, LRV – Left renal vein, LARV – Left additional renal vein, RRV – Right renal vein, RARV – Right additional renal vein.***

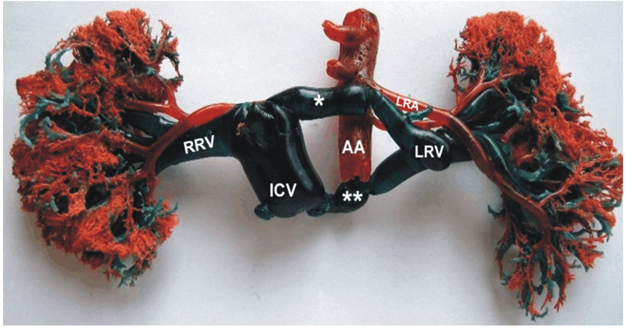

Figure 4 – ***Circumaortic left renal vein course. AA – Aortic artery, ICV – Lower vena cava, LRV – Left renal vein, RRV – Right renal vein, LRA – Left renal artery, (***) Circumaortic branches.***

Table 2 – ***Topographic location of the veins in relation to the arteries at the level of the renal pedicles***

Location of the vein with respect to the artery	Left side *n* (%)	Right side *n* (%)	Overall *n* (%)
Anterior	56 (35.9)	54 (34.6)	110 (35.3)
Antero-inferior	94 (66.3)	84 (53.9)	178 (57.1)
Antero-superior	0 (0)	8 (5.1)	8 (2.5)
Inferior	6 (3.8)	10 (6.4)	16 (5.1)

The RVs originated in the confluence of upper and lower tributaries (type IA) in 61.2% of the cases, whereas all other types of configurations and number of tributaries occurred in 38.8% (Figure 5) (p=0.004). For side of occurrence, type IA was more frequent at the left side but the difference was non-significant (p=0.363) (Table 3).

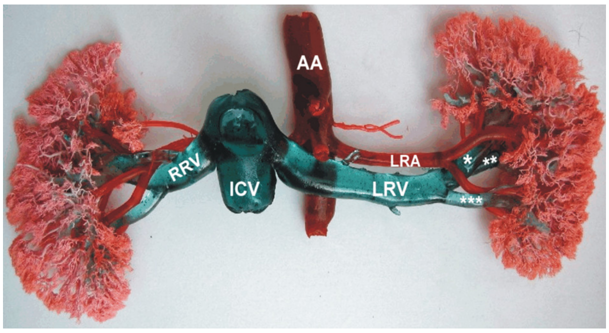

Figure 5 – ***Configuration of the tributaries of the left renal vein (Type IB). AA – Aortic artery, ICV – Lower vena cava, LRV – Left renal vein located on an anterior position relative to the renal artery, RRV – Right renal vein, LRA – Left renal artery, (*) Upper tributary branch, (**) Posterior tributary branch, (***) Lower tributary branch.***

Table 3 – ***Type of renal vein formation per side of occurrence***

Type of configuration of the renal tributaries	Right side *n* (%)	Left side *n* (%)	Overall *n* (%)
Type IA	72 (46.1)	120 (76.9)	192 (61.6)
Type IB	16 (10.3)	9 (5.8)	25 (8)
Type IIA	31 (19.9)	20 (12.8)	51 (16.3)
Type IIB	4 (2.5)	6 (3.9)	10 (3.2)
Type III	33 (21.2)	1 (0.6)	34 (10.9)

Of the 39 additional RVs, 18 (46.2%) originated at the upper renal pole, 15 (38.5%) at the lower renal pole and six (15.3%) at the hilum.

Discussion

Taking into account the wide variability spectrum indicated in the literature, the frequency of additional renal veins in our study (21.1%) is in the mid range (18–26%) reported by Kavamoto *et al.* (2005), as well as by other authors [5, 6, 8, 10, 18, 21]. The highest incidences have been reported within a range of 33–38.5% [3, 11, 22]. Of note is the low incidence of additional renal veins, range 8–17%, reported in studies conducted with diverse population groups [7, 20, 23, 26, 28]. A series of samples found only one case of an additional LRV (0.6%), a figure consistent with some prior studies. Other works have reported slightly higher incidences: Costa *et al.* (2011), 1.5% [20], Satyapal (2003), 2.6% [10], and Sahani *et al.* (2005), 4% [28]. The presence of two additional renal veins is a variant expression reported by all studies with a low frequency: Kaufman *et al.* (1995) [23] and other authors [18, 21]. Our report (range 0.7–2%), with a slightly higher incidence (3.2%), is similar to those reported by other series [3, 6, 8, 22].

The wide variability in the incidence of additional RVs reported by diverse researchers is probably due to factors such as sample size, methodology, imaging or direct dissection, and to the ancestral biologic features that determine the variable expression of these structures in the diverse population groups evaluated [3, 7, 20, 23]. Variations in the number of renal veins are clinically silent and go unnoticed until they are discovered during a surgical procedure or at necropsy. They acquire a special meaning during renal transplantation, where they greatly determine or influence the technical viability of the operation, so they need to be assessed preoperatively by venography [5].

Our findings of SRV frequency are consistent with those of prior studies reporting on the existence of non-significant gender differences [5, 19, 21]. Of note, due to the difficulty to obtain an appropriate number of samples from female subjects, direct anatomical studies have evident limitations to correlate their results per gender.

The RRV evaluated with angiographic studies, vascular bed injection, and direct dissection has been reported to be within a range of 24–26 mm in length, which is consistent with our findings [3, 6, 8, 10, 21], whereas the LRV has been reported by Satyapal *et al.* (1995), and other investigators [6, 7, 12] to be within a range of 54–59 mm in length, *i.e.*, also similar to our work. In other series, Janscheck *et al.* (2004) [8], and Beckmann *et al.* (1980) [3], report lengths of 68–70 mm. Anson *et al.* (1961) [2], report a length of 84 mm for the LRV. The length of the proximal segment of the LRV recorded in the present study (27.5 mm) is consistent with prior reports [10, 22], whereas the distal segment, comprised between the site of drainage of the LCaV and the point of entry of the LRV into the lower vena cava, is slightly shorter in our series (25.7 mm) than in other works [3, 8, 10, 22]. The divergence in the reported lengths of the renal veins can be explained by the size of the subjects evaluated in each series corresponding to diverse population groups with their respective phenotypic expressions. Similarly, the renal veins having their origin either at the hilum or at extra-hilum levels determine differences in the dimensions of these vessels.

The caliber of the LRV recorded in the present study (12.3 mm) is similar to what is noted by prior reports [6, 8, 10, 22], whereas the caliber of the RRV is slightly smaller than the one reported by Satyapal (2003) [10], 12 mm; Janscheck *et al.* (2004) [8] and Beckmann *et al.* (1980) [3], 13 mm. There is agreement between the different authors [3, 6, 8] in recording a smaller caliber for the additional veins with respect to the main renal vein, within a range of 5–9 mm.

The circumaortic expression and retroaortic course of the LRV had a very low incidence in this work (0.6%), a finding consistent with the reports by Satyapal *et al.* (1999) [5] and Baptista-Silva *et al.* (1997) [11]; some other investigators report incidences of 1.7–4.2% for the retro aortic course and 1.5–7% for the aortic ring [7, 8, 15–21, 23, 25–28]. Preoperative diagnosis of these RV variations is relevant for retroperitoneal surgery, because otherwise vessel injuries, bleeding, nephrectomy due to long periods of ischemia caused by the procedure, and even death may occur. The risk of vein injury is greater for patients with a circumaortic renal collar, because the anterior component of a renal collar may easily induce the surgeon to err by letting him/her believe that the left renal vein is normal and that there a retroaortic component is absent. These variations have surgical significance because they restrict the availability of the LRV for procedures such as renal transplantations and spleen–kidney bypasses. This confirms the importance of a full preoperative angiography with both arterial and venous phases to decide which kidney is to be removed [5, 11, 19].

The extra-hilum origin of the RV reported in prior studies [3, 26, 29] with a range of 25–28% contrasts with the high incidence found in our study (77.9%). The criteria to determine the points of origin of the RV, and the characteristics owing to the population groups evaluated could explain these divergences. The extra-hilum origin of the RV leaves the tributaries more exposed, so these structures have are more vulnerable to trauma and injury during surgical procedures.

Concerning the configuration of the RV tributaries, the presence of two tributaries (type IA) found in our series (61.6%) is consistent with the reports by Duques *et al.* (2002) [7], whereas Sampaio *et al.* (1990) [30] and Satyapal *et al.* (1995) [6] have recorded it within a range of 28–36%. There is no agreement as to the presence of retropyelic tributaries (types IB, IIB): Sampaio *et al.* (1990) [30], 69.2%; Satyapal *et al.* (1995) [6], 35.7%; Duques *et al.* (2002) [7], 14.7%, and our series, 11.2%. Our findings are consistent with the report by Satyapal *et al.* (1995) [6], that type IA is more frequent at the left side, whereas the presence of three anterior tributaries, *i.e.*, type IIA, is more frequent at the right side. The presence of a tributary that runs over the mid posterior surface of the renal pelvis increases its risk of injury during the removal of large stones from the pyelocalyceal system [30].

Conclusions

The incidence of additional renal veins observed in the present work falls within the intermediate range with respect to what has been indicated by prior studies. The dimensions of the renal veins are similar to those reported by most studies in the literature. The low incidence of the retroaortic and circumaortic expressions and of the posterior retropyelic tributaries could be a morphological trend of the Mestizo population evaluated. Knowing the variable expressions of the renal venous system allows for a better understanding of the clinical events in which these vessels are involved, and for a better surgical planning of the retroperitoneal compartment.

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Received: August 28, 2013

Accepted: January 30, 2014