

# Anatomic variations of the renal vessels: focus on the precaval right renal artery

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**Abstract** The aim of this study was to determine the prevalence of precaval right renal artery and to investigate the distribution of renal arteries and veins. We discuss a theory of development of renal vascular variants. We retrospectively reviewed 120 arterial phase contrast material-enhanced spiral computerized tomography scans of the abdomen (1- to 2-mm section thickness) performed during a two-month period. Forty percent of the study group (48 patients) had one artery and one vein on each side, with typical course. There was a 9.17% prevalence of precaval right renal artery: 10 patients had a lower pole accessory artery in precaval position and one patient had the main and the accessory arteries that pass anterior to the inferior vena cava. In these cases, associated variations of renal vessels were higher than in the patients without precaval artery variant. There were multiple arteries in 28.3% of the right kidneys and in 26.7% of the left ones. Variants of the right renal vein consisted in multiple veins in 20% (24 cases). We detected no case of multiple left renal veins, but we described variations of its course (circum- or retroaortic vein) in 9.17% (11 cases). Twenty-six patients (21.7%) had

associated variations of the renal pedicle. The current technical support allows for a minimally invasive study of vessels anatomy. In our study the prevalence of a precaval right renal artery appears to be higher than previously reported (9.17%). Knowledge on anatomical variations of right renal artery and associated renal vessels variations has major clinical implications.

**Keywords** Precaval right renal artery · Renal artery · Renal vein · Circumaortic renal vein · Retroaortic renal vein

## Introduction

The usual course of the right renal artery is posterior to the inferior vena cava. But it can also be precaval. The prevalence of this variation has been reported to be between 0.8% [8] and 5% [14]. The literature is poor about the prevalence of this variation of right renal artery. The radiological technical support allows precise study of renal vasculature. We aim to determine prevalence of precaval right renal artery and to study the variations of the number and course of renal arteries and veins.

## Materials and methods

### Patients

This single center study was conducted at the Hospital of Toulouse (France). We retrospectively reviewed computerized tomography (CT) scans made each Tuesday in May and June 2011. We chose this day because scans with thin cuts are made especially on this session. Written informed consent was not required for any component of our study.

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We reviewed a total of 329 CT scans. Patients with abdominal aortic prosthesis or aneurysm, history of kidney surgery, kidney atrophy and poor quality of the examination or enhancement were excluded.

The study group consisted of 120 patients, ranging between 21.7 and 93.4 years (mean age  $60.7 \pm 15.6$  years), including 41 women (mean age  $61.6 \pm 16.5$  years) and 79 men (mean age  $60.9 \pm 14.7$  years).

Indications for CT were: preoperative assessment of living kidney donor (10 cases), hepatobiliary–pancreatic diseases (11), abdominal trauma or emergency (14), cancer staging (39), and chronic and acute cardiovascular diseases (46).

## Methods

The same protocol was used for all CT scans: same multi-detector row CT (Siemens®), injection of intravenous iomeprol (Bracco Imaging France®, France), arterial phase of enhancement, 1- to 2-mm section thickness.

We included 120 CT scans with 18 1-mm section thickness CT scans (15%), 23 1.5-mm section thickness CT scans (19.2%) and 79 2-mm section thickness CT scans (65.8%).

One radiologist and one surgeon retrospectively reviewed all CT images with a picture archiving and communication system workstation (McKesson Corp., San Francisco, USA).

For both kidneys, the number and course of renal arteries and veins were recorded. The classical anatomical description of the renal pedicle consists in one artery and one vein for each kidney, with retrocaval course of the right renal artery and preaortic course of the left renal vein. Arteries arising from the aorta or from the iliac arteries and going to each kidney were considered to be renal arteries; it could be a main renal artery going to the hilum or an accessory artery for the lower or upper poles. Any renal artery that passed anterior to the inferior vena cava was considered as a precaval right renal artery.

## Statistical analysis

Statistical analysis was carried out using SAS software (version 9.1, Cary, NC, USA). Owing to the small number of patients, the Fisher's exact test was used to compare the proportion of morphologic variants between patients with precaval right renal artery and those without this anatomical variant. *P* value <0.05 was considered as statistically significant.

## Results

We examined 240 renal pedicles. All patients had their two kidneys. We found and excluded one case of a 33-year-old

man with a horseshoe kidney, with two renal arteries on each side, one main coming from the aorta, and one lower pole accessory artery arising from each common iliac artery.

Only 48 patients, 40% of the study group (35 men, 13 women), had the classical anatomical description, with one artery and one vein on each side, without variation of the course. The mean age of this group was  $60.3 \pm 16.6$  years.

We found 46 patients (38.3%) with isolated variations of renal vein or artery, distributed as follows:

- Isolated variations of the right renal artery (number and course variants): 16 cases (13.3%);
- Isolated variations of the left renal artery (number variants): 14 cases (11.7%);
- Isolated variations of the right renal vein (number variants): 12 cases (10%);
- Isolated variations of the left renal vein (course variants): 4 cases (3.3%).

The remaining 26 patients (21.7%) had associated variations of the renal pedicle, including one man with variants of both renal arteries and veins: he had four right renal arteries (1 main, 1 upper pole and 2 precaval lower pole arteries), two left renal arteries (1 main and 1 lower pole arteries), two right renal veins, a retroaortic left renal vein.

## Right renal artery

In our study, 11 of the 120 patients had a precaval right renal artery, with a prevalence of 9.17%. Of these 11 patients, 8 were men and 3 women. For the entire study group, we found a total of 162 right renal arteries (including main and accessory arteries) and 13 precaval arteries, with a prevalence of 8%. Anatomical disposition is summarized in Table 1. Among these 11 patients, one had an iliac ectopic right kidney (case 5, Fig. 1). The ten others had the right kidney in the lumbar region.

The precaval artery was single and accessory in seven patients. In these 7 cases, it was always a lower pole accessory artery while the main artery was retrocaval (Fig. 1).

The precaval arteries were double with one main and one accessory in one patient (Fig. 2).

There were 2 cases of patients with three right renal arteries: one of them had one main, one upper pole and one lower pole arteries with precaval course for the lower pole artery; the other had two lower pole accessory arteries with only one of those in precaval situation.

We found a case of a man with four right renal arteries (one main, one upper pole and two lower pole arteries) with precaval lower pole arteries.

There was no case of single and main precaval right renal artery or upper pole precaval artery.

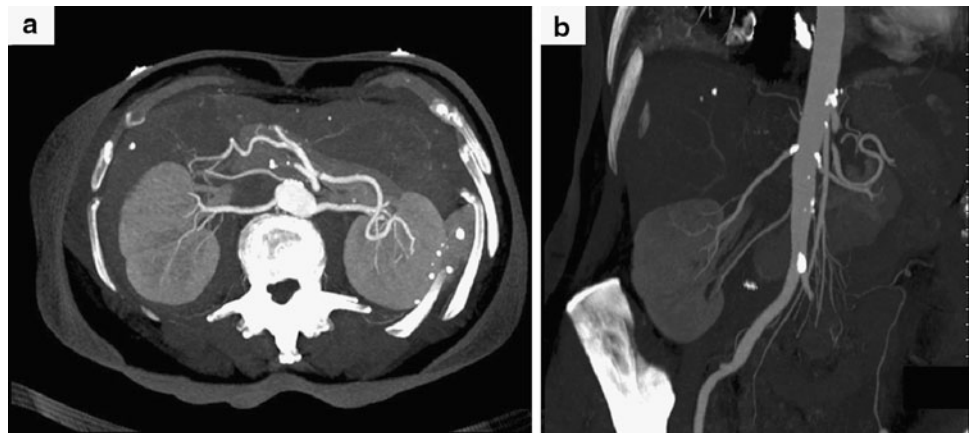
The proportion of patients with precaval renal artery who had course variants of the left renal vein (27%) was

**Table 1** Cases with precaval right renal artery and associated variations of renal pedicle

| Patients | Age (years) | Male/female | RRA (number)                                | Precaval position                   | LRA (number)               | RRV (number) | LRV (course)     |
|----------|-------------|-------------|---|-------------------------------------|----------------------------|--------------|------------------|
| Case 1   | 73.2        | F           | 1 Dominant<br>1 Lower pole                  | Dominant and<br>lower pole arteries | 1                          | 1            | Normal           |
| Case 2   | 72.1        | M           | 1 Dominant<br>1 Lower pole                  | Lower pole artery                   | 1                          | 1            | Normal           |
| Case 3   | 25.5        | M           | 1 Dominant<br>1 Lower pole                  | Lower pole artery                   | 1                          | 1            | Normal           |
| Case 4   | 22.0        | M           | 1 Dominant<br>1 Lower pole                  | Lower pole artery                   | 1                          | 1            | Retroaortic LRV  |
| Case 5   | 67.8        | F           | 1 Dominant<br>1 Lower pole                  | Lower pole artery                   | 1                          | 1            | Circumaortic LRV |
| Case 6   | 60.5        | M           | 1 Dominant<br>1 Lower pole                  | Lower pole artery                   | 1 Dominant<br>1 Lower pole | 1            | Normal           |
| Case 7   | 78.9        | F           | 1 Dominant<br>1 Lower pole                  | Lower pole artery                   | 1 Dominant<br>1 Lower pole | 1            | Normal           |
| Case 8   | 74.5        | M           | 1 Dominant<br>1 Lower pole                  | Lower pole artery                   | 1                          | 3            | Normal           |
| Case 9   | 54.4        | M           | 1 Dominant,<br>1 Lower pole<br>1 Upper pole | Lower pole artery                   | 1                          | 1            | Normal           |
| Case 10  | 65.1        | M           | 1 Dominant<br>2 Lower pole                  | Lower pole artery                   | 1 Dominant<br>1 Lower pole | 2            | Normal           |
| Case 11  | 51.2        | M           | 1 Dominant<br>1 Upper pole<br>2 Lower pole  | Lower pole arteries                 | 1 Dominant<br>1 Lower pole | 2            | Retroaortic LRV  |

RRA right renal artery, LRA left renal artery, RRV right renal vein, LRV left renal vein

**Fig. 1** Case 5. Spiral CT scan showing precaval lower pole artery, with retrocaval main right renal artery (**a** axial maximum intensity projection (MIP) image, **b** coronal MIP reconstruction)

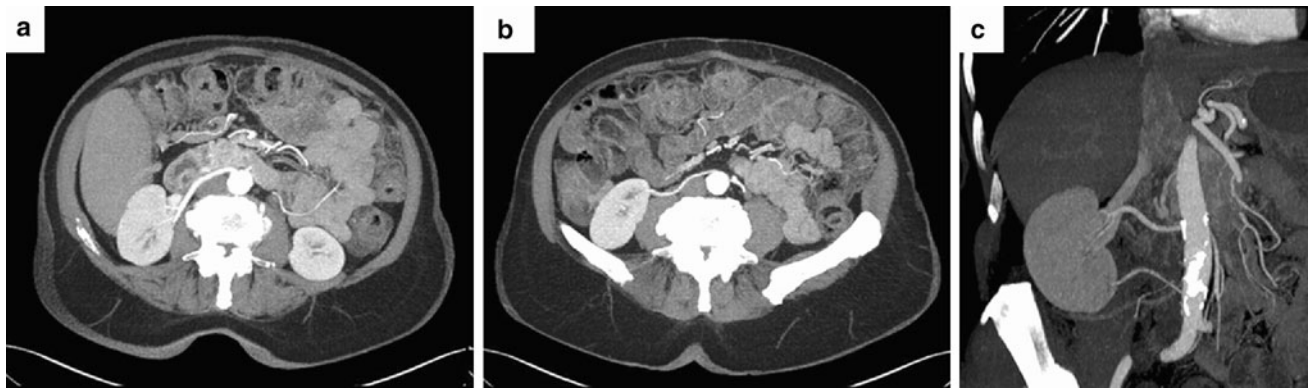


higher than that in the patients without precaval right renal artery (7%). This difference tends to be significant ( $P = 0.06$ ).

Except for the course of the right renal arteries, there were variations of the number of right artery in 34 cases (28.3%). Results are summarized in Table 2. Eighty-six patients had a unique artery (71.7%). Twenty-seven patients had two arteries (22.5%), one main and one acces-

sory: 20 cases of lower pole accessory artery, 7 cases of upper pole accessory artery. Six patients had three renal arteries (5%) and only one had four renal arteries.

In the 34 cases of multiple right renal arteries, 18 patients had associated variations of the renal pedicle: 13 had multiple left renal arteries, 4 had variations of the course of left renal vein and 2 had multiple right renal veins (one patient can have two of these variants). The remaining



**Fig. 2** Case 1. Spiral CT scan showing precaval main and lower pole right arteries (**a, b** axial MIP images; **c** coronal MIP reconstruction)

**Table 2** Number and repartition of renal arteries

| Number of arteries | Right kidney patients (%)   | Left kidney patients (%)  |
|--------------------|-----------------------------|---------------------------|
| 1                  | 86 (71.7)                   | 88 (73.3)                 |
| 2                  | 27 (22.5)                   | 30 (25)                   |
|                    | Upper pole artery 7 (5.8)   | Upper pole artery 9 (7.5) |
|                    | Lower pole artery 20 (16.7) | Lower pole artery 18 (15) |
|                    | Same caliber 0 (0)          | Same caliber 3 (2.5)      |
| 3                  | 6 (5)                       | 2 (1.7)                   |
| 4                  | 1 (0.8)                     | 0 (0)                     |
|                    | 120 patients                | 120 patients              |
|                    | 162 right arteries          | 154 left arteries         |

16 patients had isolated multiple right renal arteries (13.3%).

#### Left renal artery

We described variations of the number of left renal artery with a total of 154 left arteries for 120 left kidneys. The results are summarized in Table 2. The majority of the patients had a single left renal artery (88 patients, 73.3%). We found 30 cases of two renal arteries (25%): 18 cases of lower pole accessory artery, 9 cases of upper pole artery and 3 cases of codominant arteries with the same diameter in both arteries. There were 2 cases of triple left renal arteries (1.7%). No case of more than three left renal arteries was encountered. These multiple left renal arteries were isolated in 14 cases (11.7%).

#### Right renal vein

We found a total of 146 right renal veins in the study group of 120 patients. Indeed we detected 20% of variations of the number of right renal vein (24 cases), with two right

renal veins in 22 cases (18.3%) and three right renal veins in 2 cases (1.7%). There was no case of more than three right renal veins. Multiple right renal veins were isolated in 12 cases (10%).

#### Left renal vein

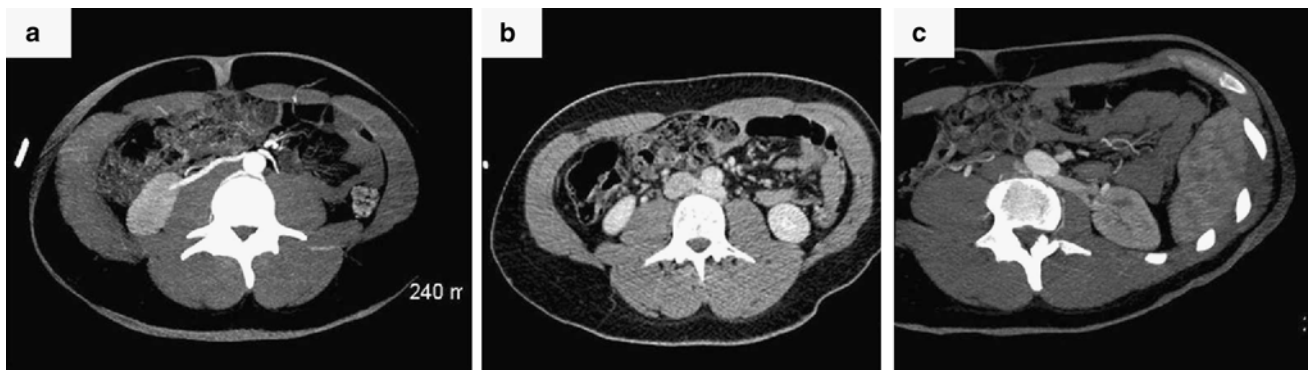
We found 9.17% of variation of the course of left renal vein. Actually we detected no case of multiple left renal veins. There were five men with retroaortic left renal vein (4.17%) and six patients (4 women, 2 men) with circumaortic left renal vein (5%). In the 11 patients, we found other ipsi- and contralateral variations in 7 patients:

- 4 cases with multiple right renal arteries, including 3 cases of precaval lower pole artery (Fig. 3);
- 2 cases of multiple left renal arteries;
- 3 cases of two right renal veins.

#### Discussion

In 1997, Petit et al. [8] asked: “Precaval right renal artery: have you seen this?”. This French radiologist found a 0.8% prevalence of precaval right renal artery. This result was based on abdominal ultrasounds or CT scans (6-mm cuts). The authors admitted that this prevalence might have been underestimated because the series was not consecutive and the sonography and conventional (thick cut) CT scans might have missed polar arteries.

In the 2000s, two studies, published by the same departments of urology and radiology, aimed to determine the prevalence of precaval right renal artery [7, 14]. The first one described 3 cases (0.6%) of precaval right renal artery (lower pole artery) on approximately 500 operative reports [7]. These were identified during laparoscopic and endourologic procedures. The authors noted features associated with precaval lower pole artery: bifid collecting system, enlarged kidney, normal renal position and rotation, normal



**Fig. 3** Case 4. Spiral CT scan showing precaval lower pole artery (a axial MIP image). Retroaortic left renal vein (b, c)

contralateral kidney, precaval lower pole artery dorsal to gonadal vein. They suggested that the discovery of an enlarged kidney and/or a bifid collecting system were evocative of precaval renal artery. However, we believe that the methodology used in this study can not identify every precaval right renal artery, especially during endourologic procedures. The second study was based on spiral CT scans with 2.5- to 7-mm section thickness [14], during the arterial phase in most cases, during the portal venous phase or delayed phase in others. Even if they found 5% prevalence, Yeh et al. thought that their study may underestimate the true prevalence (CT technique, thick cuts, enhancement phase, selection bias). In our study, CT acquisition and arterial enhancement technique were optimized so that they would be consistent, to accurately detect renal arteries and determine their position. We did not include CT scans with poor quality of enhancement or thick cuts. CT scans might then only miss accessory renal arteries smaller than 2 mm diameter.

As previously described [14], in our study, the precaval artery was commonly a lower pole accessory artery. We found only one case of a woman with main and lower pole arteries in precaval position. There was no case of precaval single artery and there are very few cases of these variants in the literature. Petit et al. [8] found 2 cases of unique precaval right renal artery, but CT technique may also have missed others right arteries. Radolinski et al. [9] described a case of a single right renal artery anterior to the inferior vena cava: that diagnosis was made on a CT scan for assessment before kidney donation. Left kidney was larger with multiple arteries and veins. The surgery confirmed this precaval position, which did not prevent a successful right laparoscopic donor nephrectomy and the dissection was also facilitated by this vascular right variant.

During embryonic development, the renal arteries result from a reduction of a series of lateral segmental arteries stemming from the aorta. These arteries originally supply blood to the mesonephric kidney [3, 6]. During migration of kidneys from pelvis to lumbar region, kidneys are vascu-

larised by those successive arteries, and the final position of the kidney determines the position and number of arteries. Complete reduction of the primitive arterial supply results in a single renal artery. Incomplete reduction can result in multiple arteries arising independently from the aorta [3]. A precaval right renal artery is likely the result of a persistent caudal vessel, arising ventrally from the aorta after formation of the inferior vena cava, but before gonadal vein descent [7]. The position of the kidney is interesting to consider regarding to the numbers and position of renal arteries. In our study, only one of the 11 patients with precaval right renal artery had an ectopic iliac kidney. There may be a very narrow window at 8 weeks of embryological development during which some process disturbs the highly complex development of renal vasculature and inferior vena cava [7]. This event may then induce anatomical variations such as precaval right renal artery, and could explain the higher proportion of associated venous variations.

Concerning the number of renal arteries, our results compare favorably to those of the literature. In our study, we found, respectively, 71.7 and 73.3% of unique renal artery on the right and the left kidney, and bilateral multiple arteries in 10% (12 cases). In the 1970 s, Gray already reported a meta-analysis with 71.1% prevalence of unique hilar artery [3]. More recently, Satyapal et al. [11] found that additional arteries occurred in 28%, with predominance on the left side, and 10.2% of bilateral variants. They also calculated, from a review of 71 investigations reported in the literature, an average incidence of additional renal arteries of 28.2% with 11.4% of bilateral variants, results which are similar to ours.

In the classical description of renal vasculature, left renal vein is preaortic, but variations as retroaortic or circumaortic veins occur. Retroaortic left renal vein is the left renal vein which passes posteriorly to the aorta before joining the inferior vena cava. Circumaortic or collar left renal vein is the left vein with preaortic and retroaortic courses, doing a collar around the aorta, before joining the inferior vena cava.

Variations of the left renal vein are well documented in the literature, as well as on cadavers [10] and on MRI [2]. The most recent study was made by magnetic resonance imaging [2] and shows 1.66% of retroaortic left renal vein and 1.02% of circumaortic left renal vein, with no gender difference. But in CT scans, slice thickness and spatial resolution of MR imaging may be insufficient to visualize the course of the vein: real prevalence of vein variations can then be underestimated.

Mechanisms of left renal vein variants seem to be understood despite the complex embryologic development of the renal vasculature. From the fifth to seventh week of embryological period, subcardinal veins develop and right and left subcardinal veins present median anastomosis [3]. Embryologically, there is a circumaortic renal venous collar formed by the ventral subcardinal anastomosis, the dorsal supracardinal anastomosis and by right and left sub-posterior cardinal anastomosis [10]. By complex balances of development and regression, the right subcardinal vein forms distal part of the inferior vena cava and the transverse ventral anastomosis becomes the left renal vein [6]. Retroaortic and circumaortic left renal veins are the results of uncommon persistence or regression of one of the anastomoses [1, 2, 10].

Knowledge of anatomical variants of renal vasculature is crucial and this study puts the emphasis on variations of course and number of renal vessels. It has major clinical implications in practice and it contributes to the safety of renal and retroperitoneal surgery. Thin cuts CT scans must remain the gold standard for preoperative assessment before laparoscopic donor nephrectomy, which is the standard of care for the procurement of allografts from potential living kidney donors [4, 5, 12]. This noninvasive imaging modality has a sensibility and accuracy of 100% for the detection of accessory arteries and major renal venous variants (multiple veins, circum- or retro-aortic left renal vein) [13].

## Conclusion

In summary, we found a higher prevalence of precaval right renal artery (9.17%) than that described in the literature. We want to highlight not only the course variations of right renal artery but also those of the left renal vein. Indeed, we are wondering about the prevalence of course variations of the left renal vein (9.17%), especially when one considers that the left kidney is preferred for the procurement of living kidney donors to have an adequate length of vasculature for

anastomosis in the recipient. We believe that variations of course and number of renal vessels are not so uncommon and should be known by radiologists and also by surgeons.

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**Conflict of interest** The authors declare that they have no conflict of interest.

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