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# The renal veins: a review

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## Summary

In clinical anatomy, the renal venous system is relatively understudied compared to the arterial system. The great complexity of the patterns and inter-relationships of the arteries and veins of the kidney is demonstrated by gross anatomical dissection and clinical practice. This review of several renal vein investigations aims to clarify and update the variable patterns of the renal venous vasculature using cadaveric human adult and foetal kidneys and to reflect on its clinical application, particularly in surgery and radiology. The study employed gross anatomical dissection and detailed morphometric and statistical analyses on resin-cast and plastinated kidneys harvested from adult and fetal cadavers. Radiological techniques were used to study intra-renal flow, renal veins and collateral pathways and renal vein valves.

The gross anatomical description of the renal veins and its relations were confirmed and updated. Additional renal veins (ARV) were observed much more frequently on the right side (31%). A practical classification system for the renal veins based on the number of primary tributaries, ARV and variations is documented. Detailed morphometric analyses of the previous parameters of the renal veins corroborated and expanded previous anatomical studies. Contrary to standard anatomical textbooks, it is noted that the left renal vein is 2.5 times the length of its counterpart and that there are variable levels of entry of the renal veins into the inferior vena cava (IVC). Radiological investigations demonstrated a non-segmental and non-lobar intrarenal venous architecture, an absence of renal vein valves, and extensive venous collaterals centering mainly on the left renal vein (LRV). These collateral channels, present in the fetus and persisting in the adult, may be of operative and clinical significance in several pathological states. The applied clinical anatomy of these findings with particular regard to renal surgery and uro-radiology is emphasized.

**Key words:** Renal veins – Review – Variations – Morphometry – Classification

## Introduction

Although the renal arterial system has been the topic of repeated anatomical investigations, statistical analyses and descriptions, there is a lack of similar exhaustive studies addressing the renal venous architecture. Most textbooks and many medical anatomical publications misrepresent the internal anatomy of the kidney, thus perpetuating previous misconceptions and positively misleading readers in other respects (Hodson, 1978). Each pair of kidneys is as individual as its owner's fingerprints. The following description is a review encompassing the researchers' investigations into several different aspects of the renal venous vasculature over the past 7 years. The review expands and corroborates this anatomy, which may be of use to both anatomists and clinicians. The following areas of renal venous anatomy are presented as detailed subsets, viz.:

i) morphometry of left (LRV) and right renal veins (RRV);
ii) renal vein valves;
iii) renal vein variations;
iv) left and right infra-renal angles, entry level of renal veins into inferior vena cava (IVC)

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and height of IVC under renal vein influence and their vertebral level;

v) classification of the renal veins and their drainage patterns;

vi) intra-renal and collateral venous flow emanating from and around renal veins in the adult and fetus

A glossary of terms is also presented.

## i) Morphometry

Although the renal veins have been the topic of repeated anatomical investigations, statistical analyses, and descriptions, it is surprising to find that there is no consensus in the literature regarding their detailed morphometry. Such information acquires special surgical significance: e.g., in renal transplantation and "shunt" surgery (Satyapal et al., 1995a).

This study subset details the measurements of the renal veins in 100 pairs of morphologically normal cadaveric kidneys. Resin casts of the venous system were prepared and various segments of the renal veins were measured.

The length and diameter were as follows: LRV: 5.9 ± 1.5 cm and 1.2 ± 0.2 cm; and RRV: 2.4 ± 0.78 cm and 1.2 ± 0.2 cm, respectively. The LRV comprised a proximal segment (length: 2.6 cm; diameter: 1.1cm) and a distal segment (length: 3.2 cm; diameter: 1.2cm) (Satyapal et al., 1995a). ARV measurements (cm) were: Length and diameter of first left: 5.5 ± 0.5 cm and 0.9 ± 0.1; right 2.5 ± 1.1, 0.7 ± 0.2; second ARV: 2.4 ± 0.9 and 0.7 ± 0.2 (right only), respectively.

Although the length of the renal veins in this study compares favorably with the literature reviewed, Williams et al. (1995) reports a higher value of 7.5 cm for the LRV. Furthermore, the length of the LRV is 2.5 times the length of the RRV unlike that quoted by Williams et al. (1995) where the "left is three times the right in length." The length of the LRV available for surgical manipulation is notably shorter than that reported in standard anatomy textbooks.

## ii) Renal vein valves

There is disagreement in the literature concerning the presence of renal vein valves. Of the literature reviewed, 12 studies have described valves in renal veins while 8 have denied their existence.

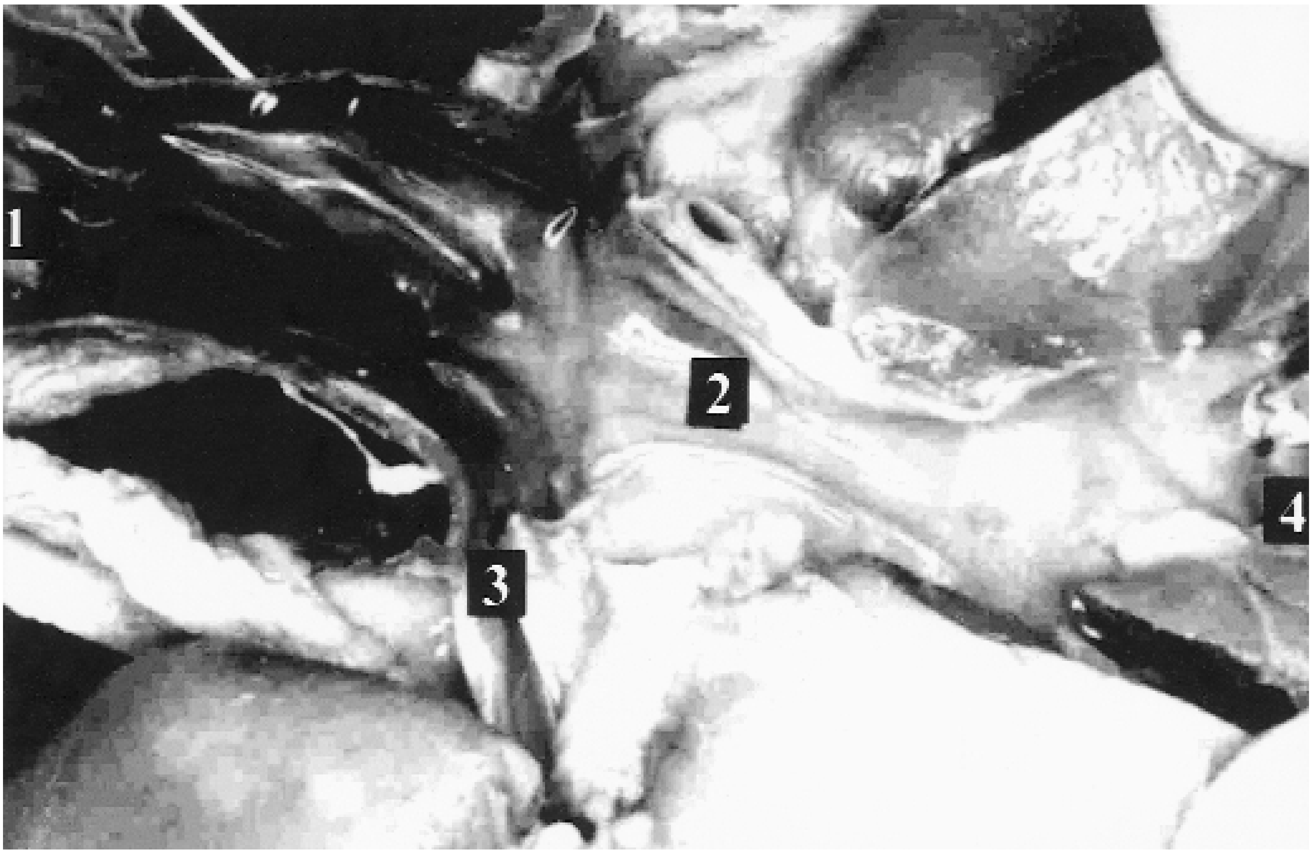


**Figure 1.** Left renal vein demonstrating an absence of valves. 1: Left renal vein. 2: Lower primary tributary. 3: Middle primary tributary. 4: Interlobular vein.
**Please note that this figure has been published as Figure 3 in the following reference:**
Satyapal KS and Kalideen JM (1996). Absence of renal vein valves in humans and baboons. *Ann Anat*, 178: 481-484.

This study subset aimed to determine the presence of renal vein valves.

Fifty-six cadaveric human adult and 11 human fetal morphologically normal fresh kidney pairs were subjected to radiological investigation as well as to macroscopic and microscopic examination.

Renal venograms, macroscopic, microscopic, as well as histological examinations failed to reveal the presence of renal vein valves in the intra-and extra-renal veins in any of the specimens (Fig. 1) (Satyapal and Kalideen, 1996).

The radiological and anatomical literatures disagree about the presence of renal vein valves. Where valves have been reported, there is a striking variation in their frequency (28-70% on the right; 4-36% on the left) (Rivington, 1873; Fagarasanu, 1938; Ahlberg et al., 1968; Takaro et al., 1970). Ahlberg et al. (1968) noted that there was a tendency towards a higher incidence of valves in renal veins supplied by gonadal veins without valves than by those with valves. Valves of the intra-renal branches were observed in 40% of cases (Kugelgen and Greinemann, 1958). The latter authors describe renal vein valves as being present in all age groups but acknowledge that partial involution may occur in adult life based on their finding of better developed valves in newborns and children. However, partial involution of these valves from fetal to adult life, as claimed by these authors, was not apparent in this study since they were absent even in the fetal kidneys.

Oleaga et al. (1978) and Beckman and Abrams (1978) emphasized that renal vein valves may create technical difficulties during renal venography. Should valves be present, the inability to demonstrate them may be due to the fact that they are very thin, often rudimentary, and may easily be overlooked and obscured in the venogram (Takaro et al., 1970; Beckmann and Abrams, 1980).

### iii) Renal vein variations

The complex embryological development of the renal veins accounts for the following variations: viz. ARVs and, on the left side, circum-aortic renal collar and retro-aortic renal veins. In order to avoid confusion in the nomenclature of these variations, definitions are provided (see glossary). When present, they hold important surgical and therapeutic implications. Their incidence also varies widely (Satyapal et al., 1999).

This study subset aimed to identify renal vein variations and document their incidence. The study comprised two subsets: cadaveric dissections including phlebography, and *in-vivo* clinical series to identify variations of the renal veins. The materials of the study included: a) *A Cadaveric Study*: Harvesting and dissection of 153 pairs of morphologically normal kidneys. Of these, 53 pairs were injected with differently colored latex to demonstrate the venous, arterial and pelvicalyceal systems and subsequent plastination using a modification of the von Hagens technique (1985). The remaining 100 pairs were injected with similarly colored polyester crystic resin and casts were prepared according to the method of Tompsett (1970). Renal venography *(in situ)* was performed on 58 adults and 20 fetuses. b) *Clinical Study:* A retrospective study comprising: i) a radiological study performed between 1974 and 1994, this yielded 104 renal venograms; ii) live related renal transplantation operations; performed between 1990 and June 1997, these yielded 148 donor left kidneys and iii) patients undergoing abdominal aortic aneurysm surgery between 1987 and 1997, yielding 525 cases, were analyzed. The total sample size was 1008.

Incidence of variations: *Additional renal veins:* Single ARVs were common on the right side (26%), while they were rare on the left side (2.6%). Second ARVs occurred infrequently on the right side (5%). (Fig. 2); *Renal collar:* 0.3% (Fig. 3); *Retroaortic vein:* 0.5% (Fig. 4) (Satyapal et al., 1999).

The kidney develops in a highly complex plexiform vascular environment. The circum-aortic renal venous collar comprises a ventral intersubcardinal anastomosis and a small part of the right and left sub-posterior cardinal anastomoses (McClure and Butler, 1925). On either side, the right and left sub-supracardinal anastomosis forms the ring, while dorsally it is completed by the inter-supracardinal anastomosis. The ventral portion of the circum-aortic plexus usually persists as the normal LRV. If the dorsal portion of the plexus persists, then the LRV is posterior to the aorta (retro-aortic renal vein). If both the dorsal and the ventral portions persist, there will be a circum-aortic venous collar in the adult (Mitty, 1975). The recorded incidence of renal vein variations varies widely and our results differ significantly from those reported in the literature: a) renal collar- 0.3% *vs.* median 5.7%, with a range of 0.2%-30%; b) retro-aortic vein- 0.5% *vs.* median 1.8%, with a range of 0.8%-7.1%; c) ARV-right: 29.3% *vs.* median 19.5%, with a range of 8.0%-28.0%, left: 0.4% *vs.* median 2.3%, with a range of 0.8%-6%.

Variations are clinically silent and remain unnoticed until discovered during operation or autopsy. To the transplant surgeon, the morphology of the renal vessels is of special significance, since variations and anomalies may strongly influence the technical feasibility of the operation. Prior knowledge of a circum-aortic venous ring is important when blood samples from the suprarenal or renal veins are to be collected. A circum-aortic venous ring may provide

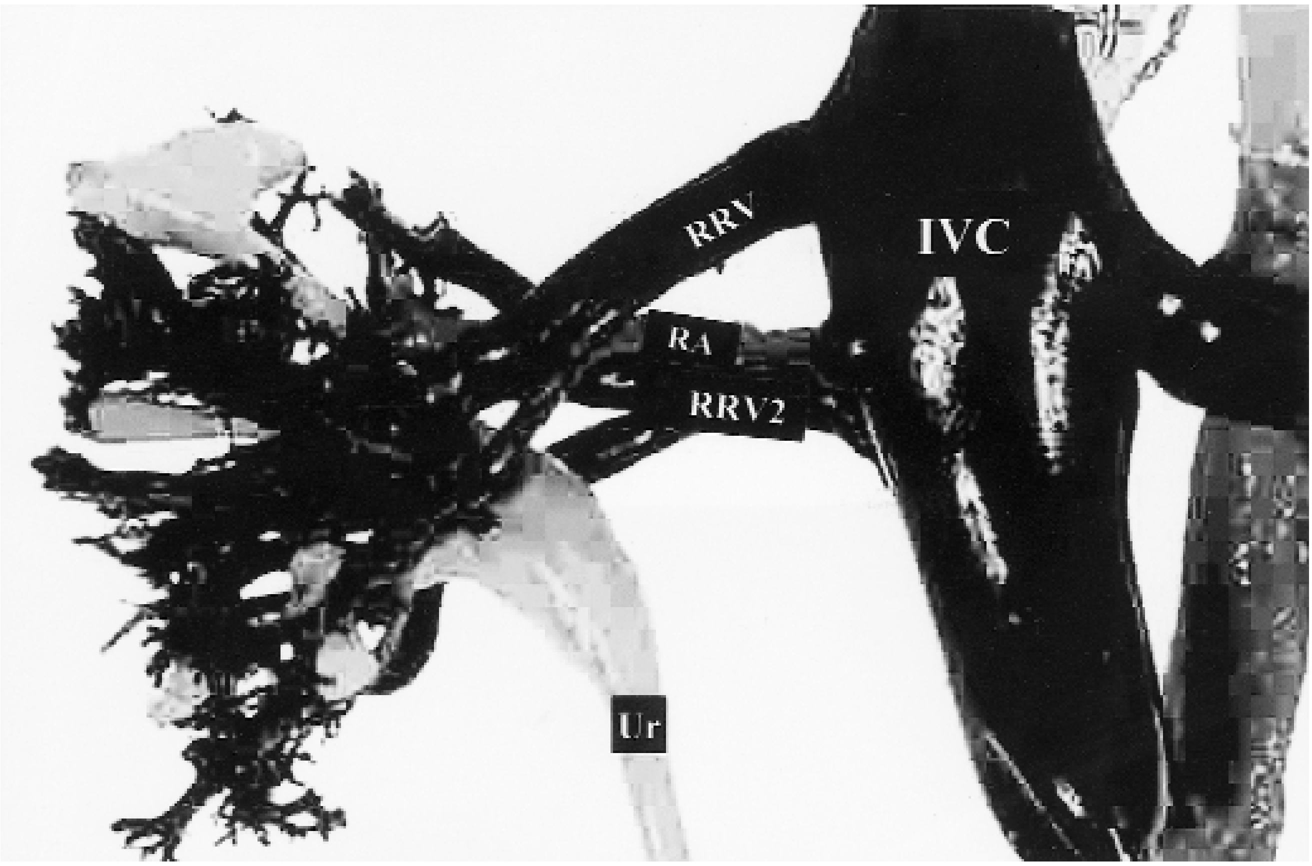


**Figure 2.** Anterior view of resin cast demonstrating an additional renal vein. RRV: Right renal vein; RRV2: Additional right renal vein; RA: Renal artery; IVC: Inferior vena cava; Ur: Ureter.
**Please note that this figure has been published as Figure 1 in the following reference:**
Satyapal KS, Rambiritch V and Pillai G (1995). Additional renal veins: Incidence and morphometry. *Clin Anat,* 8: 51-55.

a fully developed collateral pathway immediately after surgery if caval interruption is planned without awareness of its presence (Krause et al., 1963; Piccone et al., 1970). Therefore, a careful search for this anatomic anomaly must be made by renal venography before operation. Further surgical significance of the occurrence of these congenital variations is that they restrict the availability of the LRV for mobilization procedures (e.g. spleno-renal shunts) and reduce the

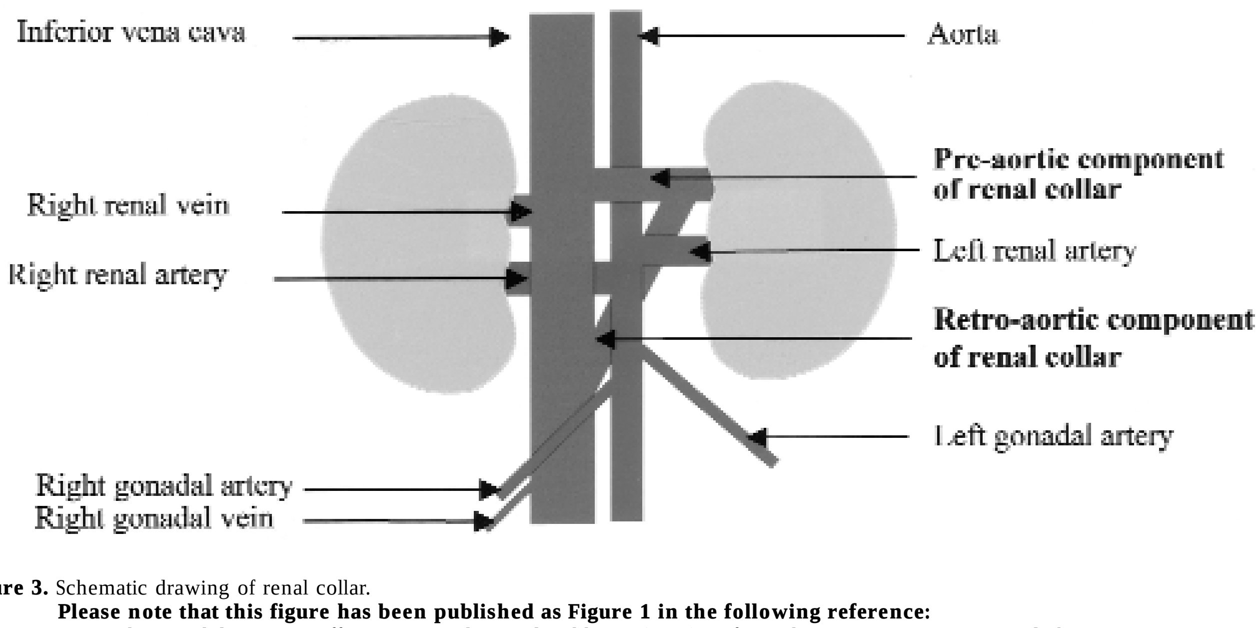


**Figure 3.** Schematic drawing of renal collar.
**Please note that this figure has been published as Figure 1 in the following reference:**
Satyapal KS, Kalideen JM, Haffejee AA, Singh B and Robbs JV (1995). Left renal vein variations. *Surg Radiol Anat,* 21: 77-81.

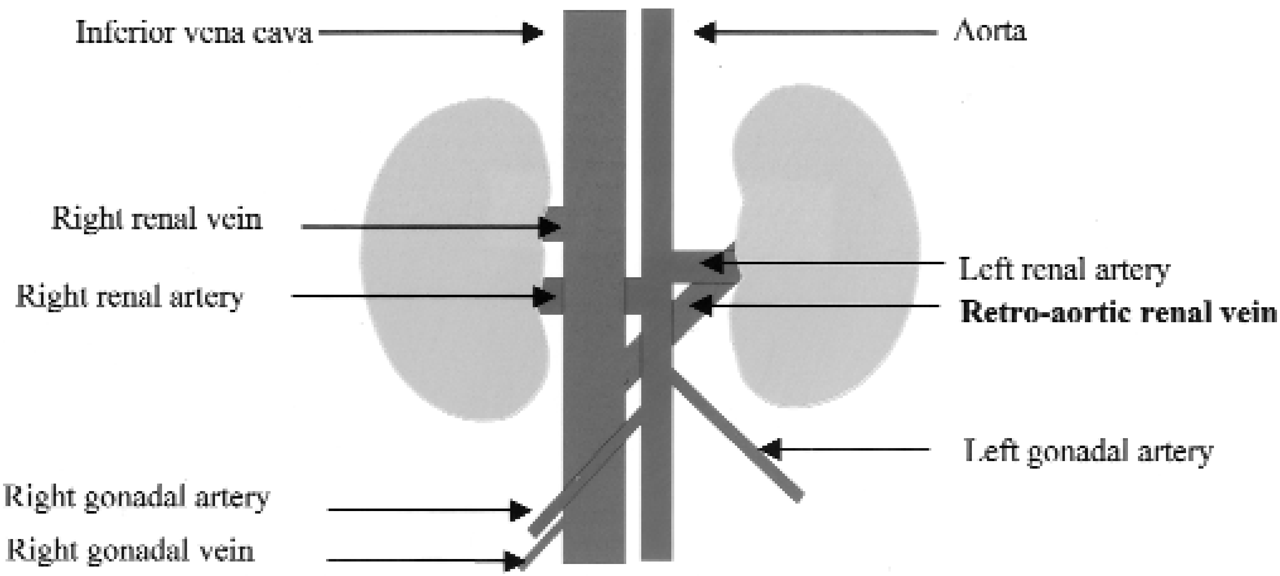


**Figure 4.** Schematic drawing of retro-aortic vein.
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Satyapal KS, Kalideen JM, Haffejee AA, Singh B and Robbs JV (1995). Left renal vein variations. *Surg Radiol Anat,* 21: 77-81.

advantages that normally accrue from their greater length (e.g. left renal transplant) (Davis and Lundberg, 1968). In repair of an abdominal aortic aneurysm where the aorta is mobilized, the retro-aortic vein becomes especially important. During retro-peritoneal surgery, the surgeon may visualize a pre-aortic vein but may be unaware of an additional retro-aortic component or posterior primary tributary and may tear it while mobilizing the kidney or clamping the aorta (Warren et al., 1972, 1974; Mitty, 1975). Furthermore, as previously indicated these variations require appreciation especially since laparoscopically assisted nephrectomy is performed with increasing frequency (Katoh et al., 1995).

There is considerable discrepancy concerning the incidence of renal vein variations. Although they are clinically silent, recognition of these uncommon variations is desirable prior to therapeutic and research decisions. Pre-operative knowledge of these anomalies is advantageous prior to nephrectomy, caval interruption procedures, aortic aneurysm corrective surgery, and porto-caval shunts.

### iv) Infrarenal angles

Standard textbooks tend to perpetuate old misconceptions regarding renal anatomy (Hodson, 1978). The classic description of Williams et al. (1995) states that "Renal veins, … open into the IVC almost at right angles. The LRV enters the IVC a little superior to the right".

This study subset aimed to determine left and right infra-renal angles (L-IRA, R-IRA); the entry level of renal veins into the IVC and the height of the IVC under renal vein influence, and their vertebral level.

One hundred morphologically normal *en-bloc* renal specimens were randomly selected from post-mortem examinations, dissected, and resin-cast. IRA were also measured from the venograms of 32 adult and 11 fetal cadavers, as were their vertebral entry levels.

The results of the IRA measurements (degrees) were L: 55º ±16º (20º-102º), R: 60º±17º (10º-93º) (Fig. 5). The left vein entered the IVC higher than the right vein - 54%, lower - 36%, opposite each other - 10%. The vertical distance between the lower borders of the veins was 1.0 ± 0.9 cm. The vertical distance of the IVC under renal vein influence was 2.3 ± 1.0 cm. The vertebral level of veins in adults lies between T12-L2. In fetuses the IRA was L: 65º±12º (45º-90º), R: 58º±7º (40º-70º); the vertebral level was between T12 - L3 (Satyapal, 1999).

From a review of the literature, similar IRA values were noted on the right, 51º (26º-100º) (Abrams et al., 1964; Kahn, 1969; Beckmann and Abrams, 1980); differences were observed on the left, 77º (43º-94º) (Abrams et al., 1964; Kahn, 1969; Lein and Kolbenstvedt, 1977), clearly differing from the report by Williams et al. (1995) that renal veins "open into the inferior vena cava almost at right angles." Large variations in IRA are not surprising since kidneys are normally considered to be "floating viscera", varying their position with posture and respiratory movements as well as being different in live *vs.* cadaveric subjects. The entry level into the IVC also differs from what was reported by Williams et al. (1995). This study only quantitated the actual

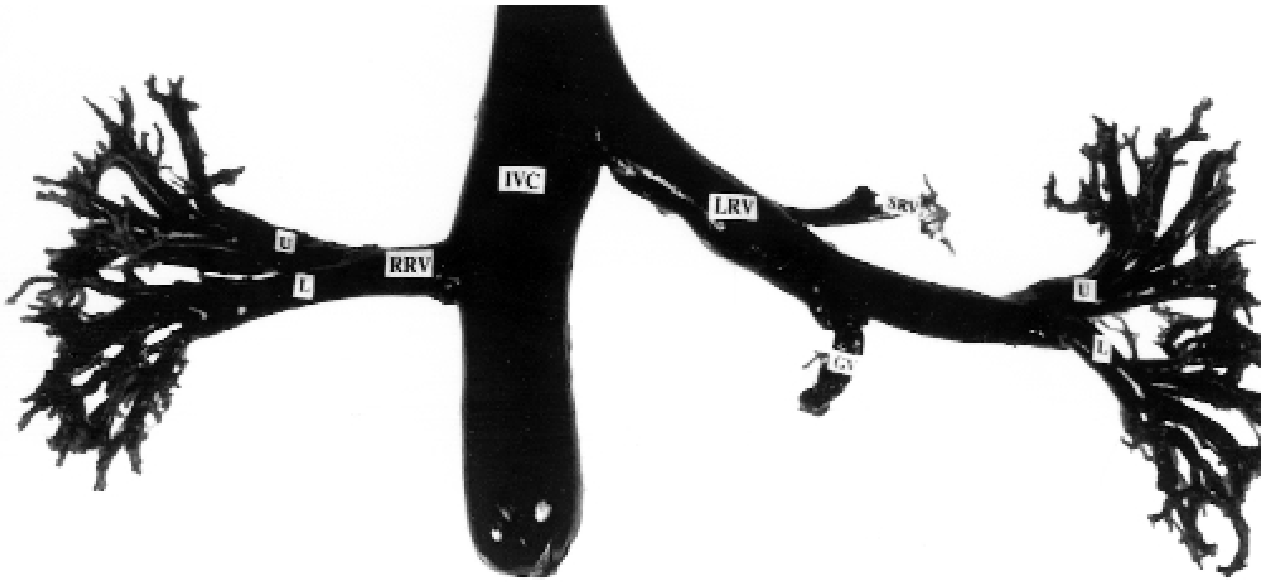


**Figure 5.** Anterior view of resin cast demonstrating infra-renal angles and vertical distance differences of the left and right renal vein entry into the IVC.
**Please note that this figure has been published as Figure 1 in the following reference:**
Satyapal KS (1999). Infra-renal angles, entry into inferior vena cava and vertebral levels of renal veins. *Anat Rec,* 256: 202-207.

height difference between the lower borders of the left and right veins. The data presented appear to be the first documentation of the vertebral level of entry of the renal veins into the IVC in fetuses. These findings are clinically important for the angiographer, catheter design, and the planning of portal-renal shunt procedures (Satyapal, 1999).

## v) Classification of the drainage patterns of the renal veins

Variations in the drainage patterns of renal veins are well documented. This study subset aimed to formulate a practical classification of their drainage patterns taking into consideration the number of primary tributaries, ARVs, and variations.

The venous system of 306 kidneys obtained from 100 pairs of resin casts and 53 pairs of plastinated kidneys were analyzed.

Based on a proposed definition of the renal vein (see glossary), three major types (I, II, III) were identified using the drainage pattern of the primary renal vein tributaries and the renal vein as a basis on both the left and right sides (Fig. 6) (Satyapal, 1995). Type IA occurred most frequently (38.6%) and was commoner on the left. Type IB was the second most frequent (25.2%), the other types showing lower and similar frequencies (10.1-14.4%). Statistically significant differences were noted between the left and right kidneys with regard to the classification into the different types ($P<0.0001$). The proposed classification system is practical and has surgical and uro-radiological relevance (Satyapal, 1995).

## vi) Intra-Renal and collateral venous drainage patterns

The LRV, which is situated at the core of an impressive set of venous plexuses and veins, has been elevated to the status of prime importance to the clinician. It may be explored by catheterization, phlebography, ultrasonography, scintigraphy, computerized tomography and magnetic resonance imaging (Gillot, 1978). This vein is a principal element on which several surgical techniques have focused, especially during procedures involving ruptured aortic aneurysms and left renal artery angioplasty without significantly impairing the function of the left kidney (Simeone and Hopkins, 1967; Szilagyi et al., 1969). This is facilitated by renal vein collaterals that adequately maintain the function of the left kidney. Furthermore, an awareness of the renal vein and IVC collaterals are of significance to the interventional radiologist.

These include the inferior phrenic and suprarenal tributaries, which enter from above, while from below and to the side come the gonadal, capsular, lumbar, and ascending lumbar veins and an anomalous vena cava (when present) (Anson and Cauldwell, 1947; Davis et al., 1958). Additionally, communication is made with the azygos veins (usually through lumbar veins) and with the extensive set of internal and external vertebral plexuses by way of interver-

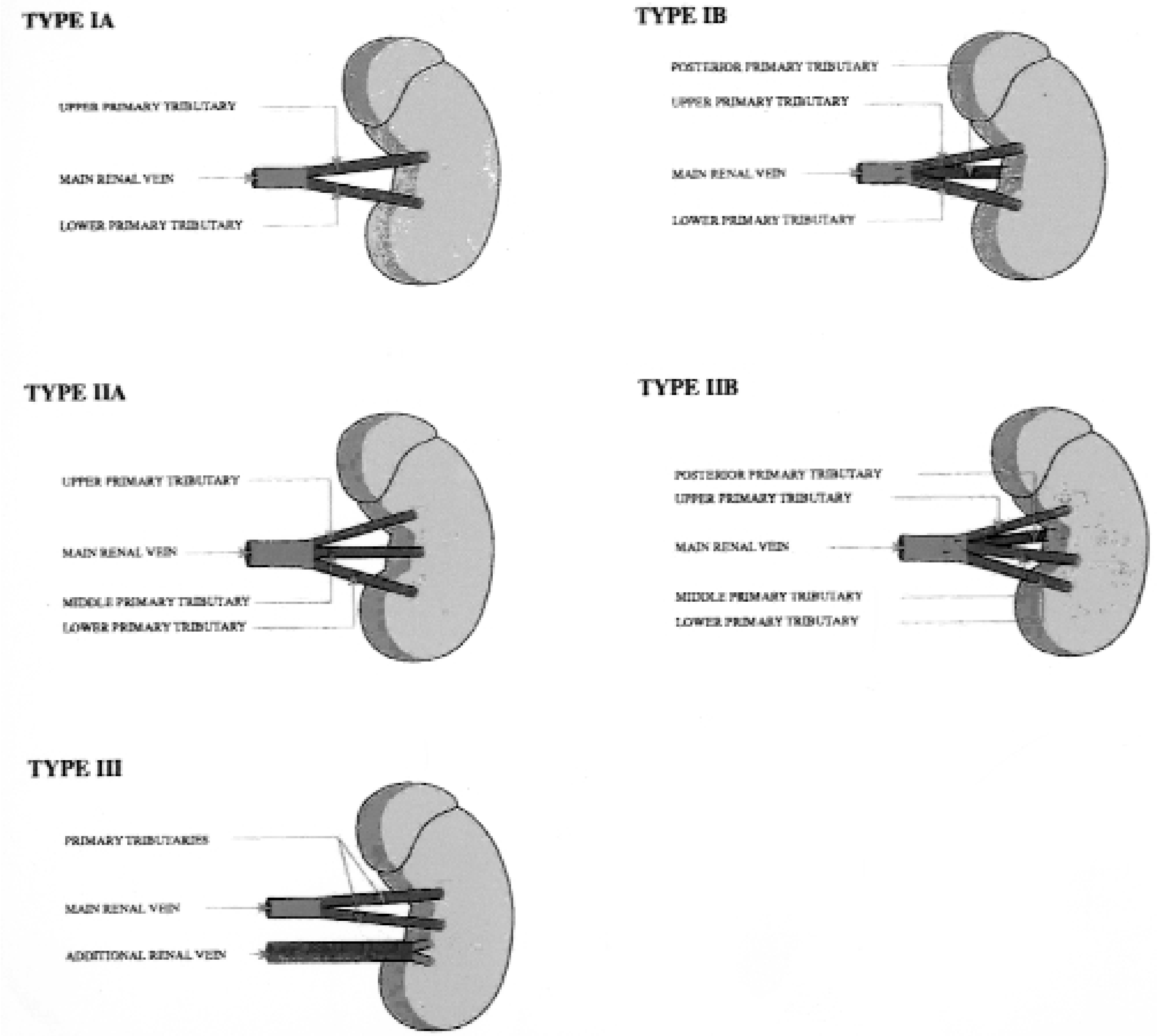


**Figure 6.** Classification types of renal venous drainage patterns.
**Please note that this figure has been published as Figure 1 in the following reference:**
Satyapal KS (1995). Classification of the drainage patterns of the renal veins. *J Anat*, 186: 329-333.

tebral and lumbar veins. At the intrarenal level, impressive veno-venous anastomoses exist (Smith, 1963).

The study subset aimed to investigate the intra-renal and collateral flow emanating from and around the renal veins in the adult and fetus.

Fifteen pairs of morphologically normal adult kidneys obtained from post-mortem specimens were included in this anatomical-radiological investigation. Experimental venous occlusion was performed along several venous pathways under the influence of the renal veins in 11 fetuses. Radiological techniques were used to investigate intra-renal and renal venous collateral flow.

Radiological investigations revealed a non-segmental and non-lobar intra-renal architecture. Furthermore, experimental venographic investigation revealed that LRV opacification was consistently achieved via extensive suprarenal, renal, and infrarenal collateral channels when contrast was perfused with proximal or distal occlusion in both adults and fetuses. Prograde and retrograde collateral flow was also achieved when the LRV per se was contrast-perfused (Fig. 7). The RRV contributed little towards collateral flow when directly perfused in a similar manner. Perfusion of a single primary tributary of the LRV with distal occlusion revealed a filling of the remaining primary tributaries via rich intrarenal anastomotic pathways. In the fetuses where the IVC below and above the renal veins was ligated, including ligation of the LRV, minimal lumbar vein filling was noted from the RRV. Ligation of the venous pathways at several sites thus showed that the

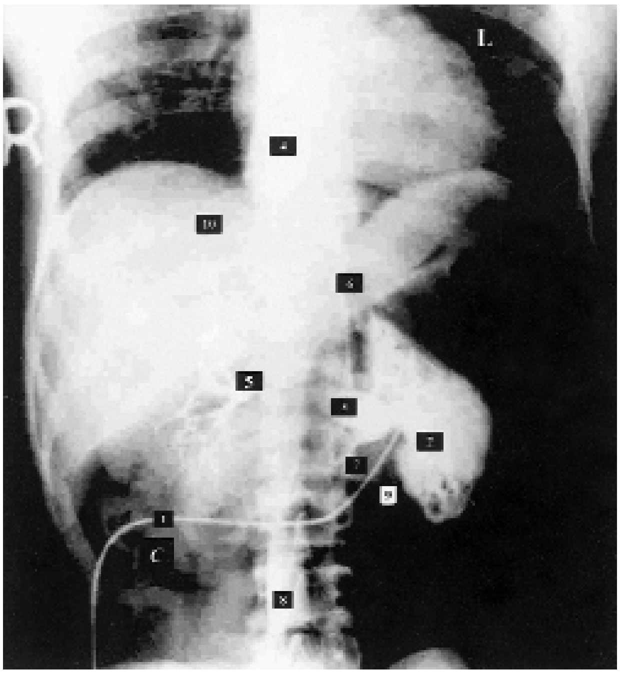

**Figure 7.** The left renal vein was ligated in the proximal segment, excluding the suprarenal and gonadal veins. The catheter was placed in the lower primary tributary and sequential radiographs were exposed following a steady perfusion of contrast. Via the lower primary tributary (through rich arcuate collateral channels), the proximal segment of the main renal vein (which contributed to collateral filling of the ascending lumbar in a retrograde direction) was filled. There was prograde filling of the azygos system. Further perfusion filled the azygos arch, superior vena cava, right atrium, hepatic portion of IVC, RRV, and sub-renal IVC. Early filling of the capsular vein on the left and hepatic vein are demonstrated. 1: cannula; 2: left renal venogram; 3: left renal vein; 4: right atrium; 5: right renal vein; 6: azygos system of veins; 7: ascending lumbar vein; 8: inferior vena cava; 9: capsular vein; 10: hepatic vein.
**Please note that this figure has been published as Figure 2c in the following reference:**
Satyapal KS and Kalideen JM (1994). The left renal vein: a major collateral system. *Clin Anat,* 7: 352-356.

collateral pathways are constituted by the renal-lumbar-azygos-vertebral axis. The infrarenal pathway was predominantly via the ascending lumbar and vertebral plexuses. The suprarenal pathway was via the azygos-vertebral axis (Satyapal and Kalideen, 1994).

Venographic analysis of the 15 pairs of kidneys demonstrated the adequacy and potential capacity for collateralization, particularly on the left side. These channels, which are central to the renal veins, play a pivotal role in pathological states of the kidney. In this regard, the formation of collateral venous circulation as a consequence of renal vein thrombosis is of clinical significance (Greweldinger et al., 1969; Itzchak et al., 1973).

One of the factors contributing to the viability of the kidney is the efficiency of the collateral veins. Since the collateral flow is more abundant on the left than on the right side, it is postulated that in the presence of renal vein thrombosis these preferential collateral veins may help to preserve renal function on this side.

Furthermore, haematogenous metastasis from carcinoma of the kidney associated with renal vein thrombosis may be expected to be more common and numerous on the left side. The higher incidence of peri-ureteric and renal vein varices on the left (Eisen et al., 1965; Weiner et al., 1974; Beckman and Abrams, 1982) may be explained by the increased collateralization that occurs on the left side. The predominance of collateral veins relating to the left kidney rather than the right one may be explained on the basis of developmental theories (Plummer, 1913; De Beer, 1966; Gillot, 1978). In morphologically normal kidneys, these channels may be operative and of clinical significance in disease states. The presence of collateral veins explains the constellation of clinico-radiological findings in pathological states. Extensive venous collaterals centering on the LRV exist. These collateral pathways are constituted by the renal-lumbar-azygos-vertebral axis. The infra-renal pathway is predominantly via the ascending lumbar veins and the vertebral plexuses. The suprarenal pathway is by the azygos-vertebral axis. The capsular and peri-ureteric venules provide an intra/extra renal communication. In this series, the major contributor of these collateral pathways was from the LRV, while the RRV contributed little, if any, to the collateral channels.

## Conclusions

*i) Morphometry*

This morphometric analysis of the renal veins, which corroborates and expands previous anatomical studies, has embryological and surgical significance. The LRV is 2.5 times the length of its counterpart.

*ii) Renal vein valves*

Whilst fully acknowledging the lack of consensus concerning the presence of renal vein valves, this study failed to corroborate their presence.

*iii) Renal vein variations*

The incidence of renal vein variations observed in this study is discussed and compared with that reported in the literature – (a) renal collar 0.3% *vs.* median 5.7%, with a range of 0.2%-30%; (b) retro-aortic vein 0.5% *vs.* median 1.8%, with a range of 0.8%-7.1%; ARV-right: 29.3% *vs.* median 19.5%, with a range of 8.0%-28.0%, left: 0.4% *vs.* median 2.3%, with a range of 0.8%-6%. The broad discrepancy in the incidence of these variations warrants further epidemiological analysis. It should be stressed that the presence of these renal vein variations in particular must be acknowledged since they are of significant clinical importance.

*iv) Infra-renal angles*

The cadaveric infra-renal angles on the right of 55º±16º and on the left of 60º±17º are different from the 90º suggested by standard textbooks of anatomy. The LRV entered the IVC higher than the right in 54% of cases; lower in 36%, and opposite each other in 10% of cases. The vertical distance between the lower borders of the renal veins was 1.0 ± 0.9 cm. The vertical distance of the IVC under renal vein influence was 2.3 ± 1.0 cm. The vertebral level of the renal veins in normally situated adult kidneys lay between T12 and L2 and, in foetuses, between T12 and L3. These differences can be accounted for in terms of vertebral growth characteristics. This study only quantitated the actual height difference between the lower borders of the left and right veins. The data presented appear to be the first documentation of the vertebral level of entry of renal veins into the IVC in foetuses. These findings are clinically important for the angiographer, catheter design, and planning the portal-renal shunt procedures.

*v) Classification of the drainage patterns of the renal veins*

The venous patterns of renal veins were classified according to the number of primary tributaries (including the posterior primary tributary), ARVs, and anomalies. The presence of a particular classification type on one side is not predictive of a similar finding on the contra-lateral kidney. Knowledge of the classification types of the renal venous patterns of the kidney may assist the renal angiographer, especially for selection for segmental vein renin assay sampling.

*vi) Intra-renal and collateral venous drainage patterns*

The intra-renal venous architecture is non-segmental and non-lobar. Extensive venous collaterals centering on the left renal vein exist. These collateral pathways are constituted by the renal-lumbar-azygos-vertebral axis. The infra-renal pathway is predominantly via the ascending lumbar veins and vertebral plexuses. The suprarenal pathway is via the azygos-vertebral axis. The capsular and peri-ureteric venules provide an intra/extra renal communication. In this series, the major contributor of these collateral pathways was from the LRV, while the RRV contributed little, if any, to the collateral channels.

## Glossary of terms

*Additional renal vein*

Any additional vessel that drains separately from the kidney and independently into the IVC should be considered as a normal variation and be named an ARV. This definition is based on a proposal by Satyapal (1995), that “a renal vein is one which is constituted from the convergence and union of a varying number of primary tributaries emerging from the kidney and which terminates separately into the IVC”; this is classified as Type III.

*Renal collar*

“The occurrence of a renal venous channel coursing both anteriorly and posteriorly to the abdominal aorta” (Huntington and McClure, 1907).

*Retro-aortic vein*

Single ectopic trunk in a relatively low position, with a trajectory that is oblique inferiorly and retro-aortic. Gérard (1920) applied the term “anastomose veineuse renocave retro-aortique” to this vessel, which Seib (1934) modified and called the retro-aortic renocaval arch.

*Primary Tributaries*

These tributaries that emerge from the kidney are classified into 3 types using the drainage pattern of the primary renal vein tributaries and the renal vein proper as a basis on both the left and right sides (Satyapal, 1995). Type IA consisted of two primary tributaries only - an upper and lower, while Type IB had in addition, a posterior primary tributary. Type IIA displayed more than two primary tributaries - eg. upper, middle and lower, while Type IIB had in addition a posterior primary tributary. Type III consisted of any of the above classification patterns as well as displaying an ARV.

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