ORIGINAL PAPER

Renal artery variations: embryological basis and surgical correlation

VIRENDRA BUDHIRAJA, RAKHI RASTOGI, A. K. ASTHANA

Department of Anatomy,
Subharti Medical College, Meerut, U.P., India

Abstract

Understanding anatomy of the vascular variations of kidney is essential for the clinician to perform procedures such as renal transplantation, interventional radiological procedures and renal vascular operations more safely and efficiently. In order to facilitate the clinical approaches, we studied renal arterial pattern in 50 formalin-fixed cadavers, on 100 kidneys. We observed prehilar multiple branching patterns in 11 (11.66%) cases, duplication of renal artery in eight (8.33%) cases and superior polar artery in seven (6.66%) cases. In the present study findings discussed with its clinical correlation.

Keywords: kidney, anatomical variations, renal polar artery, duplicated renal artery.

Introduction

Classically, a single renal artery supplies each kidney. However, renal artery variations are very common. Variations regarding their origin and number have been reported by many researchers [1–3]. As the invasive interventions such as renal transplantation, interventional radiologic procedures and urologic operations increase, awareness of the possible variations of the renal arteries is necessary for adequate surgical management in the aforementioned specialties [4, 5].

Material and Methods

During routine abdominal dissection conducted for medical undergraduates, on 50 cadavers (100 kidneys) of both sexes, aged 40–70 years, various organs including stomach, liver, spleen, duodenum with pancreas were removed and preserved as specimen for teaching purposes. Ureters were also reflected in some cases towards the urinary bladder for proper visualization of hilar pattern of renal arteries.

Results

We observed bilateral prehilar multiple branching of the renal arteries in 11 (11.66%) cases (Figures 1–3), duplication of renal arteries in eight (8.33%) cases (Figures 2 and 4), superior polar arteries in seven (6.66%) cases (Figures 2, 3 and 5).

Prehilar multiple branches were directed towards apical, superior, middle, inferior and posterior vascular segment of kidney. The apical segmental branch was entering through hilum above and anterior to renal vein in all the 11 cases, the rest of the segmental braches were entering through hilum posterior to renal vein in all except one case where the superior segmental branch was also observed entering hilum anterior to renal vein (Figure 2).

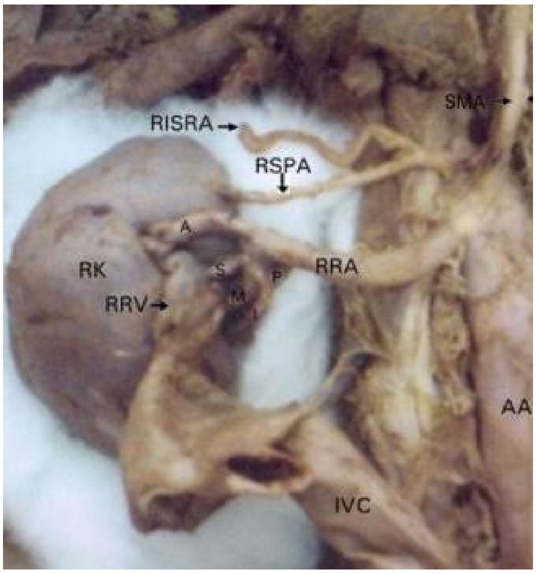

Figure 1 – *Right kidney with prehilar multiple branching of renal artery and an accessory renal artery entering superior pole (RK – Right kidney, AA – Abdominal aorta, IVC – Inferior vena cava, SMA – Superior mesenteric artery, RRA – Right renal artery, RRV – Right renal vein, RSPA – Right superior polar artery, RISRA – Right inferior suprarenal artery, A – Apical segmental branch, S – Superior segmental branch, M – Middle segmental branch, I – Inferior segmental branch, P – Posterior segmental branch).*

Duplicated renal arteries were observed on both sides. On right side, they were observed in five out of eight cases (62.5%) and three out of eight cases (37.5%) on left side. They were found running as anterior and posterior renal arteries (Figures 2 and 3) as well as accessory renal arteries (Figures 1 and 5). Anterior renal artery was giving branches to apical, superior, middle and inferior vascular segment of kidney and posterior renal artery was continuing as posterior segmental artery in all the cases.

Superior polar arteries in five out of seven cases (71.43%) were found taking origin from apical segmental branch (Figures 2 and 3), in two out of seven cases (28.57%) were originated directly from abdominal aorta (Figure 5). Superior polar artery followed an almost vertical course when it took origin from apical segmental branch and entered the kidney along the upper part of its medial border, but course was horizontal when took origin directly from abdominal aorta.

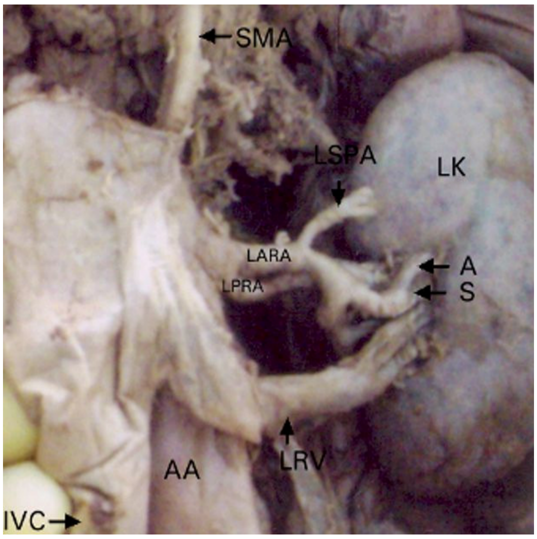

Figure 2 – ***Left kidney with duplication of renal artery and left superior polar artery (LK – Left kidney, AA – Abdominal aorta, IVC – Inferior vena cava, SMA – Superior mesenteric artery, LARA – Left anterior renal artery, LPRA – Left posterior renal artery, LRV – Left renal vein, LSPA – Left superior polar artery, A – Apical segmental branch, S – Superior segmental branch).***

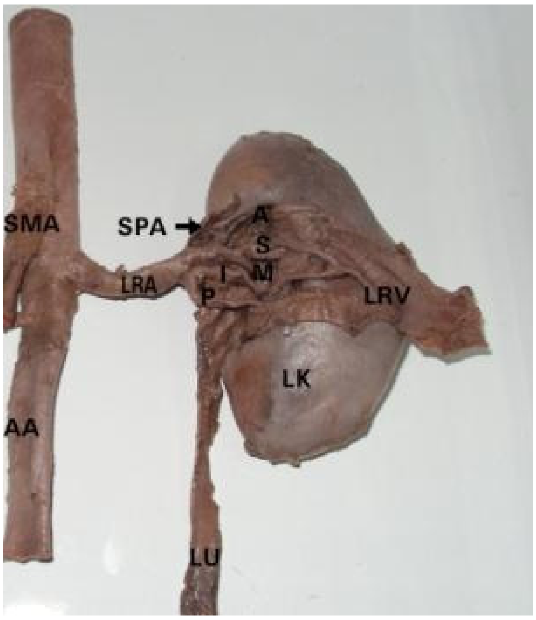

Figure 3 – ***Left kidney with prehilar multiple branching of renal artery (LK – Left kidney, AA – Abdominal aorta, SMA – Superior mesenteric artery, LRA – Left renal artery, LRV – Left renal vein, LU – Left ureter, SPA – Superior polar artery, A – Apical segmental branch, S – Superior segmental branch, M – Middle segmental branch, I – Inferior segmental branch, P – Posterior segmental branch).***

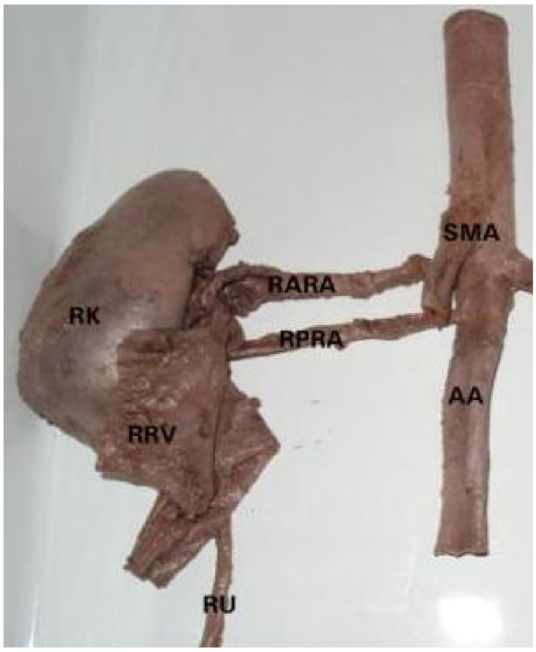

Figure 4 – ***Duplicated renal artery on right side (RK – Right kidney, AA – Abdominal aorta, SMA – Superior mesenteric artery, RARA – Right anterior renal artery, RPRA – Right posterior renal artery, RRV – Right renal vein, RU – Right ureter).***

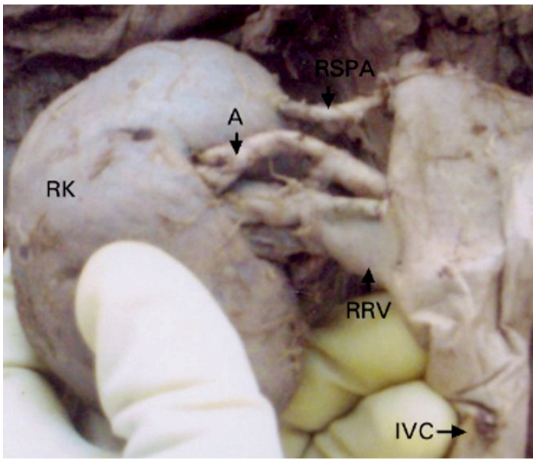

Figure 5 – ***Accessory artery entering through superior pole of right kidney (RK – Right kidney, IVC – Inferior vena cava, RSPA – Right superior polar artery, RRV – Right renal vein, A – Apical segmental branch).***

Discussion

The renal arteries originate from the abdominal aorta and account for 20% of the cardiac output to the kidneys. The renal vascular segmentation was discovered by John Hunter in 1794, but a detailed account was given in 1950's by corrosion cast studies. There are five defined arterial segments: apical, superior, middle, inferior and the posterior. The anatomical knowledge of these segments is important while performing nephrectomies [6].

Variations in renal arteries are not uncommon. Shoja MM *et al.* (2008) studied the perihilar branching pattern of renal artery. They observed fork pattern in 92.6% kidneys, duplicate in 80.2%, triplicate in 12.4% and ladder pattern in 7.4% kidneys [7]. Prehilar multiple branching of renal arteries were reported by Rao M *et al.* (2006) [2]. In our study, we observed prehilar multiple branching of renal arteries in 11 (11.66%) cases. These branches were directed towards apical, superior, middle, inferior and posterior vascular segment of kidney. As multiple branches of renal artery corresponds to segmental branches, the risk of hemorrhage during renal transplantation, segmental ischemia and postoperative hypertension due to loss of parenchyma increases [5].

The surgical accessibility to clamping of segmental arteries from anterior and posterior approaches was determined by Weld KJ *et al.* (2005) [8]. The vascular anatomy of kidney assessed in their study consisted of zero, one or two pre-segmental arteries in 49.3%, 31.5% and 19.2% of kidneys, respectively. From a posterior approach, the posterior segmental artery was accessible to isolated clamping in 81.1% of the kidneys and was accessible to clamping at the pre-segmental level in 12.7% of the kidneys with total accessibility 90.9%. The total accessibility rate for the inferior segmental artery was 88.5% from anterior and 66.7% from posterior surgical approach. The apical artery total accessibility rate was 72.3% and 40.5% from anterior and posterior approach, respectively. The corresponding middle and superior segmental artery total accessibility rate were 50.8% and 32.8%. They concluded that selective segmental vascular control might offer the benefits of total hilar control while reducing overall renal ischemic injury.

There are reports of duplication of renal arteries [9, 10]. Bordei P *et al.* (2004) studied renal vascularization and reported 54 cases of double renal arteries supplying one kidney and originating from aorta. Of the 54 cases, six cases were bilateral. In about 28 cases, supplementary renal artery entered the kidney through the hilum, in 16 cases it was inferior polar, in five cases it was superior polar [11]. Incidence of multiple arteries has been reported to be 20.2% and 19% on right and left sides, respectively by Janschek EC *et al.* in 2004 [12], however Saldarriaga B *et al.* (2008) reported ninety-seven (24.9%) out of 390 kidneys having additional arteries; 87 (22.3%) had one additional artery and 10 (2.6%) had two additional arteries. The frequency of one additional artery was 43.5% on right side and 56.3% on left side [13]. There was discrepancy regarding the side the additional arteries were presented; some authors have reported a higher frequency on the left side [3, 11, 14], others reported this variation to be more frequent on the right side [15–18]. In present study, we observed duplication of renal arteries in eight (8.33%) cases. On right side, they were observed in five out of eight cases (62.5%) and three out of eight cases (37.5%) on left side, so the frequency was more on right side.

The anatomical knowledge of multiple arteries is essential before performing any transplantation surgeries, where microvascular techniques are employed to reconstruct the renal arteries [19]. The embryological explanation of these variations has been presented and discussed by Keibel F and Mall FP [20]. In an 18 mm fetus, the developing mesonephros, metanephros, suprarenal glands and gonads are supplied by nine pairs of lateral mesonephric arteries arising from the dorsal aorta. Felix divided these arteries into three groups as follows: the 1st and 2nd arteries as the cranial group, the 3rd to 5th arteries as the middle group and 6th to 9th arteries as the caudal group. The middle group gives rise to renal arteries. Persistence of more than one renal arteries of the middle group results as multiple renal arteries [20]. Thus, the duplicated renal arteries in our study are a result of two persisting lateral mesonephric arteries from the middle group.

Accessory renal arteries are found frequently on the left side and occurrence is as high as 30–35% of cases, these arteries usually enter the upper or lower poles of the kidney [21]. In the present study, we found accessory renal arteries on right side entering the superior pole as superior polar arteries. On the left side, the superior polar arteries were found as a branch arising from apical segmental arteries. Beyer RW and Daily PO [22] have reported a case of two renal arteries on the right side and one supplying the upper pole (superior polar) being more vertical in trajectory than the usual main renal artery (as reported in the present study on left side), causing upper pole infarction.

Conclusions

With the increasing demand for kidney transplantation, living donor grafts have become the major source for maintaining the donor pool, and the successful allograft with multiple arteries has become a necessity. In the past ten years, even though being considered as a relative contraindication because of the increased risk of complications and being more complex compared to transplantation with single renal arteries, allograft with multiple renal arteries can be implanted with short and long term results comparable to those with single renal arteries by using the surgical technique that best fits a particular situation.

Nevertheless, to plan the adequate surgical procedure and to avoid any vascular complication, Multi Detector Computer Tomography (MDCT), angiography and arteriography should be performed prior to every nephrectomy.

References

[1] SHAKERI AB, TUBBS RS, SHOJA MM, PEZESHK P, FARAHANI RM, KHAKI AA, EZZATI F, SEYEDNEJAD F, *Bipolar supernumerary renal artery*, Surg Radiol Anat, 2007, 29(1):89–92.

[2] RAO M, BHAT SM, VENKATARAMANA V, DEEPTHINATH R, BOLLA SR, *Bilateral prehilar multiple branching of renal arteries: a case report and literature review*, Kathmandu University Medical Journal (KUMJ), 2006, 4(3):345–348.

[3] SATYAPAL KS, HAFFEJEE AA, SINGH B, RAMSAROOP L, ROBBS JV, KALIDEEN JM, *Additional renal arteries incidence and morphometry*, Surg Radiol Anat, 2000, 23(1):33–38.

[4] BORDEI P, SAPTE E, ILIESCU D, DINA C, *The morphology and the surgical importance of the gonadal arteries originating from renal artery*, Surg Radiol Anat, 2007, 29(5):367–371.

[5] SAMPAIO FJ, PASSOS MA, *Renal arteries: anatomic study for surgical and radiological practice*, Surg Radiol Anat, 1992, 14(2):113–117.

[6] STANDRING SUSAN, ELLIS H, HEALEY JC (eds), *Gray's anatomy: the anatomical basis of clinical practice*, Elsevier–Churchill Livingstone Publishers, London, 2005, 1274–1275.

[7] SHOJA MM, TUBBS RS, SHAKERI A, LOUKAS M, ARDALAN MR, KHOSROSHAHI HT, OAKES WJ, *Peri-hilar branching patterns and morphologies of the renal artery: a review and anatomical study*, Surg Radiol Anat, 2008, 30(5):375–382.

[8] WELD KJ, BHAYANI SB, BELANI J, AMES CD, HRUBY G, LANDMAN J, *Extrarenal vascular anatomy of kidney: assessment of variations and their relevance to partial nephrectomy*, Urology, 2005, 66(5):985–989.

[9] GURSES IA, KALE A, GAYRETLI O, BAYRAKTAR B, USTA A, KAYAALP ME, ARI Z, *Bilateral variations of renal and testicular arteries*, International Journal of Anatomical Variations, 2009, 2:45–47.

[10] BERGMAN RA, CASSELL MD, SAHINOGLU K, HEIDGER PM JR, *Human doubled renal and testicular arteries*, Ann Anat, 1992, 174(4):313–315.

[11] BORDEI P, SAPTE E, ILIESCU D, *Double renal arteries originating from the aorta*, Surg Radiol Anat, 2004, 26(6):474–479.

[12] JANSCHEK EC, ROTHE AU, HÖLZENBEIN TJ, LANGER F, BRUGGER PC, POKORNY H, DOMENIG CM, RASOUL-ROCKENSCHAUB S, MÜHLBACHER F, *Anatomic basis of right renal vein extension for cadaveric kidney transplantation*, Urology, 2004, 63(4):660–664.

[13] SALDARRIAGA B, PÉREZ AF, BALLESTEROS LE, *A direct anatomical study of additional renal arteries in a Colombian mestizo population*, Folia Morphol (Warsz), 2008, 67(2):129–134.

[14] VILHOVA I, KRYVKO YY, MACIEJEWSKI R, *The radioanatomical research of plural renal arteries*, Folia Morphol (Warsz), 2001, 60(4):337–341.

[15] CIÇEKCIBAŞI AE, ZIYLAN T, SALBACAK A, SEKER M, BÜYÜKMUMCU M, TUNCER I, *An investigation of the origin, location and variations of the renal arteries in human fetuses and their clinical relevance*, Ann Anat, 2005, 187(4):421–427.

[16] KHAMANARONG K, PRACHANEY P, UTRARAVICHIEN A, TONG-UN T, SRIPAORAYA K, *Anatomy of renal arterial supply*, Clin Anat, 2004, 17(4):334–336.

[17] OZKAN U, OĞUZKURT L, TERCAN F, KIZILKILIÇ O, KOÇ Z, KOCA N, *Renal artery origins and variations: angiographic evaluation of 855 consecutive patients*, Diagn Interv Radiol, 2006, 12(4):183–186.

[18] NAYAK S, *Common celiaco-mesenterico-phrenic trunk and renal vascular variations*, Saudi Med J, 2006, 27(12):1894–1896.

[19] BRANNEN GE, BUSH WH, CORREA RJ JR, GIBBONS RP, CUMES DM, *Microvascular management of multiple renal arteries in transplantation*, J Urol, 1982, 128(1):112–115.

[20] KEIBEL F, MALL FP (eds), *Manual of human embryology*, Vol. 2, J.B. Lippincott, Philadelphia, 1912, 820–825.

[21] SINGH G, NG YK, BAY BH, *Bilateral accessory renal arteries associated with some anomalies of the ovarian arteries: a case study*, Clin Anat, 1998, 11(6):417–420.

[22] BEYER RW, DAILY PO, *Renal artery dissection associated with GZ acceleration*, Aviat Space Environ Med, 2004, 75(3):284–287.

Corresponding author

Virendra Budhiraja, Associate Professor, Department of Anatomy, Subharti Medical College, Delhi–Hardwar by Pass Road, 250002 Meerut, U.P., India; Phone +919897244802, Fax +911212439127, e-mail: budhirajasimran46@gmail.com

Received: January 6th, 2010

Accepted: June 24th, 2010