



A Study on Anatomical Variations of Renal Vessels

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ABSTRACT:

Introduction: The unique manner of the development of the kidneys and renal vessels predisposes them to a wide range of variations and anomalies. Knowledge of anomalous renal blood vessels is very important in clinical and surgical practice. It is very much necessary to have accurate anatomic visualization of kidneys and renal vessels during surgeries especially during renal transplant since the variations and anomalies influence the technical feasibility of surgery.

Objectives: To know the various developmental anomalies pertaining to renal vessels in adult cadavers and term foetuses.

Materials and methods: The dissection method was adopted for the present study. Total number of specimens studied in present work is 30, among which 20 were adult cadavers and 10 were foetal cadavers. Foetuses were obtained from the department of obstetrics and gynaecology. Foetuses were numbered F1 to F10 and cadavers from C1 to C20. Photographs were taken after dissection. As any abnormalities appeared, necessary observations were made and summarised.

Results: Out of 10 foetal & 20 adult cadaver dissections, morphological variations found in the renal arteries was 15% and venous anomalies in 5%, perforating renal arteries in 15%, double renal arteries in 10%, multiple renal arteries 5 %, Additional renal veins were found in 5%, interposition of renal veins at hilum 5%. Of the ten foetuses studied, none revealed any anomaly.

Conclusion: Variations of renal vessels have been encountered with increasing frequency over past few years owing to the technological investigations like angiography and other imaging modalities. Knowledge of these variations is very much essential to perform renal surgeries.

Key words: developmental anomalies, renal surgery, renal vessels, variations

INTRODUCTION:

Anomalous renal blood vessels are entirely a part of their interest to medical students studying embryology and morphology of kidney and renal vessels is of considerable significance from a clinical and surgical viewpoint. Departures from

the conventional type in anatomic structures are slowly assuming a place of importance in the practical field. From a surgical standpoint, renal arterial and venous variations, emphasize the need of thorough knowledge while performing surgeries on kidney [1]. 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 [2]. Fortunately, the wide use of roentgenology has come handy to treating physicians and surgeons in description and determination of anatomic conformation [1].

Variations in the renal vessels are often due to complex mechanism of development of kidneys [3]. Very little is known of the normal stages of the development of the blood vessels of the kidney [4]. Organs which make extensive migrations from one position to another, may retain vessels from their original position or receive or incorporate vessels of different area invaded. The kidney during its growth migrates and undergoes a rotation around its long axis.

The venous anomalies are more often encountered than the arterial variations. Undoubtedly, insufficient attention has been directed to the variations in the renal veins which are subject to a greater range of variations compared to the renal arteries, particularly in performing nephrectomy. Abnormalities in the form and position of the kidneys in association with accessory renal arteries have been pointed out by a number of observers. In general, the kidney deviates from its general reniform shape in proportion to the number of vessels [1].

Displacement of the pelvis on to the anterior surface of the kidney and the deviation of the organ from the normal reniform shape are generally in direct proportion to the plurality of vessels. Abnormalities of the renal arteries are perhaps more frequently met with than any other of the larger arterial trunks and the commonest variation is the presence of an additional renal artery [4]. As many as five or six to one kidney have been reported [1]. Accessory renal arteries are found frequently, more often on the left side and occurring in 25-35% of cases. As the kidney is probably a segmental organ, its primitive blood vessels are probably segmental also and accordingly multiple [4]. The occurrence of multiple or accessory renal arteries is associated with an arrested development in the kidney and occasionally of the ureter [1].

OBJECTIVES:

To know the various developmental anomalies pertaining to renal vessels in adult cadavers and term fetuses.

MATERIALS AND METHODS:

The study was conducted on 20 adult cadavers which were routinely used for dissection and 10 term fetuses which were obtained from department of Obstetrics and Gynaecology. Institutional ethics committee approval was taken prior to the study.

The cadavers were then subjected to routine dissection to expose the abdominal aorta with renal arteries and kidneys, and renal veins with inferior vena cava.

The observations were recorded in the following manner:

1. Position of the kidney
2. Position of the renal arteries and veins
3. Anomalies pertaining to renal arteries and veins

OBSERVATIONS AND RESULTS:

A total number of 30 bodies were studied, among those 20 were adult cadavers and 10 were term fetuses. Among the 20 adult cadavers, 16 were male cadavers and four were female cadavers. Among the 10 fetuses, 4 were male fetuses and 6 were female fetuses. Of the 20 adult cadavers, arterial and venous anomalies were found in 3 cadavers. All the 3 were male cadavers. The observations were as follows:

Anomaly 1: A male cadaver aged approximately 45 years showed both arterial and venous anomalies. [Figure No.1, 2&3]

The arterial anomaly was bilateral. On the right side double, renal arteries were noted. The upper renal artery was originating from the aorta in its lateral aspect corresponding to lower border of L1. It divided into two branches, both entering the kidney through the hilum. At the point of bifurcation, it gave off a perforating renal artery entering the kidney near the upper pole. The lower renal artery was seen arising from aorta in its anterior aspect at the level of L2 and entering the kidney through the hilum. On the left side also, double renal arteries were noted. Both of these were arising from the lateral aspect of the aorta at the level of L2 and entering the kidney through the hilum. Apart from this, a perforating renal artery was seen arising from the aorta in its lateral aspect corresponding to lower border of L1 about 1.5 cm above the double renal arteries and entering the kidney near the upper pole.

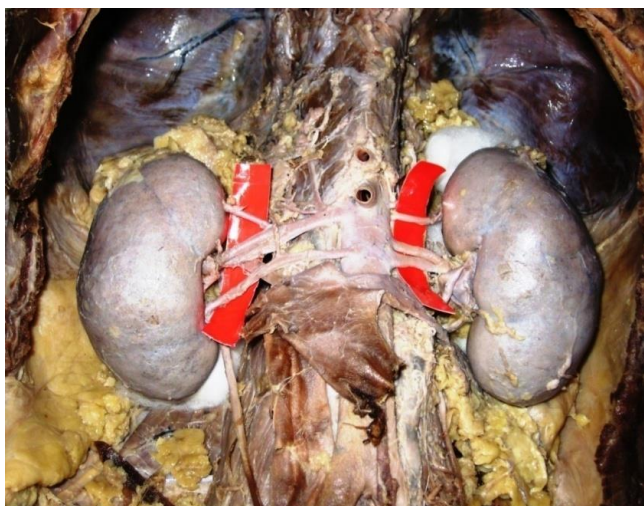


Figure. 1. Bilateral double renal arteries along with perforating arteries.

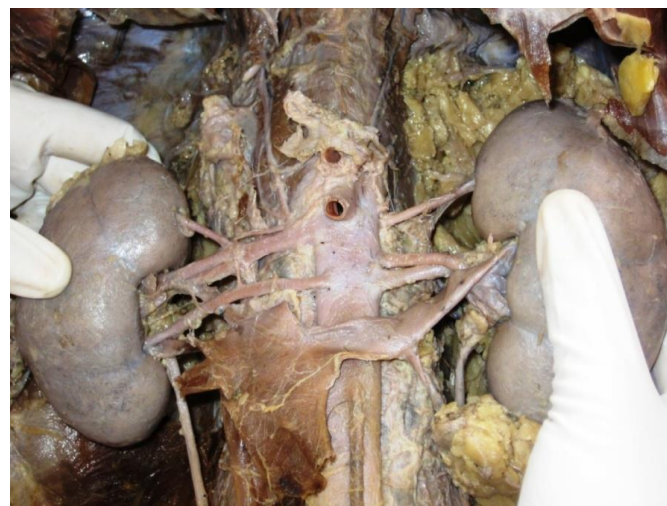


Figure. 3. Bilateral double renal artery with perforating arteries.

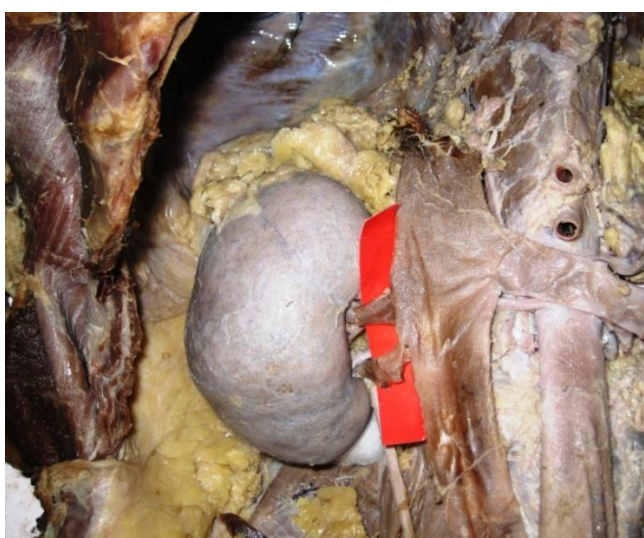


Figure. 2. Additional renal vein draining into the inferior vena cava.

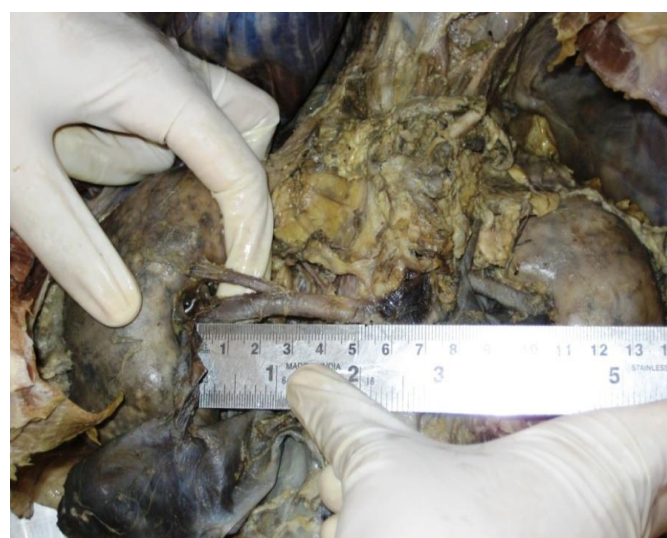


Figure. 4. Perforating artery entering the kidney outside the hilum.

The venous anomaly was observed on the right side. There were two renal veins draining the kidney separately with independent courses up to the inferior vena cava. Among these two, one was arising at the level of L2 near the hilum, and the second at the level of lower border of L2.

Anomaly 2: A male cadaver aged approximately 40 years showed bilateral arterial anomaly. [Figure No 4, 5& 6].

On the right side a perforating renal artery was arising from the main branch at the upper border of L2 and entering the kidney outside the hilum

near the upper pole. On the left side double renal arteries were noted, both arising from the lateral aspect of the aorta at the level of L1 and upper border of L2 respectively. The upper renal artery was entering the kidney through the hilum. The lower renal artery was also seen entering the kidney through the hilum. Just before the hilum, it gave off a perforating renal artery entering the kidney near the upper pole.

Anomaly 3: A male cadaver aged approximately 42 years showed unilateral arterial anomaly. [Figure No 7]

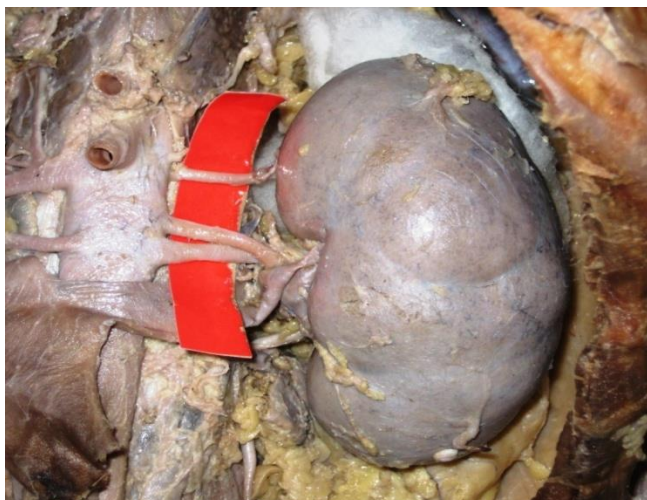


Figure 5. Left double renal arteries with a perforating artery from the aorta to the upper pole.



Figure. 7. Pre hilar multiple branching of the left renal artery along with a perforating artery to the upper pole with interposition of vessels.



Figure. 6. Left double renal arteries with a perforating artery on right side.



Figure. 8. Foetal kidneys and normal blood vessels.

On the left side the renal artery showed pre-hilar multiple branches. The artery was arising from the lateral aspect of aorta corresponding to lower border of L1. Before reaching the hilum, the artery passed anterior to the left renal vein and divided into upper and lower divisions. From the upper division three branches were arising, and two branches were arising from the lower division. All these branches were entering the kidney through the hilum and were situated anterior to the renal vein. A perforating renal artery was also seen arising from the main trunk close to the aorta and entering the kidney near the upper pole. Of the ten foetuses studied, none revealed any anomaly. [Figure 8]

From the above observations, the following results were obtained.

Anomalies of the renal vessels were more frequently encountered on the arterial side than on the venous side. Arterial anomalies accounted for 15% whereas venous anomalies accounted for only 5%. Anomalies of arterial origin were more common on the left side (15%) as compared to the right side (10%). The anomalies of venous origin were encountered only on right side (5%). Among the arterial anomalies, perforating renal arteries were most commonly encountered

followed by double renal arteries and multiple renal arteries. Perforating renal arteries accounted for 15% of the cases. They were more commonly found on the left side. All the perforating renal arteries were confined to the upper pole only (15%). The occurrence of bilateral perforating renal arteries was 10%. Double renal arteries accounted for 10% of the cases. They were found more commonly on left side. Bilateral double renal arteries were seen in 5% of the cases. Multiple renal arteries accounted for 5% of the cases. They were more commonly met on the left side. There were no cases of occurrence of triple renal artery and accessory renal artery. Among the venous anomalies additional renal veins accounted for 5% of the cases. They were commonly encountered on the right side. One case had two additional renal veins; both were occurring on the right side.

Discussion:

The unique manner of the development of the kidneys which consists in the succession of functional kidneys, particularly predisposes them to a wide range of variations and anomalies [11]. There is very limited information about the development of the blood vessels of the kidney. It is generally assumed that they are originally multiple, and that most of these disappear by fusion either completely or in part, leaving, at least in man, a single renal artery on each side, which after a longer or shorter course divide into numerous branches [4]. Primitive blood vessels are segmental and multiple owing to the fact that kidney is a segmental organ. Multiple renal arteries represent in point of fact a primitive condition, and may assist in determining the morphology of their origin. Moreover, when multiple arteries of the kidney exist there is supporting evidence to the arrest of development and the consequent retention of a primitive condition either as regards form or position of the kidney. As the organ is formed in the intermediate cell mass in the region of the first sacral vertebra, it is not surprising that it occasionally receives vessels not only from the aorta, but also from the caudal arch, i.e, the common and internal iliac arteries [4]. The instances of accessory renal arteries arising from iliac arteries, from the middle sacral and inferior mesenteric arteries are to be considered as persisting embryonic vessels of the capillary plexus supplying the normal embryonic kidney [1].

Accessory hilar renal arteries and accessory vessels to the upper and / or lower poles of the kidneys occur due to the persistence of some arteries of the urogenital rete arteriosum (Bayazit et al., 1992; Kadir et al., 1986) [5,6]. Since the process of development of kidney is very complicated, passing through stages of pronephros, mesonephros and metanephros and the shift of metanephros from pelvic region to posterior abdominal wall causes the renal vessels to undergo changes due to upward migration. The arterial degeneration begins at upper pole of metanephros, therefore the segmental branch to lower pole persists as an accessory artery [7].

1. Double renal arteries
2. Triple renal arteries
3. Accessory renal arteries: upper pole, lower pole
4. Perforating renal arteries: upper pole, lower pole

Double renal arteries: These are two vessels originating from the aorta, similar in diameter, blood supply areas, and their branches entering the kidney through the hilum. Abolhassan and Shane (2007) reported a case of accessory renal arteries on both sides with pre-hilar branching pattern in a renal transplant donor [8]. Two renal arteries were seen in relation to right kidney arising from aorta, out of which one was hilar and the other was in relation to the lower pole. Patel Shashikala et al (2012) reported a case of unilateral double renal artery during dissection [9].

Triple renal arteries: These are three vessels originating from the aorta with different diameters and blood supply areas, and their branches entering the kidney through the hilum. Nishimura et al (2002) found that aortic angiography showed three left renal arteries with aneurysms of the distal main renal artery [10]. Turanpestimalci (2009) observed a case of bilateral triple renal arteries arising from abdominal aorta and common iliac arteries during routine dissection [11].

Accessory renal arteries: These originate from the aorta, the diameter of which being comparable to segmental arteries, supplying one segment only (upper or lower pole) entering the kidney through the hilum. Dhar P and Lal K (2005) studied the incidence of accessory renal arteries in 40 cadavers [12]. They found single renal artery in

80% of specimens. Gayata Mehta and VasantiArole (2010) carried out a study on 50 adult cadaver kidneys and observed accessory renal arteries in 11 kidneys (22%) arising from abdominal aorta [13]. Unilateral accessory renal artery was seen in 10 kidneys (90.9%), bilateral accessory renal artery was seen in one kidney (9.09%)..Accessory renal arteries on left side were seen in 7 kidneys and 4 on right side. Mutyalapatti Venkataramulu et al (2011) studied the morphometric evaluation of kidneys and renal artery in 25 cadavers and found that accessory renal arteries in about 24%, with incidence being the same on both sides [14].

Perforating renal arteries: These originate from the aorta or one of its major branches, the diameter of which being comparable to segmental or subsegmental arteries, supplying one segment only (upper or lower pole) entering the kidney outside the hilum.

Total statistics in one study showed that accessory arteries were seen more commonly in lower pole 50% and in lower pole about 16.5% . Perforating arteries of upper pole were described in about 22% and lower pole arteries 4.4%. In 18.7% double renal arteries were observed and in 16.5% upper pole accessory arteries were noted. Very rarely triple renal arteries were observed in small percentage 3%. The complex embryological development of the renal vein's accounts for its variations, majority of which are clinically silent and remain unnoticed until discovered during operation or autopsy [2]. These anomalies in the renal veins show less variation than the renal arteries [15].

Classification of renal venous anomalies: (K.S Satyapal,2003) [2]

1. Additional renal veins (ARVs)
2. Circum – aortic renal collar
3. Retro - aortic renal veins

Additional renal vein: Any additional vessel that drains separately from the kidney and independently into the inferior vena cava should be considered as a normal variation and be named an Additional Renal Vein.

Circum-aortic renal collar: The occurrence of a renal venous channel coursing both anteriorly and posteriorly to the abdominal aorta (Huntington and McClure, 1907) [16].

Circum-aortic renal vein: A circum-aortic renal vein often develop due to persistence of both ventral and dorsal aortic arch in contrast to retro aortic renal vein [17,18]. This condition is asymptomatic and seen in about 1.6-14%cases [19]. A circum-aortic renal vein is very important in cases of donor nephrectomy. Presence of circum-aortic and retro-aortic renal veins are relative contra indications in some centres for donor nephrectomy [20].

Retro-aortic vein: Single ectopic trunk in a relatively low position, with a trajectory that is oblique inferiorly and retro-aortic.

Retro-aortic left renal vein: Retro-aortic renal veins are seen in about 3.2% cases [21], Retro-aortic renal veins are formed by the regression of ventral arch of aortic collar and the persisting dorsal arch forms the left renal vein. The recorded incidence of renal vein variations varies widely: renal collar with a range of 0.2% - 30%, retro – aortic vein with a range of 0.8% - 7.1%, ARV – right with a range of 8.0% - 28.0% and ARV – left with a range of 0.8% - 6.0% [2].

Hemorrhage from an overlooked accessory renal artery, or from an aberrant renal vein, either immediate or post-operative, may be followed by a fatal result. Among the most hazardous and disconcerting complications of nephrectomy is a tear or rupture of the inferior vena cava. The relative shortness of the right renal vein is the most frequent cause of this accident. Fonstein has collected 75 cases in which this perilous complication has occurred. Altogether there were 22 deaths, a mortality of 29 percent [1]. It is of utmost importance to be remember that accessory renal arteries are end arteries [18]. If there is a damage to accessory renal artery or if it is ligated the region supplied by it undergoes ischaemic changes.

In recent years more and more cases of aberrant renal vessels have been reported [22]. This may be due to extensive use of specialised imaging modalities and angiography. Knowledge of variations of renal vascular anatomy is important in the exploration and treatment of renal trauma, renal transplantation, renovascular hypertension, renal artery embolization, angioplasty or vascular reconstruction for congenital and acquired lesions,

surgery for abdominal aortic aneurysm and conservative or radical renal surgery. Transplanting a kidney with accessory renal arteries has several theoretical disadvantages – acute tubular necrosis and rejection episodes, decreased graft function, and prolonged hospitalization [17]. Potential plural renal arteries crossings with ureters may be the reason for venous renal congestion and urine voiding disorders, and thus a cause of hydronephrosis, pyelonephritis and secondary nephrolithiasis.[3] Left renal vein compression can be a possible aetiological factor of idiopathic varicocele in man and/or orthostatic albuminuria and can also lead to a phenomenon called the “nutcracker effect”, in which there will be compression of left renal vein by aorta and superior mesenteric vessels [23].

In the present study the occurrence of arterial anomalies was commoner than the venous anomalies, a fact which correlated well with the available literature. Arterial anomalies were more common on the left side whereas venous anomalies were common on the right. This finding was also matching with the literature. The distribution of various arterial anomalies in the present study also correlated well with the studies done by Irena Vilhova et al in 2001[24] and others except for accessory renal arteries which were not encountered in our study. The distribution of various venous anomalies in the present study were also on par with the available literature, correlating well with the extensive studies done by Satyapal et al in 2003 [2] and others.

Conclusion:

The present study done on 20 adult and 10 foetal cadavers exhibits a wide spectrum of variants among the renal vessels in a group of South Indian subjects. Based on the observations, among the arterial anomalies perforating renal arteries to the upper pole were most common followed by double renal arteries and multiple renal arteries. All these anomalies were commonly met on the left side. Among the venous anomalies additional renal veins were common and were distributed more towards the right side.

The renal vasculature often exhibits differences among different groups of populations. Therefore, before planning for any renal surgeries, it is very much essential to review the data on variations of

renal blood vessels. These variations have been observed frequently in recent times due to extensive use of imaging techniques like angiography and other invasive and interventional diagnostic techniques.

Knowledge of variations of renal vascular anatomy and its variations is very important for surgeons and radiologists for performing angiographic procedures and treating traumatic renal conditions, transplant surgery and other procedures on kidney. The present study adds to the data on the anatomy and variations of renal vessels which is very much useful for transplant surgeons.

REFERENCES

1. Lipshutz B, Hoffman C. Renal arterial variations and extraperitoneal abdominal nephrectomy. *Ann Surg.* 1926 Oct;84(4):525-32. PMID: 17865547; PMCID: PMC1399149.
2. K.S.Satyapal, The renal veins: a review, *Eur J Anat*, 7 Suppl. 1:43-52 (2003)
3. Vilhova I, Kryvko YY, Maciejewski R. The radioanatomical research of plural renal arteries. *Folia Morphol (Warsz).* 2001 Nov;60(4):337-41. PMID: 11770346.
4. Young AH, Thompson P. Abnormalities of the Renal Arteries, with Remarks on their Development and Morphology. *J Anat Physiol.* 1903 Oct;38(Pt 1):1-14.1. PMID: 17232579; PMCID: PMC1287385.
5. Bayazit M, Göl MK, Zorlutuna Y, Tasdemir O, Bayazit K. Bilateral triple renal arteries in a patient with iliac artery occlusion: a case report. *Surg Radiol Anat.* 1992;14(1):81-3. doi: 10.1007/BF01628048. PMID: 1589852.
6. Kadir S. Kidneys. In: Kadir S, editor. *Atlas of normal and variant angiographic anatomy*. Philadelphia: Saunders; 1991. pp. 387–428.
7. Park BS, Jeong TK, Ma SK, Kim SW, Kim NH, Choi KC, Jeong YY. Hydronephrosis by an aberrant renal artery: a case report. *Korean J Intern Med.* 2003 Mar;18(1):57-60. doi: 10.3904/kjim.2003.18.1.57. PMID: 12760271; PMCID: PMC4531603.
8. Shakeri AB, Tubbs RS, Shoja MM, Pezeshk P, Farahani RM, Khaki AA, Ezzati F, Seyednejad F. Bipolar supernumerary renal artery. *Surg Radiol Anat.* 2007 Feb;29(1):89-92. doi: 10.1007/s00276-006-0158-0. Epub 2006 Oct 24. PMID: 17061029.

9. Patel Shashikala, Wanjari Anjali, Naik Anshuman, Deshpande Jayshree. A case report: double renal arteries. *Int. J Anat* 2012; 5:22-24.
10. Nishimura K, Maeda T, Hiroe T, Honda T, Kamihira S, Kanaoka Y, Ohgi S. Left renal artery aneurysm with left accessory renal arteries. A case report. *Int Angiol*. 2002 Mar;21(1):103-6. PMID: 11941283.
11. Pestemalci T, Mavi A, Yildiz YZ, Yildirim M, Gumusburun E. Bilateral triple renal arteries. *Saudi J Kidney Dis Transpl*. 2009 May;20(3):468-70. PMID: 19414954.
12. Dhar P, Lal K. Main and accessory renal arteries--a morphological study. *Ital J Anat Embryol*. 2005 Apr-Jun;110(2):101-10. PMID: 16277160.
13. Mehta, Gyata&Arole, Vasanti. (2014). Accessory Renal Arteries: A Cadaveric Study. *International Journal of Biomedical and Advance Research*. 5. 204. 10.7439/ijbar.v5i4.727.
14. Ramulu, M. V., & Prasanna, L. C. (2017). Morphometric evaluation of the kidney and its main renal artery. *International Journal of Research in Medical Sciences*, 3(2), 429–432.
15. Thejodhar P, Kumar Po, Rao MS, et al. Co-existence of circumaortic renal collar, accessory renal artery and anomalous arrangement of hilar structures in the same cadaver: A case report. *Eur J Anat*. 2007; 11: 185–188.
16. Huntington, G. S. & McClure, C. F. W. (1907a). Development of the postcava and tributaries in the domestic cat. *The Anat. Rec*. 1(3), 29-30
17. Bass JE, Redwine MD, Kramer LA, Huynh PT, Harris JH Jr. Spectrum of congenital anomalies of the inferior vena cava: cross-sectional imaging findings. *Radiographics*. 2000 May-Jun;20(3):639-52.
18. Aljabri B, MacDonald PS, Satin R, Stein LS, Obrand DI, Steinmetz OK. Incidence of major venous and renal anomalies relevant to aortoiliac surgery as demonstrated by computed tomography. *Ann Vasc Surg*. 2001 Nov;15(6):615-8. doi: 10.1007/s10016-001-0095-7. PMID: 11769141.
19. Trigaux JP, Vandroogenbroek S, De Wispelaere JF, Lacrosse M, Jamart J. Congenital anomalies of the inferior vena cava and left renal vein: evaluation with spiral CT. *J VascIntervRadiol*. 1998 Mar-Apr;9(2):339-45. doi: 10.1016/s1051-0443(98)70278-7. PMID: 9540920.
20. Lin CH, Steinberg AP, Ramani AP, Abreu SC, Desai MM, Kaouk J, Goldfarb DA, Gill IS. Laparoscopic live donor nephrectomy in the presence of circumaortic or retroaortic left renal vein. *J Urol*. 2004 Jan;171(1):44-6. doi: 10.1097/01. ju.0000099895.62724.04. PMID: 14665840.
21. Walker TG, Geller SC, Delmonico FL, Waltman AC, Athanasoulis CA. Donor renal angiography: its influence on the decision to use the right or left kidney. *AJR Am J Roentgenol*. 1988 Dec;151(6):1149-51. doi: 10.2214/ajr.151.6.1149. PMID: 3055890.
22. Park BS, Jeong TK, Ma SK, Kim SW, Kim NH, Choi KC, Jeong YY. Hydronephrosis by an aberrant renal artery: a case report. *Korean J Intern Med*. 2003 Mar;18(1):57-60. doi: 10.3904/kjim.2003.18.1.57. PMID: 12760271; PMCID: PMC4531603.
23. Ranade AV, Rai R, Prahbu LV, Mangala K, Nayak SR. Arched left gonadal artery over the left renal vein associated with double left renal artery. *Singapore Med J*. 2007 Dec;48(12):e332-4. PMID: 18043830.
24. Vilhova I, Kryvko YY, Maciejewski R. The frequency of different plural renal arteries rare variants. *Ann Univ Mariae Curie Sklodowska Med*. 2002;57(2):68-73. PMID: 12898821.