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# Study Of Variations in The Origin and Course of Extra-Renal Part of Renal Arteries Together with Associated Clinical Implications: Narrative Review

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**Abstract:**

Each kidney is irrigated by single renal artery conveying twenty percent of total cardiac output to the kidneys. These arteries originate from abdominal aorta inferior to superior mesenteric artery. This is normal configuration of renal arteries. But variation in the origin, number, course and branching pattern of renal arteries is well documented. Aim of the study is to throw light on the aforementioned variations of renal arteries so as to minimize complications during various procedures performed involving kidneys.

The study was carried out in the department of Anatomy. The literature was scrutinized using data bases: PubMed, Medline, Scielo, google scholar, research gate, Scopus and web of science. Various terms related to kidney were used to explore the literature. Only English language articles and standard text books of Anatomy were consulted.

The literature search revealed that single renal artery was found to irrigate kidneys in 62.9%-80% of individuals and it was observed to arise from abdominal aorta in 92% of cases. The renal arteries may also arise from celiac trunk, superior mesenteric artery, thoracic aorta, common iliac artery etc. The variable incidence of accessory renal artery is reported in literature.

The in depth information of variations in the origin, number, course and branching pattern of renal arteries will be of paramount importance to urologists, interventional radiologists and surgeons in averting misinterpretations of radiographs, minimizing complications and in preventing inadvertent iatrogenic damage to renal arteries.

**Keywords:** renal artery, abdominal aorta, accessory renal artery, urologist, variation

## 1. Introduction:

Each kidney is irrigated by single renal artery originating from lateral aspect of abdominal aorta (Figure 1) caudal to superior mesenteric artery between first and second lumbar vertebra (Standring, 2021).

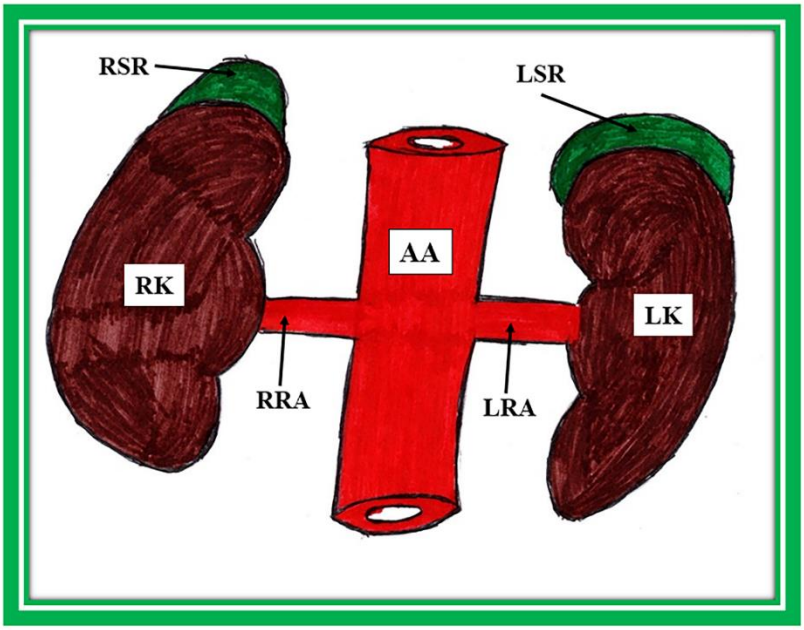


Figure 1: Single renal artery supplying both kidneys

RRA: right renal artery, LRA: left renal artery, RK: right kidney, LK: left kidney, AA: abdominal aorta, RSR: right suprarenal gland, LSR: left suprarenal gland

Twenty percent of total cardiac output reaches kidney through renal arteries. The renal artery supplying blood to right kidney is more in length as compared to renal artery supplying the left kidney. Also, right renal artery (ReA) arises cranial to the left renal artery. In addition, ReA of right kidney courses deep to inferior vena cava while that supplying left kidney traverses deep to left renal vein. Near the vicinity of hilum, the arteries irrigating the kidney, bifurcates into two branches, each of which give rise to segmental arteries irrigating the various segments of the kidney (Standring, 2021). This is the standard configuration of ReAs as elaborated in standard text books of Anatomy.

But the ReAs are observed to vary in number, origin, course and lumen. There may be extra branches irrigating kidney known as accessory ReA or the renal artery irrigates the kidney bypassing the hilum of the kidney. Such arteries which supply blood to kidneys without reaching hilum are known as aberrant renal artery (Standring, 2021).

The comprehension of variations in the anatomy of ReA such as variation in the number, origin and course is of utmost use during ligating the renal vessels to avoid hemorrhage, during interventional radiographs to avert misinterpretation and misdiagnosis and during kidney transplantation (Yamuna et al., 2024).

The aim of this review is to expound the variations of extra-renal course, origin and number of ReAs so as to manage renal diseases with minimum complications.

**Material and Methods:**

The study was conducted in the Department of Anatomy, GEIMS, India. The literature was scanned using following data bases: PubMed, Medline, Scielo, google scholar, research gate, Scopus and web of science. Only articles in English were referred. Standard text books of Anatomy were also mentioned. Terms used

to explore the literature were: renal artery, variations of renal artery, variations in origin and course of renal artery and clinical implications due variation of renal artery, anatomical variations of renal arteries, multiple renal arteries, aberrant renal arteries.

Only full texts were used and articles those with only abstract were excluded from the study.

The data was compiled and interpreted.

**Results and discussion:**

The results of literature search are discussed in the following paragraphs:

**Variations in the origin of renal arteries:**

In standard conditions, the ReAs originate from the lateral aspect of abdominal aorta between the first and second lumbar vertebra. Disparity from the conventional description in relations to origin, course and branching pattern of ReAs are observed to occur most frequently with incidence of 35% (Cruzat and Olave, 2013; Arquez, 2014). The prevalence of ReA variations is found to differ in various ethnic groups and its frequency ranges between 4% to 61.5% (Gulas et al., 2016; Gulas et al., 2018). The prevalence of number of additional ReAs depending on side along with type of study (computed tomography or dissection) also found to differ and this is 3% on single side and 30% on both sides (Cho and Yoon, 2021; Gulas et al., 2018). Renal arterial variation up to 38.5% in the Ethiopian people has been reported (Gebremickael et al., 2021).

**Variations in the origin of ReA can be described under following headings:**

a. Origin of ReA from various aspect of abdominal aorta
b. Origin of ReA from sources other than abdominal aorta
c. Origin ReA at various levels of lumbar vertebrae

**Origin renal artery from various aspect of abdominal aorta**

The commonest site of origin of ReA from abdominal aorta is lateral (92%) and less commonly on anterolateral (6%) and posterolateral (2%) aspect of abdominal aorta, as elaborated in studies in early nineties.

**Origin of renal artery from sources other than abdominal aorta**

The main ReA is also observed to originate from sources other than abdominal aorta. It may arise from thoracic aorta (Ashalatha et al., 2017), from superior mesenteric artery, from coeliac trunk (Nachiappan et al., 2011), from common iliac artery, external iliac artery, gonadal artery (Tuncay et al., 2011). The right ReA originating from splenic artery is also reported in early nineties.

**Origin of renal artery at various levels of lumbar vertebrae:**

Conventionally, the ReAs irrigating kidneys arise at the level between the first and second lumbar vertebrae. But variations in the origin of ReAs in the level related to lumbar vertebrae has been reported by various authors in literature which is elaborated below:

In one studies carried out in 2005, authors observed the renal arteries originating at the level of lower part of first lumbar vertebra (Pennington and Soames, 2005). There is another study in which the renal artery of left kidney arose at the level of L2 vertebra (Das, 2008). There are two more studies describing variant level of origin of ReAs with respect to lumbar vertebrae. Prakash et al. in their work found left ReA in 82% and right ReA in 80% individual originating at the level of first lumbar vertebra (Prakash et al., 2011). In a case report, authors elaborate the abnormal origin of ReA at the level of caudal margin of first lumbar vertebra (Rao and Rachana, 2011).

In a scientific work carried in 2014, investigators observed the ReAs of left and right kidney to be arising at the level of first lumbar vertebra in 36.76 % and 77.5 % of individual and in same study, the ReAs were detected to arise at the second lumbar vertebra in 11.63% of cases (Bhandari et al., 2014).

Variations in the number of renal arteries supplying the kidneys

In standard conditions, both kidneys are irrigated by sole renal artery but incidences of kidneys irrigated by single ReA varies greatly. Range of incidence of occurrence of single ReA irrigating each kidney ranges between 62.9%-80% (Standring, 2009; Dhar and Lal, 2005; Saldarriaga et al., 2008). Maximum incidence of 80% of single ReA is reported by Dhar and Lal and minimum of 62.9% by Saldarriaga et al.

Presence of more than one ReA unilaterally and bilaterally is also reported. Various terms are used for multiple arteries such as accessory, additional, supplementary, and aberrant (Ashalatha et al., 2017). As per these authors, Merklin and Michels in 1958 (quoted by Ashalatha, et al., 2017) classified multiple renal arteries into three categories depending on site of origin.

1. Supernumerary ReAs originating from the aorta;

2. Supernumerary ReAs originating from main renal arteries;

3. Supernumerary ReAs that can come from other sources.

Accessory renal artery is artery which is present in addition to the main artery, enters the hilum irrigating the kidney while the aberrant renal artery is that ReA which irrigates the kidney without entering the hilum [Standring, 2009]

Wide range of overall incidence of multiple renal arteries with range of 2- 36% (Kaushik et al., 2024) has been reported. Minimum of 2% is reported in nineties and maximum of 36% has been reported in recent study by Arasu et al., 2022.

Incidence of accessory renal arteries originating from aorta varies between 8-30.8% as elaborated in old literature quoted by Kaushik et al., 2024. The same study elaborates the percentage of accessory renal originating from main renal artery to be between 7.8% to 12.8% (Kaushik et al., 2024) and that originating from the superior mesenteric artery is 1.2% (Patra et al., 2016).

Additionally, they may arise from various other arteries, including the thoracic aorta, celiac artery, inferior phrenic artery, gonadal artery, superior mesenteric artery, inferior mesenteric artery, common iliac artery, external iliac artery, and internal iliac artery (Manoharan et al., 2025).

Incidence of double ReAs (Figure 2A, B, C) with incidence of 20% have been reported in literature (Dhar and Lal, 2005; Yamuna et al., 2024)

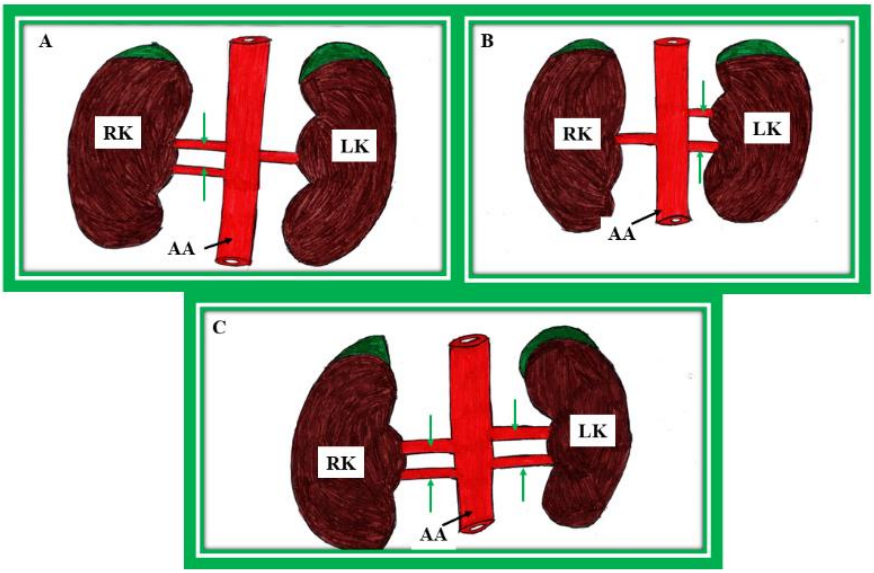


Figure 2: Double renal arteries

A) Double renal arteries on right side B) Double renal arteries on left side C) Double renal arteries both on right and left sides. Green arrows indicating double renal arteries

RK: right kidney, LK: left kidney, AA: abdominal aorta

while prevalence of triple ReA (Figure 3A, B, C) was found to be between 25-30% of population (Natsis et al., 2014; Ephraim and Sadananda, 2015; Budhiraja et al., 2013; Yamuna et al., 2024).

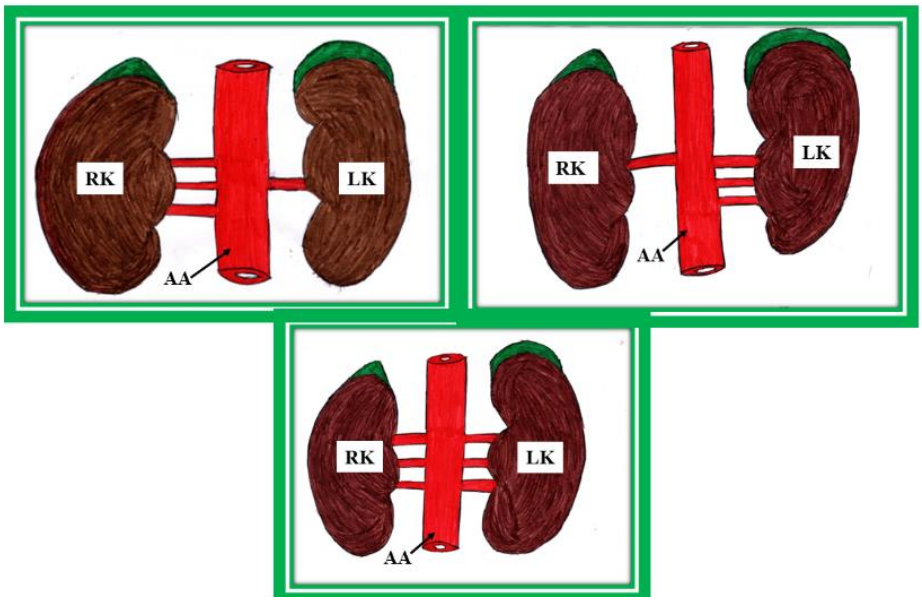


Figure 3: Triple renal arteries

A) Triple renal arteries on right side B) Triple renal arteries on left side C) Triple renal arteries both on right and left sides

**Type of aberrant renal artery:**

The aberrant renal artery may be superior and inferior polar artery (Kaushik et al., 2024). The incidence of superior polar renal arteries (Figure 4) was reported to be 3.3% to 9.3 and that of inferior polar artery to be 5%- 29.6% (Kaushik et al., 2024). In another study, the incidence of superior polar renal was as high as 78% and that of inferior polar artery is as low as 28% (García-Barrios et al., 2024).

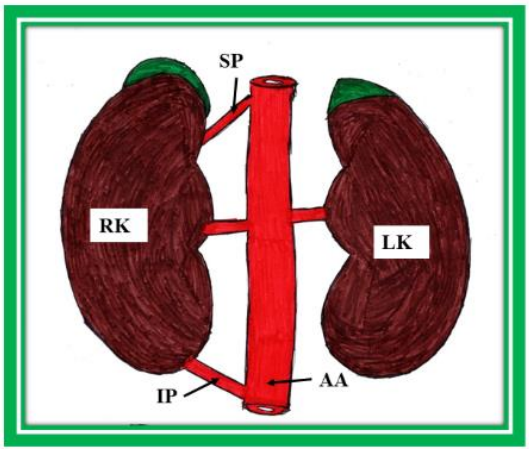


Figure 4: Polar arteries

RK: right kidney, LK: left kidney, AA: abdominal aorta, SP: Superior polar artery, IP: inferior polar artery

Incidence of aberrant ReA variations was highest for polar arteries with varying degrees (Çınar et al., 2016; García-Barrios et al., 2024).

Pre-hilar division of renal artery:

The incidence of pre-hilar division of ReA ranges between 8.12-21% in literature (García-Barrios et al., 2024; Ogeng'o et al., 2010).

Old literature describes pre-hilar division of renal artery into anterior and posterior division with percentage of 21.2 while in recent study the percentage of pre-hilar division of renal artery is reported to be 38.3% (Kaushik et al., 2024).

Symmetry of accessory renal artery:

The unilateral and bilateral incidences of accessory renal artery is documented to be 30% and 10% respectively (Yamuna et al., 2024; Ephraim and Sadananda, 2015). But incidence of unilateral and bilateral accessory renal artery as high as 78.7% and 21.3% has also been reported (Zainel et al., 2020).

As side is concerned, there is no common consensus in the scientific world. Arterial variations are observed to be on higher side on right than on left side (Ugurel et al., 2010; García-Barrios et al., 2024; Kaushik et al., 2024). However, in some studies the prevalence of accessory renal artery was observed on higher side on left side (Patra et al., 2016; Zainel et al., 2020; Budhiraja et al 2013, Jamkar et al., 2017).

**Incidence of extra-renal branches:**

Extra renal branches are the arteries originating from ReAs supplying structures other than kidneys. Mostly, extra- renal branches supplying suprarenal gland and diaphragm have been reported in literature. Aberrant renal artery giving rise to suprarenal arteries is reported to occur in 15% of individuals (Like Ali et al., 2009) and 6% of individuals (Yamuna et al., 2024). Old literature describes origin of right inferior phrenic artery supplying diaphragm from right renal artery with variable incidence as quoted in recent study (Yamuna et al., 2024). The incidence of inferior phrenic artery, in recent study conducted by Yamuna et al., 2024, is 6%. Yet in another study, the inferior phrenic artery was found to originate from the right ReA in individuals with hepatocellular carcinoma (Faria et al., 2016).

**Embryological factors in the variations in the number of renal artery:**

Felix as early as in 1912 elaborated the theory expounding the development of accessory ReA (Manoharan et al., 2025). Nine set of mesonephric arteries arising from the aorta between C6 and L3 vertebrae develop irrigating kidneys, suprarenal glands and gonads. Renal arteries develop from middle third and fourth pair of mesonephric arteries. Rest of the mesonephric arteries degenerates. When other mesonephric arteries persist and do not regress, it results in formation of accessory ReA (Ozkan et al., 2006). Also, developing kidneys receive blood supply from adjacent arteries such as common iliac and aorta which persists and so ReA may arise from sources other than aorta (Munnusamy et al., 2016).

If there is delay in establishing communication between the factors such as glial derived neurotropic factor and hepatocytic growth factor in mesenchyma of arteries and factors residing in mesenchyma of metanephrons, it may lead to pre-hilar bifurcation of ReA (Munnusamy et al., 2016).

**Implications of varied anatomy of renal artery:**

Comprehension of variations of ReA is essential to circumvent events like hemorrhage during ligating ReA, reading of angiography, interventional imaging and during kidney transplantation (Yamuna et al., 2024) and in surgeries of urinary system.

Knowledge of accessory ReA is of utmost use during carrying out laparoscopic surgeries, in selecting donors for renal transplantation, for renal artery embolization, angioplasty and vascular reconstruction and surgery for aneurysms of abdominal aorta (Yamuna et al., 2024). In depth information about the presence of accessory ReA is also useful to prevent ischemic changes in segments of kidney while performing renal resection of kidney segment wise or during limited nephrectomy as these arteries serves as segmental end arteries (Ashalatha et al., 2017) and to avoid hypertension after surgery involving kidney (reported by authors in early nineties). The individuals with accessory ReAs are more prone to hypertension, stenosis and thrombosis (Manoharan et al., 2025). In addition, prior information about the presence of accessory ReAis useful in procedures like renal denervation therapy in patients with high blood pressure (VonAchen et al., 2016).

Multiple ReAs coursing anterior to ureter may be one of the cause of hydronephrosis (Kaushik et al., 2024; Gulas et al., 2018). Understanding of branching of ReA before hilum is important to acquire proper arterio-arterial anastomosis during kidney transplantation where the length of ReA should be more than two centimeters (Sungura, 2012).

Presence of polar artery specifically inferior polar artery coursing anterior to renal pelvic can block the ureter culminating into expansion of renal pelvis, hydronephrosis and infection (quoted by Manoharan et al., 2025). Unaware of presence of polar arteries may cause damage to these arteries when clearing adipose tissue at the poles of the kidneys (Manoharan et al., 2025). Existence of polar arteries is also useful during kidney transplantation as these arteries may be injured during kidney harvesting causing ischemic changes in the segment of kidney irrigated by that particular artery along with ischemia of the ureter (Manoharan et al., 2025).

Recently, it is reported that there is strong association between existence of accessory ReA and renal cell carcinoma of high grade and so accessory ReA may be indicator of high grade renal carcinoma (Lv et al., 2023).

Now a days, these is increased incidence of use of laparoscopy for renal donor methods for which anatomy of ReA cannot be ignored and so for assessing donors for donating kidney, imaging with 64-slice multidetector computerized tomography is recommended to know the ReA variations (Manoharan et al., 2025).

Presence of accessory ReAs is associated with resistant hypertension (Triantafyllou et al., 2025). Percutaneous sympathetic denervation has been advocated for management of hypertension (Kasprzycki et al., 2023) but it was not successful and the reasons for this was presence of multiple ReAs (Kasprzycki et al., 2023).

**Conclusion:**

In standard configuration, there is single renal artery irrigating each kidney arising from abdominal aorta. But renal artery budding from other sources like thoracic aorta, superior mesenteric artery, common iliac artery, external iliac artery and gonadal artery is reported in literature. Multiple artery supplying kidney is well documented. The accessory renal artery travelling anterior to ureter may obstruct the ureter causing hydronephrosis, dilatation of renal pelvis along with infection. Early branching of renal artery may pose problems in kidney transplantation as bit lengthier renal artery is required in this procedure.

Comprehension of varied renal anatomy is important for management of renal trauma, Takayasu disease, renal transplantation, vascular surgeries for renal artery stenosis, renovascular hypertension and endovascular procedures like therapeutic embolization, renal angioplasties and intravenous pyelogram including uro-radiological interventions.

Thus, in depth knowledge of variations in the origin, course and branching pattern of the renal artery is of paramount importance to the urologists, nephrologists, surgeons and radiologists to avoid pre and post-operative complications.

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