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Research Article

Anatomical Variations of the Renal Artery: A Cross-Sectional Cadaveric Study

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ABSTRACT

Background & Objectives: The renal arteries are the primary blood supply to the kidneys and usually arise as single branches from the abdominal aorta at the L1–L2 level. However, variations in their number, origin, and branching pattern are common and carry important implications for renal transplantation, vascular surgery, and interventional radiology. This study aimed to document anatomical variations of renal arteries in cadaveric specimens with respect to their number, level of origin, source of accessory arteries, and length.

Materials and Methods: An observational cross-sectional study was conducted on 32 kidneys from 16 formalin-fixed cadavers during routine dissection sessions at the Department of Anatomy, Karnali Academy of Health Sciences, Jumla. Renal arteries were dissected to trace their origin, course, and branching pattern. Variations were recorded, artery lengths were measured with a Vernier caliper, and representative findings were photographed. Data were analyzed descriptively.

Results: Out of 32 kidneys, 27 (84.37%) had a single renal artery, while 5 (15.62%) had double arteries, more common on the left side (9.37%) than the right (6.25%). Renal arteries originated at the same level in 56.25% of specimens, while a higher origin was more frequent on the right (25%) compared with the left (9.37%). All main renal arteries arose from the aorta. Accessory arteries originated either from the aorta (35.71%) or from the main renal artery (64.28%). Artery lengths ranged from 0.8 to 5.6 cm, with the right consistently longer than the left.

Conclusions: Renal arteries demonstrated considerable anatomical variation in number, origin, and length. Awareness of these variations is crucial to minimize complications in surgical and interventional procedures involving the kidneys.

Keywords: Accessory arteries, Anatomical variation, Cadaveric study, Renal artery, Vascular anatomy

INTRODUCTION

The kidneys are paired retroperitoneal organs that play a pivotal role in maintaining homeostasis through the processes of filtration, secretion, and reabsorption [1]. In addition to their excretory functions, they regulate blood pressure, electrolyte balance, and red blood cell production via endocrine mechanisms. A constant and adequate blood supply is vital for these diverse physiological activities. The vascular architecture of the kidneys is therefore of immense importance in both normal physiology and clinical practice [2]. The renal arteries are the principal vessels supplying blood to the kidneys, typically arising as paired lateral branches from the abdominal aorta at the level of the first and second lumbar vertebrae. After entering the hilum, each artery divides into segmental branches, which further subdivide into interlobar, arcuate, and interlobular arteries to perfuse the renal parenchyma [3].

Classical anatomical texts, such as Gray's Anatomy, describe the renal arteries as usually single on each side, with the right renal artery being longer and more oblique due to its course behind the inferior vena cava. The left renal artery, in contrast, tends to be shorter and more horizontal, lying posterior to the left renal vein [4]. Despite this general pattern, multiple studies have consistently documented considerable variability in the number, origin, course, and branching of renal arteries. Such variations are the result of complex embryological development, in which transient mesonephric arteries arising from the dorsal aorta may persist, giving rise to accessory or aberrant renal arteries [5].

Anatomical variations of the renal artery are more than incidental curiosities. Their presence has important clinical implications across several disciplines. In renal transplantation, the presence of multiple renal arteries can complicate donor nephrectomy and vascular anastomosis, increasing the risk of ischemia and delayed graft function [6]. In vascular and urological surgery, failure to recognize accessory arteries may lead to inadvertent ligation, resulting in partial renal infarction or compromised renal function. Interventional radiologists must also be aware of such variations, since unidentified accessory arteries may cause incomplete embolization in procedures such as renal artery embolization or selective catheterization. Furthermore, variant anatomy has implications in imaging interpretation, where misidentification of aberrant vessels could lead to diagnostic errors [7].

In Nepal, limited literature exists on renal artery variations, and most available information is derived from international studies [8,9]. Considering the growing demand for renal transplantation and interventional procedures in the country, local anatomical data are essential for improving surgical safety and patient outcomes. The present cadaveric study was therefore undertaken at the Karnali Academy of Health Sciences, Jumla, to document the number, level of origin, source of accessory arteries, and length of renal arteries in a sample of the Nepali population. By systematically analyzing cadaveric specimens, this study aimed to contribute valuable baseline information for surgeons, radiologists, and anatomists, while also enriching the regional anatomical database.

MATERIALS AND METHODS

Study Design

This was an observational, cross-sectional, cadaveric study conducted to evaluate anatomical variations of the renal arteries in terms of number, origin, branching pattern, and length.

Study Setting

The study was carried out in the Department of Anatomy, Karnali Academy of Health Sciences, Jumla, Nepal. Ethical approval was obtained from the Institutional Review Committee prior to the commencement of the study (Ethical clearance no: 2025/070). The dissections were performed during routine undergraduate anatomy sessions.

Sample Study

A total of 32 kidneys obtained from 16 embalmed cadavers (both sexes, adults) were included in the study. Both right and left kidneys were examined for renal artery variations.

Inclusion and Exclusion Criteria

Cadavers with intact abdominal cavities and preserved renal vasculature were included whereas specimens with damaged, poorly preserved, or previously dissected renal arteries were excluded from the analysis.

Procedure

The abdominal cavity was opened during standard cadaveric dissection. Visceral organs were systematically removed to expose the posterior abdominal wall. The abdominal aorta and renal vessels were identified, and the renal arteries were carefully dissected to trace their origin, course, and branching pattern. Variations such as double arteries, accessory branches, and aberrant origins were recorded. The length of each renal artery was measured from its origin at the aorta or main renal artery to its entry at the renal hilum using a Vernier caliper. Representative findings were photographed for documentation [10].

Statistical Analysis

Data were recorded in structured tables and analyzed descriptively. Frequencies and percentages were calculated to present the prevalence of variations. Measurements of renal artery length were expressed in cm, and descriptive statistics were applied to summarize the observed range and side-to-side differences. Microsoft Excell 2019 was used for data analysis.

RESULTS

Among the specimens, a single renal artery was observed in 27 kidneys (84.37%), while 5 kidneys (15.62%) had double arteries (Table 1). Double arteries were slightly more frequent on the left side (9.37%) compared to the right side (6.25%). Representative dissections of single and double renal arteries are shown in Figures 1 and 2.

Renal arteries arose from the abdominal aorta at the same vertebral level in 18 specimens (56.25%). A higher origin of the renal artery was identified more commonly on the right side, present in 8 specimens (25%), whereas only 3 specimens (9.37%) demonstrated a higher origin on the left. A lower origin of the artery was less common, being found in 1 specimen (3.12%) on the right and 2 specimens (6.25%) on the left

(Table 2) Table shows comparison of renal arteries arising at the same, higher, or lower level relative to each other on the right and left sides.

All main renal arteries originated directly from the abdominal aorta. Accessory arteries, however, showed variable origins. Out of 14 accessory arteries documented, 5 (35.71%) arose directly from the abdominal aorta, while 9 (64.28%) originated from the main renal artery (Table 3, Figure 3). Accessory renal arteries arising either directly from the abdominal aorta or from the main renal artery (MRA) in right and left kidneys.

Figure 1: Single renal artery. Dissection showing a single renal artery supplying the kidney, arising directly from the abdominal aorta

Figure 2: Double renal arteries on the right side. Cadaveric specimen demonstrating two renal arteries supplying the right kidney, arising separately from the abdominal aorta

Table 1: Number of renal arteries in cadaveric specimens.

Number	Right		Left		Total	
	No. of Specimens	%	No. of Specimens	%	No. of Specimens	%
Single	14	43.75	13	40.62	27	84.37
Double	2	6.25	3	9.37	5	15.62

Table 2: Level of origin of renal arteries from the abdominal aorta.

Level	Right Side		Left side		Total	
	No. of Specimens	%	No. of Specimens	%	No. of Specimens	%
Same level	9	28.12	9	28.12	18	56.25
High	8	25	3	9.37	7	34.37
Low	1	3.12	2	6.25	7	9.37

Table 3: Source of origin of accessory renal arteries

Source	Right side		Left side		Total	
	No. of Specimens	%	No. of Specimens	%	No. of Specimens	%
Aorta	2	14.28	3	21.42	5	35.71
MRA	6	42.85	3	21.42	9	64.28

Figure 3: Left accessory renal artery and right aberrant renal artery. Dissection showing a left accessory renal artery arising

from the abdominal aorta and a right aberrant renal artery originating from the main renal artery

The lengths of renal arteries varied widely, ranging from 0.8 to 5.6 cm (Table 4). In general, right renal arteries were consistently longer than the left, reflecting their anatomical course across the midline posterior to the inferior vena cava. The shortest artery observed measured 0.8 cm on the right, while the longest was 5.6 cm in a specimen with a double right renal artery. On the left, the arterial length ranged between 0.7 cm and 5.3 cm.

Table 4: Length of renal arteries in cadaveric specimens

Body Number	Right Kidney (cm)	Left Kidney (cm)
1	3.0	2.5
2	4.9	3.2
3	5.3	3.7
4	3.7	1.9
5	Upper- 4.4 Lower- 4.9	3.9
6	4.2	3.2
7	4.1	2.6
8	5	2.7
9	5.4	2.3
10	Upper- 3.2 Lower - 5.6	4.1
11	3.7	Upper- 0.7 Lower- 5.3
12	2.6	3.4
13	5.1	4.3
14	4.9	Upper- 3.3 Lower- 5.3
15	0.8	Upper-1.2 Lower- 3.8
16	4.8	3.4

DISCUSSION

The present cadaveric study of 32 kidneys demonstrated that the majority (84.37%) were supplied by a single renal artery, while 15.62% had double arteries. These findings align with classical anatomical descriptions in which a single renal artery is the most frequent pattern of renal vascularization [11]. However, the observed prevalence of double arteries in this study is higher than some earlier reports. For instance, Anturlikar et al. [12] reported a prevalence of accessory or multiple renal arteries in 12% of specimens from Maharashtra, India, while Gray's Anatomy describes accessory arteries in approximately 25–30% of cases [4].

Our data thus falls within the expected global range but emphasizes notable variability in the Nepali population. Interestingly, double arteries were slightly more common on the left side (9.37%) compared with the right (6.25%), a pattern also noted in previous cadaveric and radiological studies [13]. Although the exact cause of this asymmetry is not fully understood, it is plausibly related to differences in embryological vascular regression and anatomical configuration between the two sides. The right renal artery develops in close relation to the inferior vena cava and follows a longer, more complex course, which may influence vascular remodeling during development. In contrast, the relatively direct course of the left renal artery may favor persistence of additional embryonic arterial channels, resulting in a higher incidence of accessory or double renal arteries on the left.

With regard to the level of origin, the renal arteries arose at the same level bilaterally in 56.25% of cases, whereas a higher origin was more frequently observed on the right (25%) than on the left (9.37%). These results are consistent with the anatomical relationship of the right renal artery, which typically arises

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higher and courses posterior to the inferior vena cava before reaching the hilum. Prior studies have reported a right-sided predominance of higher origins, with incidences ranging from 20–30% [14,15]. Our findings corroborate this anatomical tendency and highlight its relevance in retroperitoneal surgeries and vascular interventions.

All main renal arteries in our study originated directly from the abdominal aorta, consistent with classical anatomy. However, accessory renal arteries showed variability in their source of origin. While 35.71% arose directly from the aorta, the majority (64.28%) originated from the main renal artery (MRA). This pattern reflects the persistence of embryonic mesonephric arteries, which normally regress during development but may persist as accessory vessels. Comparatively, study by Satyapal et al. [16] have described accessory arteries most commonly arising directly from the aorta, whereas our findings suggest a higher frequency of origin from the MRA in this population. This observation may represent a population-specific trend requiring further validation through larger-scale studies.

The length of renal arteries ranged from 0.8 to 5.6 cm, with the right renal arteries consistently longer than the left. This asymmetry corresponds to the anatomical course of the right renal artery, which must cross behind the inferior vena cava, thereby increasing its length. Similar trends have been widely reported in anatomical and radiological studies, with right renal arteries typically measuring 1–2 cm longer than the left [17]. From a surgical perspective, longer right renal arteries can be advantageous in transplantation procedures, as they provide greater flexibility for vascular anastomosis. Conversely, short renal arteries, particularly on the left, may increase technical challenges during donor nephrectomy. The findings of this study confirm the wide variability in renal artery anatomy, which holds significant implications for clinical practice. In renal transplantation, the presence of multiple or accessory arteries may increase the risk of vascular complications, delayed graft function, and technical difficulties during anastomosis. In interventional radiology, unrecognized accessory arteries may compromise embolization procedures or lead to incomplete therapeutic outcomes. Likewise, in urological and vascular surgeries, variant arteries may be inadvertently damaged if not identified preoperatively. For these reasons, pre-procedural imaging modalities such as CT angiography or MR angiography remain indispensable tools for mapping renal vascular anatomy.

CONCLUSION

The renal arteries exhibit considerable variability in number, level of origin, and branching pattern. While a single artery is most common, accessory arteries and aberrant branches are not uncommon. The right renal artery frequently originates higher and tends to be longer than the left. These findings underscore the importance of preoperative vascular mapping and anatomical awareness to minimize complications in surgical and interventional procedures involving the kidneys.

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