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PATHOLOGICAL STUDY

# A report on accessory renal arteries incidence in Slovak adults: Cadaveric study and surgical correlation

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**ABSTRACT**

OBJECTIVES: The aim of the study was to evaluate renal arterial variations in Slovak context.

METHODS: Forty cadavers (80 formalin-fixed cadaveric kidneys) were included in the study. The accessory renal arteries (ARAs) were evaluated on the basis of point of origin, termination in the kidney (superior pole, hilum, inferior pole), and symmetry.

RESULTS: The incidence of ARAs was detected in 20 % (8/40) of the cadavers. Double renal arteries were observed in 9 (11.25 %, n = 80) of kidneys. Among 8 cadavers with ARAs, the unilateral presence of ARA was found in 7 cadavers and bilateral presence in 1 cadaver. Among 9 ARAs, *polar artery* was the most common anomaly seen in 7 (78 %) kidneys (inferior polar artery 5, superior polar artery 2) followed by the hilar artery in 2 kidneys.

CONCLUSIONS: This is the first cadaveric study on the incidence and morphology of ARAs in Slovakia. The study has shown that the variations in renal arterial anatomy are a frequent finding (20 % of cadavers) while all of the described variants have significant implications for a variety of surgical procedures in the retroperitoneal space. The variations in renal arteries should be considered an integral part of anatomy teaching as they point to the diverse clinical reality of anatomy *(Tab. 1, Fig. 1, Ref. 35)*. Text in PDF *www.elis.sk*

KEY WORDS: renal artery, variation, polar artery, double renal artery, cadaver.

## Introduction

Generally, the renal arteries are two large trunks, which arise from the sides of the aorta, immediately below the superior mesenteric artery. The renal arteries originate from the aorta at the level of the lower third of L1 vertebra with a variation of one vertebral body, cephalad or caudad (1). Each renal artery forms nearly a right angle with the aorta and passes across the crus of the diaphragm. The right renal artery is longer than the left one, on account of the position of the aorta; it passes behind the inferior vena cava. Previously to entering the kidney, each renal artery divides into anterior and posterior divisions, which receive approximately 75 % and 25 % of blood, respectively. The anterior division further divides into the upper, middle, lower, and apical segmental arteries while the posterior division forms the posterior segmental artery. Segmental arteries subsequently divide into lobar, interlobar, arcuate, and interlobular arteries before forming the afferent arterioles which feed into the glomerular capillaries. At the hilum of kidney, segmental branches lie between the renal vein and ureter, the vein being usually in front, the ureter behind. Each renal artery gives off some small branches to the suprarenal glands, ureter, and surrounding cellular membrane and capsules (2).

The arrangement of arteries of kidneys varies among individuals. The most commonly observed variation is the presence of an accessory renal artery, occurring in approximately 30 % of cases, arising from the aorta above or below the main renal artery (3–5). On the basis of the number, the renal arteries originating from the aorta can be double (4, 6, 7), triple or quadruple (1). Among renal arterial morphological variations, the double renal arteries are the most frequent (1, 7). Four renal arteries originating from the aorta were described only in rare cases (0.4 %; 1.4 %) (8–10). Accessory arteries are categorized as either hilar or polar. Hilar artery enters the kidney through the hilum while polar artery enters the kidney through the capsule outside the hilum. Polar arteries perfuse the superior or inferior renal poles (11). There are no reports on the frequency of occurrence and types of the accessory renal arteries in Slovakia. The presence of accessory renal arteries principally relates to surgical applications.

## Material and methods

During routine cadaveric educational dissections of 40 adult cadavers, the renal blood supply was examined for the presence,

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**Tab. 1. Number and percent of categories of renal arteries of both genders.**

| Categories | Total | Figure |
|---|---|---|
| Single artery (1 hilar artery) | 71 (88,75%) | |
| Double artery | 9 (11,25%) | |
| One hilar artery + 1 inferior polar artery | 5 (6.25%) | Fig 1A, 1B, 1C, 1D, 1E |
| One hilar artery + 1 superior polar artery | 2 (2.5%) | Fig 1F, 1G |
| Two hilar arteries | 2 (2.5%) | Fig 1H |

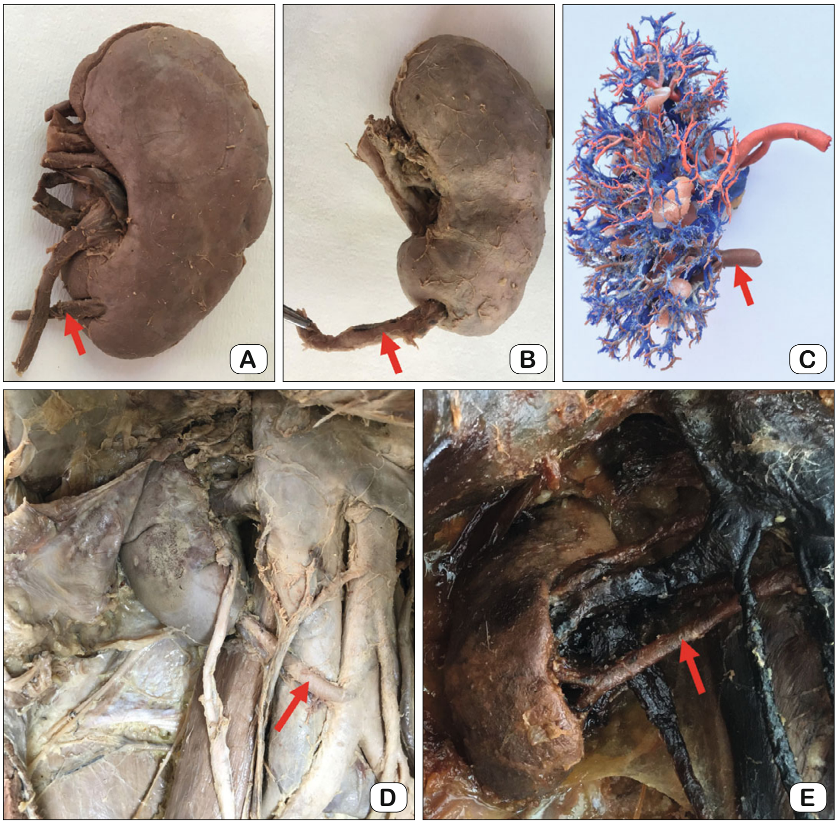


**Fig. 1. Types of accessory renal arteries in our study. Accessory renal arteries are highlighted. A, B, C, D, E: One hilar artery with one inferior polar artery, 6.25 % (5/80 kidneys). Inferior polar artery is highlighted.**

morphological characteristics, and incidence of accessory renal arteries. We dissected 80 cadaveric kidneys in the anatomy laboratory from 2015 to 2022 at the Department of Anatomy, Pavol Jozef Šafárik University, Košice. The age of cadavers was in range of 60–93 years (21 males, 19 females). The cadavers were obtained from the body donation program following receipt of a signed informed consent from the donors themselves. The complete medical history of the cadavers was not available. The cadavers were embalmed soon after death and were preserved by an injection of formalin-based preservative solutions. The dissection was performed in accordance with all legal requirements posed by the University's Ethical Committee. The abdominal cavity was opened by standard dissection of the abdominal wall. The peritoneum, intestines, lymph nodes and connective tissue around the great vessels were removed to provide a clear vision. The renal fascia and fatty capsule were carefully cut out, but the kidneys were attached to their vessels in the body cavity. The renal veins were cleaned and cut close to the inferior vena cava. While doing so, the arterial supply to the kidneys was carefully observed for any variations. The renal arteries were cleaned and photographed, in particular for their origins and courses. Then, the renal arteries were cut from the aorta and the renal pelvis was cut away from the ureter. The kidneys were removed from the cadaver and in the next step, the silicon plastination technique was used to preserve cadaveric kidneys as specimens for anatomy teaching. The number and percent of accessory renal arteries are reported.

## Results

We found accessory renal arteries in 8 cadavers (20 %, n =4 0). A total of 80 kidneys were dissected. The following nomenclature was used to categorize the accessory renal artery originating from the aorta: *hilar artery*, an aortic branch that penetrated the kidney in the hilar region; *superior polar artery*, an aortic branch that penetrated the kidney at its superior pole; *and inferior polar artery*, an aortic branch that penetrated the kidney at its inferior pole. A single renal artery was detected in 71 (88.75 %) of the 80 kidneys investigated. The number and view of renal hilar and polar arteries are presented in Table 1 and Figure 1A – H. Double renal arteries were observed in 9 kidneys (11.25%); of these, 5 kidneys (6.25%, N=80) had one hilar artery combined with one inferior polar artery; 2 kidneys (2.5 %, n = 80) had one hilar artery combined with one superior polar artery; 2 kidneys (2.5 %, n = 80) had two hilar arteries (Fig. 1). Bilateral double renal arteries were found only in one cadaver (2.5 %, n = 40).

## Discussion

The arterial supply of kidney is quite variable. In our study, we use the term ´accessory renal artery´ (ARA) for more than one additional renal artery originating from the abdominal aorta. This term is widely adopted and proposed by Mishal in *Bergman´s Comprehensive Encyclopedia of Human Anatomic Variation* (1). However, some authors claimed that it is incorrect to refer to these vessels as being ´accessory´ because they are not superfluous; instead, they are essential tissue-sustaining, non-anastomotic arteries, corresponding to the segmental branch of a single renal artery (3, 4, 12, 13).

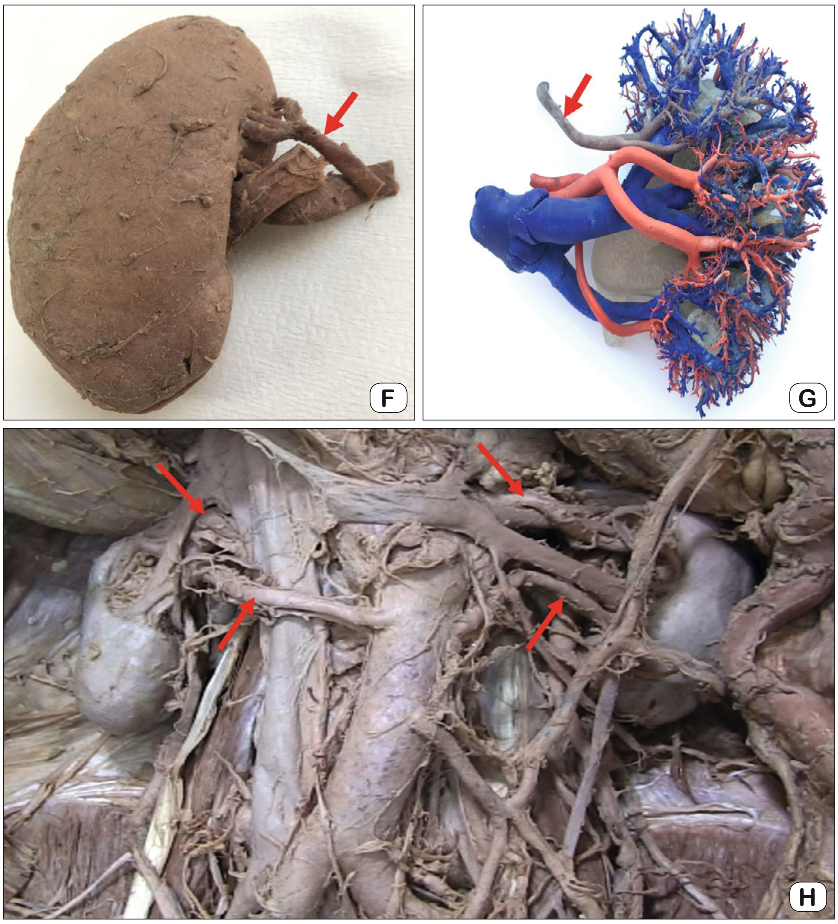


**Fig. 1. Types of accessory renal arteries in our study. Accessory renal arteries are highlighted. F, G: One hilar artery with one superior polar artery, 2.25 % (2/80 kidneys). Superior polar artery is highlighted. H: Two hilar arteries, 2.25 % (2/80 kidneys). Double renal arteries were found to be bilateral only in a singular cadaver (2.5 %, n = 40).**

In this study, 71 kidneys (88.8 %) had a normal arterial supply with a single renal artery vascularizing the kidney. Similar findings were reported by Tardo et al (87.8 %) (9), Natsis et al (88.8 %) (13), Aristotle et al (86.6 %) (14), and Khamanarong et al (82.2 %) (6). However, studies by Hlaing et al (96.3 %) (15), and Budhiraja et al (91.7 %) (16) found comparatively higher prevalence rates. On the other hand, Palmieriet al (38.5 %) (17), Shoja et al (56.8 %) (18), and Johnson et al (63.9 %) (19) reported lower prevalence rates. This might be because the accessory renal artery terminology is unclear and numerous terms have been utilized, including ´aberrant´, ´abnormal´, ´additional´, ´extra´, ´multiple´, ´supernumerary´, and ´supplementary´ and samples of various studies included also the early division of pre-hilar branches (4, 20). The detection of accessory renal arteries in multiple studies may also depend on the sensitivity of diagnostic procedures, for example, on that of cadaveric or radiological examinations. On magnetic resonance imaging and angiographic studies, the accessory renal arteries are frequently confused with the adrenal or capsular arteries (21).

In the present study, double renal arteries were observed as the only pattern of ARAs. Double renal arteries were observed in 11.25 % (9 cases, n = 80) of kidneys. Several authors discovered a similar incidence of double renal arteries (13, 14), whereas others found a variable incidence from 5.6 % to 27.6 % (3, 6, 8, 9, 19). Three or four renal arteries supplying one kidney were not found in our study. Several studies reported a presence of three or four renal arteries in rare cases (8, 9, 22, 23). The frequency of presence of accessory renal arteries varies widely with ethnicity, ranging from 4 % in Malaysians to 61.5 % in Indians and the incidence of ARAs is influenced also by hereditary factors (4). The significant differences between results may simply be related to the size of the samples analyzed.

In our study, all accessory renal arteries arose from the abdominal aorta. On rare occasions, ARAs arise from the coeliac trunk, superior mesenteric, inferior mesenteric, common iliac, and external or internal iliac artery (1, 24). The most common origin of accessory renal artery is abdominal aorta, as confirmed by Natsis et al (13), Gulas et al (4), and Tardo et al (9). The accessory renal artery originating from the aorta may have a significant impact on endovascular aneurysm repair because graft deployment and seating may need to be adjusted in the face of anomalies. Even in open aneurysmorrhaphy, careful attention must be paid to the planning of aortic cross clamp placement to prevent inadvertent occlusion of these end arteries and renal ischemia (19).

Among 8 cadavers with ARAs, the unilateral presence of ARA was found in 7 cadavers and bilateral presence in 1 cadaver. The unilateral presence of ARA was reported by majority of studies (9, 16, 25).

Among 9 accessory renal arteries, the *polar artery* was the most common anomaly seen in 7 (78 %) kidneys (inferior polar artery 5, superior polar artery 2) followed by the hilar artery in 2 kidneys. Similarly, the presence of polar artery was the most common variation found in 76 % of the 72 kidneys with ARAs reported by Chhetri et al (11). Ligation of aortic polar renal arteries is associated with segmental ischemia and failure of the kidney, as these arteries are end arteries and failure in their patency can cause an infarction of approximately 30 % of the renal parenchyma (26).

In our study, the most common combination of anomalies was the presence of an inferior polar artery with one hilar renal artery. The same result has been reported by Coen and Raftery (27), Talovic et al (25), Johnson et al (17), Tardo et al (9), and

Bouzouita et al (28). Inferior polar arteries appear to be of greater significance than superior polar arteries for two important reasons. Firstly, the upper part of the ureter receives critical blood supply from a branch of the inferior polar artery if one is present. Damage to this vessel will result in ureteric necrosis and subsequent paralysis, or development of urinary leak. Secondly, there is a reported risk of ureteropelvic obstruction occurring if the inferior polar artery crosses the ureter anteriorly or posteriorly. Consequently, this can lead to the development of hydronephrosis which in time has the potential to progress to pyelonephritis (9, 19, 28). Eitan et al (29) reported an additional aortic inferior polar artery injury during paraaortic lymphadenectomy for endometrial cancer. The damage of the inferior polar artery caused an infarction of the lower pole of the kidney. Iatrogenic damage to the inferior polar artery can occur during laparoscopic operations in aortocaval and precaval regions. Intraoperative bleeding is the most common complication during lymphadenectomy. Anomalous vessels may be encountered in every patient who undergoes surgery in the aorto-caval region (30).

The occurrence of ARA may also be associated with coexistence of other atypical variants of vascularization, especially those connected with the genito-urinary system (4). For example, ARA can be accompanied by double testicular arteries (31). The relationship between anatomic variations of renal and gonadal vessels lies in the complicated and partially integrated embryologic development of the kidneys, gonads and their vasculature (32).

The knowledge of the embryonic development of the kidney forms the basis for understanding the cause of ARAs. The kidneys are derived from the embryonic urogenital ridge in the intermediate mesoderm. The urogenital ridge is supplied by a network of capillaries called *´rete arteriosum urogenitale´* which arises from the abdominal aorta, later referred to as segmental lateral splanchnic arteries (33). Within the initial development of the metanephric kidney in the sacral region and its subsequent ascent to its final destination in the lumbar region, the caudal branches of the lateral splanchnic vessels degenerate in favor of more proximal vessels that are relatively close to the position of the kidney. A failure of regression of the lateral splanchnic vessels can give rise to ARAs anywhere between the eleventh thoracic and fifth lumbar vertebral levels. Chemical factors including the degree of oxygenation, nutrients, availability of transcription factors, and hemodynamic selection, along with the genetic disposition of the individual, have been identified as critical regulators in the development of the renal vasculature (1, 34).

The presence of ARAs increases the challenge and complexity of diagnostic and surgical procedures. ARAs may increase operation time during kidney transplantation. Accessory lower polar arteries are associated with a higher rate of recipient ureteral complications indicating the importance of arterial imaging (21, 27). Partial nephrectomy is gaining, nowadays, more interest in oncologic kidney surgery. This type of surgery requires good knowledge of vascular renal anatomy to make it safe and guarantee good functional and oncological outcomes. Good preoperative vascular mapping will be of great help for the surgeon (28). It is agreed generally that the presence of inferior polar arteries can complicate abdominal aortic aneurysms repair, and the patients are most likely to suffer severe bleeding (35).

This study provides an insight into the renal artery variations in Slovakia. We found accessory renal arteries in 20 % of cadavers and 11 % of the kidneys examined. These results are consistent with the available body of literature; unilateral renal arterial variation being more common than the bilateral one. *Polar* arterial supply was the most common arterial variant in this study. In preparation for surgical interventions, such as living renal donation, vascular reconstruction, repair of abdominal aortic aneurysm, periaortic lymph node dissection, radical or partial nephrectomy, the results indicate that preoperative renal imaging is necessary and that operative techniques with attention to accessory renal arteries should be considered.

Moreover, we emphasize that the cadaver dissection is an ideal method for teaching anatomy that gives opportunity to medical students the to reveal many anatomical variations. Our emphasis on dissection as appropriate learning strategy comes at a time when many medical schools are moving away from dissection and shifting towards plastic anatomical models and digital software while overlooking anatomical variations.

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