

Atypical sites of origin of the main renal artery — narrative review

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Abstract: Anatomical and clinical records were analyzed to identify cases of anomalous origins of the main renal artery. Instead of typically branching from the abdominal aorta at the vertebral level of L1–L2, the main renal artery can originate from the thoracic aorta, the inferior abdominal aorta (below the L2 vertebra), or from nearby arterial vessels such as the celiac trunk, superior mesenteric artery, inferior mesenteric artery, or common iliac artery.

Keywords: renal artery, renal blood supply, kidney.

Introduction

Variation in the blood supply to the kidney refers to the origin, course, and number of renal arteries. Approximately 70% of individuals in the human population have a single renal artery that originates from the abdominal aorta. The remaining 30% of individuals exhibit variations in the arrangement and number of renal arteries [1, 2]. Harrison *et al.* reported that a bilaterally present single renal artery exhibiting a hilar segmental branching pattern was observed in only 46% of patients who were subjected to arteriographic examination [3].

Sampaio and Passos distinguished several patterns of arterial supply to the kidney, among which a single hilar artery occurred in 55.3%, whereas the remaining patterns involved extra-hilar branches varying in number, origin, and positioning relative to the main renal artery. However, no statistically significant difference in arterial variation between the right and left kidneys was noted. Bilateral variation was observed in only 4.5% of the individuals [4].

In a study performed by O'Neill *et al.*, 70.6% of patients had a single left renal artery, and 69.4% of patients had a single right renal artery. Single renal arteries were identified bilaterally in 54.4% of patients [5]. Khamanarong *et al.* found a higher overall prevalence of a single renal artery in



81.6% of their cases, with 38.9% in the right kidney and 42.7% in the left [6]. Dhar and Lal documented the existence of a single main renal artery on either side in 80% of the specimens [7].

Due to the considerable anatomical variation that characterizes the renal vasculature, it is crucial to have detailed knowledge in this field for safe conducting surgical procedures such as renal transplantation and renovascular reconstruction, as well as for proper and accurate radiological assessment of the blood supply to the kidney. Therefore, the presence of anomalous renal arteries draws the attention of clinicians, necessitating careful planning and execution of urological procedures, particularly in cases where anatomical variations are uncommon. Therefore, we focused our analysis on clinical reports that present unusual sites of origin of the main renal artery.

Typical size, origin, and course of the main renal artery

In normally situated kidneys, the right and left main renal arteries typically originate as a single vessel from the lateral side of the abdominal aorta at the L1–L2 vertebral level. Each renal artery enters the renal hilum in front of the ureter and divides into multiple branches that embrace the pelvicalyceal system inside the kidney (Fig. 1).

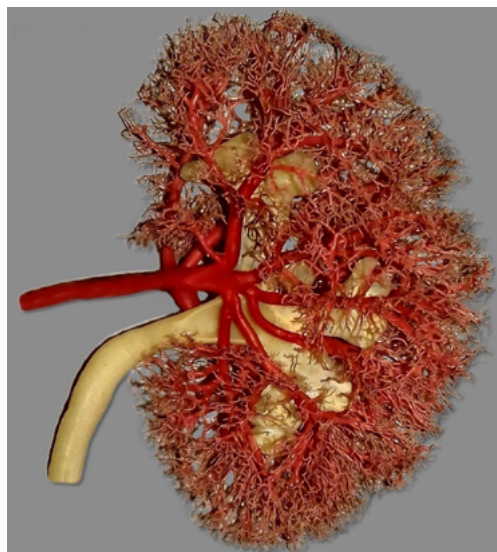


Fig. 1. The corrosion cast of the human kidney demonstrates the main renal artery that enters the renal hilum as a single trunk and divides into an intrarenal arterial network surrounding the pelvicalyceal system. The specimen derives from the museum collection of the Department of Anatomy, Jagiellonian University Medical College.

The main renal arteries are usually 4–6 cm in length and 5–8 mm in diameter, depending on the side on which the kidney is located and the sex of individual. Females usually, have smaller renal arteries compared to males [8, 9]. The right renal artery is longer than the left one, regardless of sex. The differences in the lengths of the renal arteries result from the position of the aorta, which runs on the left side of the vertebral column in the region of the kidneys location. The right renal artery is frequently situated at a higher level than that of the left renal artery [10, 11]. Occurrence of the ostia of the right and left renal arteries located at the same level is rare, representing only 10% of all cases [12]. According to Özkan *et al.*, the most frequent point of origin for the main renal arteries from the aorta is located between the upper margin of L1 and the lower margin of the L2 vertebra, with a prevalence of 98% on the right side and 97% on the left side [13]. Similarly,

Beregi *et al.* found that most of the right (88%) and left (87%) renal arteries originate between the lower third of the L1 vertebra and the lower border of the L2 vertebra [14].

The main renal arteries can originate from the abdominal aorta at an angle of approximately 90°. Woźniak reports that the right renal artery usually arises at an angle of approximately 75°, whereas the left renal artery arises at an angle of approximately 85° [15]. Additionally, a study by Garcier *et al.* has shown that the angles in the frontal plane were 73.8° for the right renal artery and 65.6° for the left renal artery [16]. The relationship between the right and left renal arteries and their origins from the aorta was analyzed by Beregi *et al.* [14]. With reference to the transverse axis of the aorta, the angle of origin of the right renal artery varied from -10° to $+55^{\circ}$, whereas that of the left renal artery varied from -55° to $+30^{\circ}$.

Materials and Methods

To collect relevant literature data regarding variations in the origins of the main renal arteries, we first employed the Google Scholar search engine. Subsequently, we determined whether the identified articles were indexed in the PubMed database. We decided to use Google Scholar because it indexes scholarly literature included in journal articles, theses, books, and conference papers. Although Google Scholar is a broad source of information, it does not ensure that all the materials listed are of academic quality because some of the results may come from non-peer-reviewed sources. Therefore, it was essential to determine which of the retrieved data came from the articles indexed in PubMed. This verification process allowed us to assess the credibility of the resources we located.

Our research was limited to a single database, PubMed, because it mainly contains biomedical literature. In comparison, Scopus is more appropriate for interdisciplinary research, whereas Web of Science focuses on high-impact research. From our point of view, PubMed appeared to be the most suitable source of information about anatomical variants of the renal artery in humans. Since our research focused exclusively on the abnormal origins of the main renal artery, we excluded case reports that described variations in accessory renal arteries entering the renal hilum or other sites of the kidney.

Results

The literature indicates that the most frequent location for the origin of renal arteries from the abdominal aorta is the lateral aspect, accounting for 92% of the cases. In contrast, anterolateral and posterolateral positions are less common, representing 6% and 2%, respectively, at the L1–L2 level of the abdominal aorta [17]. According to Keen, the right renal artery usually arises near the anterior midline of the aorta and higher than the left renal artery, which normally arises in a strictly lateral orientation at the angle of 90 degrees [10].

Nevertheless, renal arteries may have different origins. Instead of branching off directly from the abdominal aorta, at the typical level of the L1–L2 vertebrae, the renal arteries can originate from a location above this level or below from arteries that are branches of the descending aorta. Numerous case reports have provided evidence indicating that the potential sites of origin of the main renal artery can span from the 10th thoracic vertebra to the level of the 3rd lumbar vertebra. Therefore, the ectopic origin of the main renal artery can be classified as supradiaphragmatic (from the thoracic aorta) or infradiaphragmatic (from the abdominal aorta or its branches).

Additionally, the ectopic site of origin of the renal artery may be related to the anterior, lateral, or posterior aspect of the descending aorta (Fig. 2).

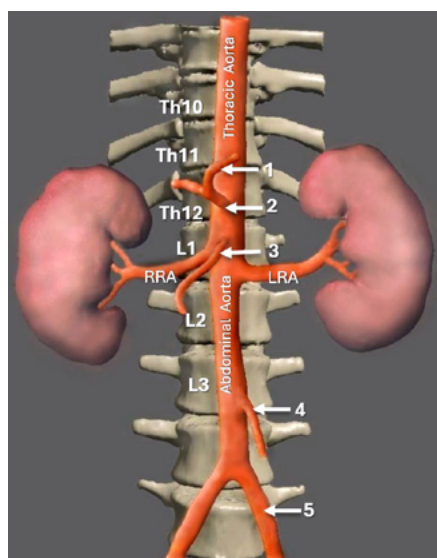


Fig. 2. Schematic illustration showing the levels (Th10–Th12 and L1–L3) at which renal arteries can originate from the ascending aorta (thoracic and abdominal). The visceral branches from the abdominal aorta, which can serve as potential sites for the origin of the main renal arteries, were labeled as: 1 — splenic artery, 2 — celiac trunk, 3 — superior mesenteric artery, 4 — inferior mesenteric artery, 5 — common iliac artery. Right and left renal arteries (RRA, LRA) are depicted in typical origin from the aorta.

Origin of the renal artery from the thoracic aorta

One of the first reports concerning the ectopic origin of a single renal artery from the aorta was by Doppman (1967), who found such an anomaly at the level of the Th11 vertebra [18]. Further research confirmed the possibility of emerging the renal arteries above the diaphragm. Al-Smair *et al.* reported the supradiaphragmatic origin of the right renal artery in a 66-year-old woman [19]. Furthermore, Delasotta *et al.* reported the occurrence of a right renal artery arising from the thoracic aorta in the lower portion of the Th10 vertebral body [20]. Gadabanahalli and Bhat identified in the contrast-enhanced computed tomography examination of the 40-year-old male patient a single renal artery arising from the posterior aspect of the aorta at the level of the intervertebral disk located between Th10–Th11. The same authors found in an angiographic study of a 28-year-old female patient with a single right renal artery arising from the aorta at the level of the Th11 vertebra [21].

Ichikawa *et al.* and Ishida *et al.* presented cases of a 38-year-old male and a 37-year-old male, with the right renal artery originating from the thoracic aorta at the same level as the Th11 vertebra [22, 23]. Similarly, Fernet *et al.* reported that the right renal artery originated from the aorta at the level of the intervertebral disc, located between the Th11 and Th12 thoracic vertebrae [24]. Matusz *et al.* identified that in a 72-year-old male, the right renal artery emerged from the thoracic aorta at the upper-third level of the Th12 vertebra [25].

In turn, Tegtmeier observed at a 40-year-old woman a single right renal artery originating at the level of the Th11 thoracic vertebra; however, there was agenesis of the left kidney in this case [26]. In contrast, Kim presented a case of a 28-year-old male in which the left renal artery originated posterolaterally from the thoracic aorta at the level of the Th12. Stinson *et al.* identified a single left renal artery in a 74-year-old man that originated from the posterior aspect of the thoracic aorta at the level of the Th12 vertebra [27, 28].

The aforementioned cases reveal that atypical sites of origin of the main renal arteries from the thoracic aorta can encompass the levels from Th10 to Th12 in both sexes. This variation was more common in the right renal artery than in the left one.

Origin of the renal artery from the celiac trunk

The main renal artery can originate from the celiac trunk (also known as the celiac artery, celiac axis or coeliac axis) or may have a site of origin in its proximity, either from the celiacomesenteric trunk if it was developed. However, such anatomical variations have rarely been documented in literature [29, 30]. Mankowitz reported a common origin from the celiac trunk for the right and left renal arteries, along with the superior mesenteric artery observed in a 28-year-old female who suffered from celiac artery compression syndrome [31]. Garti and Meiraz presented two cases of a single main left renal artery, with one case originating above the celiac trunk and the other arising directly from the celiac trunk [32]. Furthermore, Nachiappan *et al.* identified during a CT examination of a 75-year-old female patient that the main right renal artery originated directly from the celiac trunk [33].

Origin of the renal artery from the splenic artery

The splenic artery (a branch of the celiac trunk) was identified as the site of origin of the renal artery. Krut reported that a single left renal artery originated from the splenic artery [34]. Such an extraordinary origin of the renal artery was found in an angiographic examination and confirmed by computed tomography. This is the only case we found in the literature reviewed.

Origin of the renal artery from the superior mesenteric artery

The main renal arteries can arise from the abdominal aorta in proximity to the origin of the superior mesenteric artery or directly from it. An extensive analysis of this topographical relationship was performed by Sośnik and Sośnik [35]. Their study revealed that in females, the distance from the superior mesenteric artery to the point where the renal arteries branch off from the aorta varied between 0.0 and 4.5 cm, while in males, this distance ranged from 0.0 to 5.0 cm. Furthermore, the average distance between the superior mesenteric artery and the renal arteries was smaller if they existed as singular vessels, compared to subjects with multiple renal arteries.

Dalçık *et al.* reported a case of a 50-year-old male in whom a common arterial trunk emerging from the aorta at the L2 level gave rise to the right renal and superior mesenteric arteries [36]. Furthermore, Hong *et al.* and Lacout *et al.* independently described cases of main renal arteries originating from the superior mesenteric artery that were observed in male individuals of similar ages (62 years and 57 years). However, in the case described by Hong *et al.*, there existed a second right renal artery originating from the aorta [37, 38].

Origin of the renal artery from the inferior mesenteric artery

Cases of the main renal artery originating from the inferior mesenteric artery are rarely documented in medical literature. This anomaly seems uncommon, although it can already be recognized in human fetuses. Nuzhat examined 100 fetuses from the second and third trimesters, among them

only one had a single left renal artery originating from the inferior mesenteric artery [39]. Other reports on this anomaly concern adults. Garti *et al.* identified in an angiographic examination a common origin of the inferior mesenteric artery and a single main renal artery in a patient with an ipsilateral ectopic kidney [40]. In addition, Tisnado *et al.* reported an extremely rare anomaly in which the renal artery originated from the inferior mesenteric artery in a normally positioned kidney, as demonstrated by selective arteriography in a 22-year-old male [41].

Origin of the renal artery from the common iliac artery

In rare cases, the renal artery can originate from the common iliac artery. Halloul *et al.* identified that the right kidney of a 66-year-old man was supplied by a renal artery originating from the left common iliac artery [42]. In turn, Kim *et al.* reported an exceptional case of the right main renal artery originating from the left common iliac artery along with other accessory arteries observed in a 60-year-old male [43]. The majority of cases in which the renal artery originates from the common iliac arteries involve accessory renal arteries. The first documented such case dates back to the 16th century and was presented by Eustachi [44].

Contralateral origin of the renal artery

Atypical blood supply to the kidney may involve cases in which the main renal artery originates from the arteries located on the opposite side of the body. Such a case described Jeffery, who found that the right renal artery originated from the left renal artery in a 65-year-old woman [45]. Another example comes from Giavroglou and Kokkinakis, who reported that in a 65-year-old man, the left main renal artery originated from the right renal artery, whereas the right kidney was supplied by one renal artery arising from the aorta [46]. A notable case was reported by Kónya, who found that the entire left kidney was supplied by a single renal artery originating from the right renal artery [47]. Although contralateral origins of the main renal arteries are rare, they may occur alongside accessory renal arteries, thus complicating radiological evaluation of the blood supply to the kidney.

Discussion

The abnormal origin of the renal arteries results from the intricate embryological development of the kidneys and their associated blood vessels. Since the early 20th century, researchers have highlighted the importance of comparative anatomy for explaining anomalies of the human kidneys and their blood supply [48]. Therefore, the anatomical variation of renal vasculature has been extensively examined and discussed, emphasizing the significance of kidney migration during embryogenesis, their growth along the craniocaudal axis, and the potential impact of adjacent developing organs [49–52].

During the formation of the urogenital system, the kidneys ascend from the pelvis to the abdominal cavity. In the period between 4 and 9 weeks of fetal development, the mesonephric arteries exhibit a segmental arrangement and supply the blood to the mesonephros as a kidney precursor. The mesonephric arteries undergo obliteration and regression around the 8th week of fetal development. This process continues until the 12th week, when the definitive renal arteries are fully formed and properly situated. If the mesonephric arteries do not regress, multiple renal arteries can be formed; therefore, they are termed accessory or supernumerary renal arteries.

Aragão *et al.* estimated the frequency of multiple renal arteries in human fetuses to be 21.67% [53]. Moreover, Çiçekcibaşı *et al.* found that anatomical variation in renal arteries was more frequent among male fetuses and involved the right kidney [54]. Differences in the origin and number of renal arteries have also been linked to the ethnic backgrounds of the individuals involved in the study. The incidence of accessory renal arteries may range from 4% to over 60% depending on the population [55].

Our review was focused on the atypical origins of the main renal arteries as singular vessels. Therefore, we do not discuss findings from the studies that explored anomalous blood supply to the human kidneys involving accessory renal arteries.

Conclusions

The main renal arteries typically originate from the abdominal aorta at the L1–L2 level; however, they can emerge at higher levels of the aorta, ranging from Th10 to Th12. Moreover, the main renal arteries can originate from arteries other than the thoracic aorta or abdominal aorta. These include the celiac trunk, splenic, superior mesenteric, inferior mesenteric, and common iliac arteries. Variations of renal artery origin may have important implications for diagnostic and surgical procedures performed by urologists, especially in unusual cases where the renal artery does not exist in a standard arrangement.

Conflict of interest

The authors declare no conflicts of interest or any financial interests associated with the current study.

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