Seven renal arteries: a case report using MDCT angiography

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Abstract
We report an atypical case of a 63-year-old male with the presence of seven renal arteries (RAs) (three right and four left) found incidentally on multi-detector computed tomography (MDCT) angiography which was used to investigate peripheral vascular disease of the lower limbs. Each arterial lumen was analyzed for the diameter at its origin; length and trajectory in the frontal plane (ascendant + or descendant -); and the distance between the point of origin from the abdominal aorta (AA) to its renal intraparenchymal penetration point. We also analyzed the distance between the extreme points of origin of the right and left RAs from the AA and the distance between the extreme points of penetration into the renal parenchyma of the right and left RAs. On each side, the endoluminal diameter at the origin of the main RA was significantly larger than that of the other AdRAs; however, the AdRAs were much longer than that of the main RA. From the six AdRAs, four were hilar RAs and two were superior polar RAs. Knowledge of such cases is of great clinical significance, as it may be beneficial in various urological operations or invasive arterial procedures.

Keywords: renal arteries, kidney, anatomic variants, embryology, morphological considerations, clinical and surgical implications.

Introduction
Traditionally, each kidney is irrigated by a single renal artery (RA) arising from the lateral aspect of the abdominal aorta (AA) at the level of the L2 vertebral body. Variations in the renal vasculature are reported with an incidence of 20–75% [1]. The most common variation is the presence of numerous renal arteries (RAs) [2, 3]. In 1928, Adachi [4] studied a series of 1838 kidneys and found additional renal arteries (AdRAs) present in 23.1% of cases. He also noted that the number of additional renal arteries ranged from 1–4 with a prevalence of 19.81%, 2.88%, 0.44%, and 0.05%, respectively. In a later study conducted in 2011 by Matusz et al. [5], the prevalence of AdRAs was 18.2%. The number of AdRAs found ranged from 1–6 with a prevalence of 9%, 7%, 1.6%, 0.3%, 0.2%, and 0.1%, respectively. Sampaio and Passos [6] reported the bilateral presence of AdRAs in 4.5% of cases, with the bilateral presence of the same variation in 1.9%.

Knowledge of anatomical variations in the renal vasculature has diagnostic and therapeutic implications and is important and relevant for uroradiological procedures; vascular reconstruction; renovascular hypertension; renal trauma; and renal transplant surgery. The aim of this study was to document a rare case with seven RAs (two main RAs and five AdRAs) using on multi-detector computed tomography (MDCT) angiography.

Patient, Methods and Results
A 63-year-old male with peripheral arterial disease of the lower limbs presented at the Neuromed Diagnostic Imaging Center (Timișoara, Romania) for vascular assessment. Using MDCT angiography (64-slice MDCT system; SOMATOM Sensation, Siemens Medical Solutions, Forchheim, Germany), we identified the vascular lesions of the lower limbs. However, we incidentally found a peculiar network of renal vessels supplying the two kidneys. Instead of having two main renal arteries, we found seven renal arteries including: two main RAs and five AdRAs branching from the AA.

MDCT angiographic data were acquired in the craniocaudal direction from the dome of the diaphragm to the feet (scan length 1.49 mm; scan time 28.97 s). The reconstructed image data sets were transferred to an offline workstation (Syngo MultiModality Workplace) for post-processing. The images were analyzed using a 3D task card, performing 3D Maximum Intensity Projection (MIP) reconstruction and InSpace task card for 3D Volume Rendering Technique (VRT) reconstructions.

For each RA, we analyzed the endoluminal diameter at the origin from the AA; the arterial length and trajectory in the frontal plane (ascendant + or descendant -); the distance between the point of origin and the renal intraparenchymal penetration point. We also analyzed the distance between the extreme points of origin of the right

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and left RAs from the AA; and the distance between the extreme points of penetration into the renal parenchyma of the right and left RAs (Table 1).

Table 1 – Morphological parameters of the renal arteries

<table>
<thead>
<tr>
<th>Right renal arteries</th>
<th>Morphological parameters measured [mm]</th>
<th>RRA 1</th>
<th>RRA 2</th>
<th>RRA 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endoluminal diameter at origin</td>
<td>3.5</td>
<td>6.7</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>Arterial length</td>
<td>68</td>
<td>67.5</td>
<td>69.5</td>
<td></td>
</tr>
<tr>
<td>Trajectory (ascendant +; descendant -)</td>
<td>+28.6</td>
<td>+20.4</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>Distance between origin extreme points at aortic level</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance between origin extreme points of renal penetration</td>
<td>52.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Left renal arteries</th>
<th>Morphological parameters measured [mm]</th>
<th>LRA 1</th>
<th>LRA 2</th>
<th>LRA 3</th>
<th>LRA 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endoluminal diameter at origin</td>
<td>3.1</td>
<td>4.3</td>
<td>3.1</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>Arterial length</td>
<td>70.5</td>
<td>63.9</td>
<td>67.4</td>
<td>67.3</td>
<td></td>
</tr>
<tr>
<td>Trajectory (ascendant +; descendant -)</td>
<td>+43.8</td>
<td>+21.7</td>
<td>+23.3</td>
<td>+33.9</td>
<td></td>
</tr>
<tr>
<td>Distance between origin extreme points at aortic level</td>
<td>40.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance between origin extreme points of renal penetration</td>
<td>38.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Three RAs branched from the right wall of the AA and were designated (cranial to caudal) as RRA 1, RRA 2 and RRA 3: (i) RRA 1 (additional superior polar RA): originated from the level of the lower third of the L1 vertebral body, and penetrated the superior renal pole on the medial edge of the kidney; (ii) RRA 2 (main right RA): originated from the level of the L1–L2 intervertebral disc. Its anterior and posterior branches penetrated the superior part of the renal sinus; (iii) RRA 3 (additional inferior hilar RA): originated from the level of the upper third of the L2 vertebral body, and penetrated the inferior part of the renal sinus.

The arteries generally had a divergent arrangement. The left wall of the AA gave rise to four RAs, which were designated (cranial to caudal) LRA 1, LRA 2, LRA 3 and LRA 4: (i) LRA 1 (additional superior polar RA): originated from the level of the L1–L2 intervertebral disc, and penetrated the upper renal pole on the medial edge of the kidney; (ii) LRA 2 (main left RA): originated at the level of the L1–L2 intervertebral disk. Its anterior and posterior branches penetrated the upper part of the renal hilum; (iii) LRA 3 (additional middle hilar RA): originated from the level of the L1–L2 intervertebral disc, and penetrated the middle part of the renal hilum; (iv) LRA 4 (additional inferior hilar RA): originated from the level of the L2–L3 intervertebral disc, and penetrated the lower part of the renal hilum (Figure 1).

The left sided arteries generally ascended in a convergent arrangement. On each side, the endoluminal diameter at the origin of the main RA was significantly larger than that of other AdRAs. The AdRAs were much longer than that of the main RA.

The right inferior phrenic artery (RIPA) originated from the RRA1 at the level of the lower third of the L1 vertebral body. The left inferior phrenic artery (LIPA) originated from the left wall of the AA at the level of the T12–L1 intervertebral disk. MDCT angiography did not show the testicular arteries (Figure 2).
Discussion

Studies conducted by Kruyt [7] revealed that one AdRA was found in 17.6% of cases; two AdRAs were found in 2.3% of cases; and three or more AdRAs were found in 1% of cases. Patients with multiple renal arteries typically are asymptomatic clinically. However, such an anomaly can significantly impair certain surgical interventions. We will discuss RA development and morphological considerations with clinical and surgical implications.

Embryology

There are three stages in the development of the urinary organs. They include the development of the pronephros, mesonephros, and metanephros (permanent kidney). The pronephros appears during the 4th week of development. It is located far caudally in the pelvis and opens into the cloaca [8]. The pronephros usually degenerates by the 25th day [9, 10]; however, most of the pronephric ducts remain and are used by the mesonephros [8].

The mesonephros develops between day 24th and the 16th week of gestation [11] caudal to the pronephros. It is located between the 6th cervical and the 3rd lumbar segments [12] and is supplied by temporary aortic branches (in maximo 30 mesonephric arteries) [10, 13]. Felix [12] studied an 18 mm long embryo (with complete degeneration of mesonephros) and found nine lateral mesonephric arteries from the 10th thoracic to the 3rd lumbar segment. The metanephros ascends from the pelvic to lumbar level in the retroperitoneal space between the 6th and 9th week, until it comes in contact with the adrenal glands. During its migration, the metanephros acquires its vascular supply from pelvic branches of the iliac arteries and later from branches of the dorsal aorta [9]. In the angle created by the mesonephros (laterally), the metanephros (dorsally) and the reproductive gland (ventrally), the 5–9 mesonephric arteries form the rete arteriosum urogenitale. This arterial network connects the vessels of the metanephros (which actually enter the renal sinus) with the mesonephric arteries and the AA. When one of the mesonephric arteries persists, it becomes the permanent main RA (at the level of L2 vertebral body [10]. If more than one mesonephric artery persists during the transition phase from mesonephros to metanephros, then AdRAs result [1, 10, 14].

Three [15, 16], four [1, 17], five [2], six [18], seven [19] and eight AdRAs [20] have been reported in case reports.

Morphological considerations with clinical and surgical implications

Bilateral AdRAs have been reported with a prevalence ranging from 4.3% to 10.2% [16, 21]. AdRAs are more commonly found in males than females [16] and have a predilection for the left side [15].

Usually, the AdRAs arise from the lateral aspect of the AA or iliac arteries anywhere from T11 to L4. In rare instances, they may originate from the lumbar, suprarenal, celiac trunk, superior mesenteric, inferior mesenteric or middle sacral arteries [22]. In our case, all the RAs originated from the AA, from the level of the lower third of the L1 vertebral body (RRA 1) to the level of the L2–L3 intervertebral disk (LRA 4).

Compared to the main RA, the course of the AdRAs is quite variable. The vessels can be parallel (horizontal, descending or ascending), divergent, convergent or crossed [15]. The most common structural arrangement is the horizontal parallel pattern [15, 16]. In our case, six RAs (two main RAs and four AdRAs) had an ascending trajectory (between 2.04 cm for RRA 2 and 4.38 cm for LRA 1) and one AdRA (RRA 3) had a descending trajectory (-0.1 cm).

Studies of Bordei et al. [15] revealed that the AdRAs entered the kidney through the hilum, together with the main RA in 61.11% of the cases; the superior pole in 9.26% of the cases; and the inferior pole in 29.63% of the cases. In our case, three AdRAs (60%) entered the hilum and two AdRAs (40%) entered the superior pole.

Widespread use of transcatheter arterial chemoembolization as a treatment for unresectable hepatocellular carcinomas (HCCs) requires knowledge of the anatomy of the extrahepatic collateral arteries, especially the inferior phrenic arteries [23–27]. Kim et al. [25] analyzed the extrahepatic collateral vessels supplying the hepatocellular carcinoma in 3179 patients and found that the most common artery observed was the RIPA followed by the renal artery, intercostal artery, subcostal artery, cistic artery and LIPA in decreasing order of frequency.

Although the RIPA is well known to originate from
the right main renal artery in the majority of the cases, some anomalous origins have been reported. From six studies involving 1696 cases, the origin of the RIPA was the right renal artery in 9.5% of cases [26]. Loukas et al. [28] studied 300 formalin-fixed adult cadavers and found that the right renal artery was the origin in 17% of cases. Miclaus et al. [26] on the other hand reported one case where the inferior phrenic artery trunk originated from the AA via a common stem, which also supplied the superior additional left renal artery. Our case describes the RIPA arising from the right additional renal artery. To the best of our knowledge, this is the first case reporting such an anomaly.

The presence of additional renal arteries is of great clinical significance as they can complicate many surgical procedures including transplants [29]. In addition, the anomalous origins of the inferior phrenic artery can also complicate surgical procedures such as transcatheter arterial chemoembolization, which is used for the treatment of unresectable HCCs [25, 27, 30].

Conclusions

Our study presents a very rare case where seven RAs (three right and four left) originated from the AA to supply the kidneys, and for the first time one RIPA originated from an right AdRA. Knowledge of this possible occurrence is extremely beneficial as it can better prepare physicians for uroradiological procedures; vascular reconstruction; renovascular hypertension; renal trauma; renal transplant surgery; and transcatheter arterial chemoembolization as a treatment for unresectable HCCs.

References


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