Abstract
We report an atypical case of a 53-year-old male with the presence of six renal arteries (RAs) (bilateral triple) found incidentally on multi-detector computed tomography (MDCT) angiography, which was used to investigate peripheral vascular disease of the lower limbs. The distance between the extreme points of RAs origin from abdominal aorta (AA) was in right 4.42 cm, and in left 2.40 cm. The distance between the extreme points of penetration into the renal parenchyma was in right 2.01 cm, and in left 2.56 cm. On each side, the endoluminal diameter at the origin of the main RA (in right 0.54 cm, and in left 0.42 cm) was significantly larger in comparison with the other additional renal arteries (AdRAs) (in right 0.21–0.29 cm, in left 0.24–0.35 cm); however, the AdRAs were much longer (in right 7.42–10.82 cm, in left 5.90–6.65 cm) than the main RA (in right 6.21 cm, in left 5.73 cm). All the four AdRAs were hilar RAs. Knowledge of this anatomical variation should not be ignoring when planning the adequate interventional radiological and surgical procedure.

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

Introduction
Usually, in the classical papers, each kidney is described as being supplied by a single renal artery (RA), which typically branches from the lateral aspect of the abdominal aorta (AA) at the level of the second lumbar vertebrae (L2) [1]. Variations of the renal vasculature are frequent, and were reported to have an incidence of 20–75% in various articles [2]. From these, the variation in the number of RAs represents the most common and clinically important renal vascular variation [3]. Reviewing the literature, Satyapal et al. [4] in the description of a RA other than the “main” RA, described it as “accessory”, “aberrant”, “anomalous” and “supernumerary”, “supplementary”, “multiple”, “accessory aortic hilar”, “aortic superior polar”, and “aortic inferior polar”, “upper polar artery” and “lower polar artery”. According with Glodny et al. [5], the multiple RAs can be divided into additional renal arteries (AdRAs) arising from the AA, and accessory renal arteries arising from branches of the AA [5]. According with Glodny et al. [6], the frequencies of additional and accessory renal arteries varies between 10.4% and 56% of cases.

Early reports [1, 7] in a continuous series of 1000 MDCT angiographies revealed 182 cases with AdRAs (18.2%); the number of AdRAs varied between one and six (one AdRAs: 8.9%; two AdRAs: 5.0%; three AdRAs: 1.6%; four AdRAs: 0.3%; five AdRAs: 0.2%; and six AdRAs: 0.1%). Bilateral symmetry in the number of the AdRAs was evident in 6.6% of cases, i.e., in 6.3% for bilateral double, 0.2% for bilateral triple, and only 0.1% for bilateral quadruple RAs.

Extensive studies on the bilateral RAs refers only to bilateral double RAs are very rare in the literature [4, 8]. Only few case reports revealed bilateral triple RAs [2, 9–13], quadruple bilateral RAs [1] and quintuple bilateral RAs [14].

The aim of the present study was to document by imagistic procedures, and to reveal one extremely rare case with bilateral triple RAs, without other major anatomical variations or pathology.

Case report
The authors report a 53-year-old male with peripheral arterial disease of the lower limbs history of five years, smoker of 15–20 cigarettes/day since 1982 (33 years), with claudication in both lower legs after 20–30 minutes of walking, presented at the Neuromed Diagnostic Imaging Center (Timisoara, Romania) for vascular assessment. The clinical examination in the Surgical Department was completed with multidetector computed tomograph (MDCT) angiography (64-slice MDCT system; SOMATOM Sensation, Siemens Medical Solutions, Forchheim, Germany), at the Neuromed Diagnostic Imaging Centre. In addition, the vascular lesions of the lower limbs were associated with the presence of bilateral triple renal arteries (in each part one main RA and two AdRAs). The images were analyzed using 3D Volume Rendering Technique (VRT) reconstructions (Figure 1). The measurements of the endoluminal diameter of the arterial elements were analyzed performing 3D Maximum Intensity Projection (MIP) reconstruction.

The right kidney has a maximum length of 9.65 cm, a maximum width of 5.75 cm, and a maximum thickness of 6.65 cm. The upper pole is located in the horizontal plane passing through the upper edge of the transverse process of the L1 vertebra, at 7.90 cm to the mediasagittal plane. The lower pole is located in the horizontal plane passing through the lower edge of the L2 vertebral body, at 6.25 cm to the mediasagittal plane. Upper pole is placed at 2.09 cm posterior to the coronal plane of the anterior face of the vertebral bodies and the inferior pole at 0.5 cm anterior of it. The vertical axis of the kidney made an angle of 24° with the vertical axis of the body. Renal hilum is
oriented medially, making an angle of $30^\circ$ to the coronal plane.

The left kidney has a maximum length of 10.15 cm, a maximum width of 6.05 cm, and a maximum thickness of 6.70 cm. The upper pole is located in the horizontal plane passing through the lower edge of the T12 vertebral body, at 7.35 cm to the mediosagittal plane. The lower pole is located in the horizontal plane passing through the lower edge of the L4 transverse process, at 9.15 cm to the mediosagittal plane. Upper pole is placed at 3.35 cm posterior to the coronal plane of the anterior face of the vertebral bodies and the inferior pole at 1.85 cm posterior from it. The vertical axis of the kidney made an angle of 15$^\circ$ with the vertical axis of the body. Renal hilum is oriented antero-medially, making an angle of 46$^\circ$ to the coronal plane.

Considering all these morphological parameters, it follows that both kidneys show a degree of malrotation: the right kidney is malrotated in transversal axis, with the lower pole oriented to anterior and medially; the left kidney is insufficient rotated medial, and the renal hilum is oriented antero-medially.

As in the previous studies [1, 15] and for each RA, the authors analyzed the following aspects: intraluminal diameter at the point of origin; arterial length; course in the frontal plane [ascending (+) or descending (–)]; distance between the outermost points of origin of the right and left RAs at the level of the AA distance between the outermost points of penetration of the right and left RAs in the renal parenchyma (Table 1).

The three right RAs branched from AA and were designated (cranial to caudal) as RRA 1, RRA 2 and RRA 3: (i) RRA 1 (superior hilar AdRA): originated from the right edge of AA, at the level of the upper edge of the L2 vertebral body, and penetrated the middle part of the renal hilum; (ii) RRA 2 (main right RA): originated from the right edge of AA, at the level of the lower third of the L2 vertebral body, and penetrated the upper part of the renal hilum; (iii) RRA 3 (inferior hilar AdRA): originated from the antero-lateral right face of AA, at the level of the upper edge of the L3 vertebral body, and penetrated the lower part of the renal hilum. The right renal arteries generally had a convergent descendant trajectory.
The three left RAs branched from AA and were designated (cranial to caudal) as LRA 1, LRA 2 and LRA 3: (i) LRA 1 (main left RA): originated from the left edge of AA, at the level of the L1–L2 intervertebral disc, and penetrated the middle part of the renal hilum; (ii) LRA 2 (superior hilar AdRA): originated from the left edge of AA, at the level of the middle third of the L2 vertebral body, and penetrated the upper part of the renal hilum; (iii) LRA 3 (lower hilar AdRA): originated from the anterolateral left face of AA level of the lower edge of the L2 vertebral body, and penetrated the lower part of the renal hilum.

In both parts (right and left), the diameter at the origin of the main RA was significantly larger than that of other AdRAs. All the AdRAs were much longer than that of the main RAs. In the right part, the both AdRAs are located one above, the other below the main RA. In the left, both AdRAs are located below the main RA.

The celiac trunk (CT) with classical configuration arises from the anterior face of the AA, at the level of the upper third of the T12 vertebral body. The SMA arises from the anterior face of the AA at the level of the lower third of the T12 vertebral body.

Discussion

Prevalence

According with Bayazit et al. [2], variations of the renal vasculature are frequent, which have been reported to have a prevalence of 20–75% in various studies. Among these, one revealed most frequently – variations in number of the RAs. Khamanarong et al. [16] on 267 Thai dissected cadavers (534 kidneys) revealed the double RAs in 17.43% of cases, and triple RAs in 0.92% of cases. Bordei et al. [8] on 272 studied kidneys revealed double RAs in 20% of cases, and triple RAs in 1.1% of cases. A percent of 11% of cases of multiple RAs have bilateral anomalies.

Embryology

All the anatomical variations of the arterial supply of the kidneys can be explained by considering the embryological development. The mesonephros (transitory kidney) develops between 5th week and the 16th week of gestation [15], located between the 6th cervical and the 3rd lumbar segments [23]. The mesonephros is supplied by temporary aortic branches (in the 5th week) (in the 30th week) [24]. When complete degeneration of mesonephros (18 mm long embryo), Felix [23] revealed only nine lateral mesonephric arteries, from the 10th thoracic to the 3rd lumbar segment.

The metanephros (the permanent kidney) ascends between the 6th and 9th week, in the retroperitoneal space, from the pelvic to lumbar level. During its ascending, the metanephros acquires its arterial supply from iliac arteries (branches and trunks), and later from AA.

According with Graves [24], in the angle created laterally by the mesonephros, dorsally by the mesonephros and ventrally by the reproductive gland, the 5–9 mesonephric arteries form the rete arteriosum urogenitale. This arterial network connects the vessels of the mesonephros with the mesonephric arteries and the AA. One of its mesonephric branches enlarged, and the remaining artery at the L2 level becomes the permanent main RA [1]. During the transition phase from mesonephros to metanephros, if more than one mesonephric arteries persist, then AdRAs result. Thus, the multiple RAs must be considered persistent mesonephric arteries [2].

Morphology of previous cases

Five cases are described in the literature with bilateral triple RAs. The case presented by Bayazit et al. [2] on each side there is an upper AdRA and a lower AdRA. The main right RA and the right inferior AdRA have an early bifurcation; only the two main RAs are hilar arteries. The case of Şener et al. [12] is actually a case of bilateral double RAs, in which on each side the superior RA (main RA) has early bifurcation (near the aortic origin). All RAs are hilar arteries. In the case of Pestemalci et al. [9] in the right side, the main RA (with aortic origin) is located.
between the two AdRAs (the upper AdRA originated from AA, and the lower AdRA originated from right common iliac artery). In the left side, the main RA (with aortic origin) is located beneath the two AdRAs (with AA origin). The lower right AdRA originated from right common iliac artery is an inferior polar artery. The other five RAs (two main RAs and three AdRAs) are hilar arteries. In the case of Zăhoi et al. [10] on each side, the two AdRAs originate from AA, below the main RAs. The right kidney is malrotated with inferior pole oriented to anterior, and with lateral edge almost horizontally, in contact with the iliac crest. All six RAs (two main and four additional) are hilar arteries. In the case of Uzmansel et al. [13], in the right side, the main RA (with aortic origin) is located between the two AdRAs (both originated from AA). In the left side, the main RA (with aortic origin) is located above the two AdRAs (with AA origin). The inferior left AdRA in an inferior polar RA. The other five RAs (two main RAs and three AdRAs) are hilar arteries.

Locating of the AdRAs, according to the main RA position is variable in the cases presented in the literature. On both sides (right and left) the main RAs are placed above AdRAs [10, 13], on both sides between AdRAs (upper and lower) [2], in right between two AdRAs, and in left below the two AdRAs [9]. In our case, the right main RA is situated between the two AdRAs and the left above of them. All of these morphological aspects have an embryological explanation, their position being determined by the evolution of mesonephric arteries.

In terms of penetration of AdRAs in the renal parenchyma, in the case of Bayazit et al. [2], all the four AdRAs are polar arteries (two upper and two lower). Pestemalci et al. [9] report only lower AdRAs (right and left) as polar arteries, and Uzmansel et al. [13] only lower left AdRA. In the case described Zăhoi et al. [10] all RAs (two main and four additional) are hilar arteries. The same situation is also in the case described by us.

Morphological considerations with clinical and surgical implications

In most of the cases, the AdRAs arise from the lateral aspect of the AA or iliac arteries anywhere from T11 to L4 [15]. According with Khamanarong et al. [16], in rare instances, the AdRAs may originate from the lumbar, suprarenal, celiac trunk, superior mesenteric, inferior mesenteric or middle sacral arteries. In our case, all the RAs originated from the AA, from the level of the upper edge of the L2 vertebral body (RRA 1 and LRA 1) to the level of the upper edge of the L3 vertebral body. If in horseshoe kidney, the origins of some of AdRAs (especially those lower polar) can be located on the anterior or anterolateral face of AA (due to positioning median inferior pole of the kidneys), in case of separate kidneys, this situation occurs only if the kidney is malrotated (kidney with the lower pole and the hilum directed in front, and the kidneys closer to the midline). This particular aspect is present also in our case, in which the lowers AdRAs originate in the anterolateral aspect of AA, right kidney with inferior pole facing forward, and left kidney with renal hilum oriented antero-medial.

According with Bordei et al. [8], the distance between the origin, from the AA, of the double RAs was highly variable, with an average ranging between 1–2 mm and 4–6 cm. In cases of bilateral triple RAs distance between extreme points of origin at aortic level [2, 10] corresponds height of 2–4 vertebral bodies. In a case with seven RAs (three right and four left), Miclăuș et al. [15] revealed that the distance between origin extreme points at aortic level in right was 1.70 cm, while in left was 4.09 cm. Respecting the same procedure, in case of bilateral quadruple RAs, Miclaus et al. [1] revealed that this distance in right was 10.66 cm and in left was 8.00 cm. In case with eight RAs (four right and four left), Miclaus et al. [1] reported a distance between origin extreme points at aortic level of 10.66 cm in right, and 8.00 cm in left, respectively. Respecting the same procedure, in case of seven RAs (three right and four left), Miclăuș et al. [15] revealed the distance between origin extreme points at aortic level in right of 1.70 cm, and in left of 4.09 cm. In the present case, these distances are of 4.42 cm in the right and of 2.40 cm on the left, respectively.

The presence of AdRAs increases the complexity and the time of renal transplant achievement [1, 25, 26]. If RAs originating spaced, the arterial anastomosis time increase endanger the success of renal transplantation. If the origin of the RA on the same side is close, arterial pedicle crop can be harvested with aortic patch [27]. In the case of harvesting kidneys from cadaver, en bloc anastomosis technique for unilateral dual kidney transplantation [28] significantly shortens time to achievement of renal transplantation.

As in previous studied cases [1, 15] and in this case too, the AdRAs have a smaller size and greater length that the main RAs. Early report of Bordei et al. [8] revealed that in 61.11% of cases, the AdRAs entered the kidney through the hilum, together with the main RA; in 9.26% of the cases, the superior pole; and in 29.63% of the cases, the inferior pole. In our case, all RA (main and additional) entered the kidney through the hilum. Usually, the AdRAs are terminal vessels, so their lesions may produce segmental ischemia with subsequent hypertension [1] or partial parenchymal necrosis.

The examination of the reno-urinary system with the 64-slice MDCT system can offer excellent three-dimensional (3D) reformatted images, which demonstrate the details of anatomic structures, and can provide good delineation of vascular and urinary tract anomalies [29, 30].

Conclusions

This study presents a very rare case where six RAs (three right and three left), originated from the AA, which penetrated the renal hilum and supply the kidneys. An awareness of renal arterial variation is important to prepare for the radiologists and for urological and vascular surgical procedures including renal transplant surgery.

Conflict of interests

The authors declare that they have no conflict of interests.

References

Bilateral triple renal arteries


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