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CASE REPORT

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Replaced right hepatic artery arising from inferior pancreaticoduodenal artery, in association with left multiple renal arteries: a case report using MDCT angiography

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Abstract

The authors illustrate a case of a 61-year-old male who presented an extremely rare association of anatomical variations highlighted by multi-detector computed tomography (MDCT) angiography, with a replaced right hepatic artery (RRHA) arising from inferior pancreaticoduodenal artery (IPDA), in association with left multiple renal arteries (RAs). The celiac trunk (CT) arises from the abdominal aorta (AA), at the level of middle 1/3 of L1 vertebral body. The superior mesenteric artery (SMA) origin was located at the anterior aspect of AA, at 2.5 mm below the origin of CT, at the level of L1/L2 intervertebral discs. The SMA has at origin an endoluminal diameter of 11.3 mm. At 22.7 mm from its aortic origin, from the right aspect of the SMA trunk, arises IPDA. At 10.4 mm from its origin in IPDA, arises RRHA with a 78.5 mm artery length and the endoluminal diameter at origin of 2.9 mm. From the arising point, the RRHA is oriented ascending to the right, passing initially posterior to the hepatic portal vein and the head of the pancreas, then lateral to the head of the pancreas and posterior to the hepatic portal vein, after entering the hepatic parenchyma to bifurcate into the anterior and posterior branches. From left aspect of AA arise three RAs: one main, one additional (from AA), and an accessory renal (from left common iliac artery). Knowledge of this hepatic and renal anatomical variation is important for interventional radiologists, vascular experts, oncologists, vascular, hepatic and urologic surgeons.

Keywords: replaced right hepatic artery, inferior pancreaticoduodenal artery, multiple renal arteries, morphological considerations, clinical and surgical implications, MDTC angiography.

Introduction

As described by Haller in 1756, the celiac trunk (CT), the classical "*tripod of Haller*", arises from the anterior aspect of abdominal aorta (AA) just below diaphragm and is forking in: (*i*) left gastric artery (LGA), (*ii*) common hepatic artery (CHA), and (*iii*) splenic artery (SA) [1]. At 1 cm lower the origin of CT, from the anterior aspect of AA originates the superior mesenteric artery (SMA) [2]. CHA is branched into the hepatic artery proper (HAP), which continues the CHA pathway to the hepatic parenchyma, and the gastroduodenal artery (GDA). The last one it divides into right and left branches at a variable level below the *porta hepatis* [3]. Through the anterior and posterior branches, the right branch of the HAP is supplying the right lateral division of the liver (segments V and VIII), respectively the right medial division of the lever (segments VI and VII). The left branch of the HAP through the lateral and medial branches supplying the left lateral division of the liver (segments II and III), respectively the left medial division of the liver (segment IV) [3–5]. This pattern considered normal anatomical liver vascularization pattern is reported from 50.7% [6] to 81.56% of cases [7].

Hepatic arteries are subjected to large number of possible variations. In 1966, based on a series of 200 autopsies, the American anatomist Michels [8] described 10 different morphological types considered as "aberrant" arteries and classified as "accessory" or "replaced". An accessory hepatic artery is an aberrant artery present in addition to the normal artery and who serves a volume of the liver parenchyma usually served by the normal artery. A replaced hepatic artery has an aberrant origin and supply the usual volume of liver parenchyma of the normal artery (which is absent as a morphological entity). Hiatt *et al.*, in 1994 [9], analyzing the arterial pattern in 1000 donor livers, described only six types of hepatic arterial variations. Because the intrahepatic branches are not dissected, extrahepatic examination cannot indicate whether an extrahepatic artery is accessory or replaced. On these grounds, Hiatt *et al.* [9] reduces from 10 to six the morphological types described by Michels.

The most common replaced right hepatic artery (RRHA), with a prevalence that varies between 13–26% of cases, is the right hepatic artery arising from SMA [10]. In rare cases, RRHA has been reported with origins in: AA [11]; CT [11–14]; LGA [15]; SA [16]; CHA [15]; GDA [12, 15]; right inferior phrenic artery [11]; right renal artery (RA) [17]; inferior mesenteric artery [11].

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The aim of this study is to document an unusual origin of RRHA from inferior pancreaticoduodenal artery (IPDA), in association with left multiple RAs, by multidetector computed tomography (MDCT) angiography.

Case presentation

We report the case of a 61-year-old male patient with clinical symptoms of peripheral vascular disease of the lower limb. The MDCT angiography examination (64-slice MDCT system; SOMATOM Sensation, Siemens Medical Solutions, Forchheim, Germany), highlights associated with peripheral vascular lesions, the presence of a RRHA arising from IPDA and right kidney with three RAs [one main RA, one additional RA (AdRA) arising from AA and one accessory RA (AcRA) arising from left common iliac artery] (Figure 1, A and B; Figure 2, A and B).

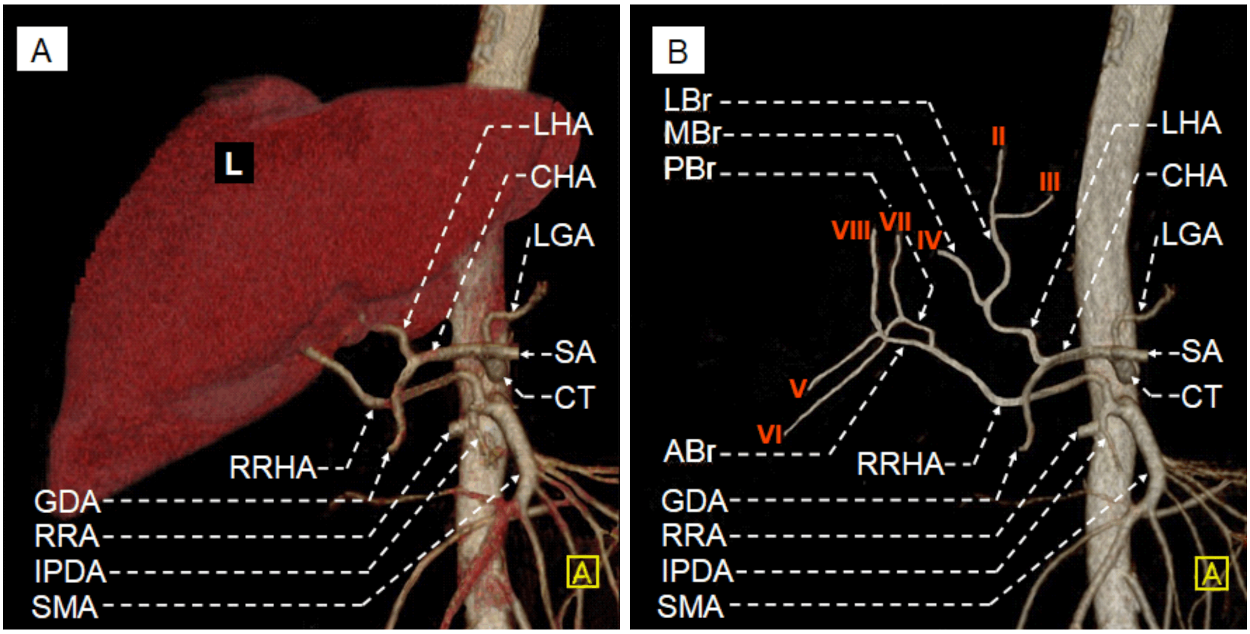

Figure 1 – ***MDCT angiographies with 3D reconstruction of the liver with the abdominal part of aorta, celiac trunk, superior mesenteric artery and replaced right hepatic artery arising from inferior pancreaticoduodenal artery – coronal aspect: (A) VRT image with the liver in situ; (B) VRT image after subtraction of the liver parenchyma. MDCT: Multi-detector computed tomography; 3D: Three-dimensional; VRT: Volume rendering technique; L: Liver; CT: Celiac trunk; CHA: Common hepatic artery; LGA: Left gastric artery; SA: Splenic artery; GDA: Gastroduodenal artery; LHA: Left hepatic artery; LBr: Lateral branch; MBr: Medial branch; RRA: Right renal artery; SMA: Superior mesenteric artery; IPDA: Inferior pancreaticoduodenal artery; RRHA: Replaced right hepatic artery; ABr: Anterior branch; PBr: Posterior branch; II–VIII: Hepatic segments from II to VIII.***

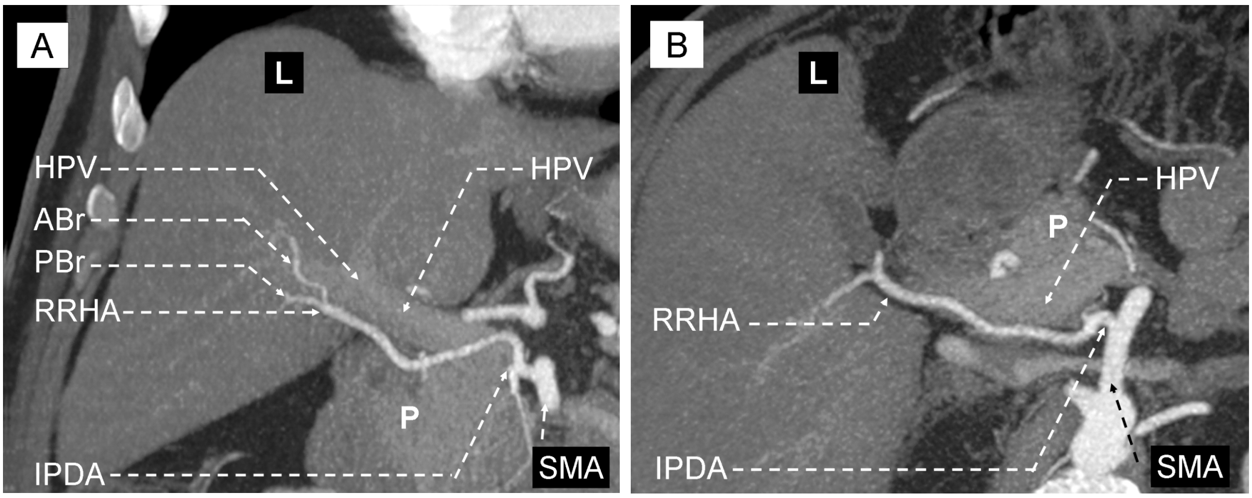

Figure 2 – ***MDCT angiography of the liver. MIP image shows the superior mesenteric artery and replaced right hepatic artery: (A) Coronal image; (B) Transversal image. MDCT: Multidetector computed tomography; MIP: Maximum intensity projection; L: liver; P: Head of pancreas; HPV: Hepatic portal vein; SMA: Superior mesenteric artery; IPDA: Inferior pancreaticoduodenal artery; RRHA: Replaced right hepatic artery; ABr: Anterior branch; PBr: Posterior branch.***

The CT arises from AA at the level of middle 1/3 of L1 vertebral body. The CT with an endoluminal diameter in the proximal portion of the arterial trunk of 5.6 mm, and a length of 26.2 mm has a classical configuration, ends dividing into a trifurcation in CHA, LGA and SA. The CHA with an endoluminal diameter in the proximal portion of the arterial trunk of 4.4 mm and a length of 38.4 mm forking in GDA and HAP. The latter placed in the liver pedicle, being located anterior in relation to the trunk of the portal hepatic vein, and after 27.7 mm, in the upper portion of the hepatic pedicle is divided into the medial branch, intended for the left medial division of the liver (segment IV) parenchyma, and the lateral branch, intended for the left lateral division (segments II and III) parenchyma.

The SMA arises from the anterior aspect of AA at the level of intervertebral disc L1/L2, at 2.5 mm below of the origin of CT. The SMA has at origin an endoluminal diameter of 11.3 mm. At 22.7 mm from its aortic origin, from the right aspect of the SMA trunk, arises IPDA, having an endoluminal root diameter of 4.5 mm. At 10.4 mm from its origin in IPDA, arises RRHA with a 78.5 mm artery length and an endoluminal diameter at the proximal portion of 2.9 mm. From the arising point, the RRHA is oriented ascending to the right, passing initially posterior to the hepatic portal vein and the head of the pancreas, then lateral to the head of the pancreas and posterior to the hepatic portal vein, and after entering the hepatic parenchyma to bifurcate into the anterior and posterior branches. The anterior branch with an endoluminal diameter at the proximal portion of 2.5 mm and a length of 35.7 mm is distributed to the right medial division of the liver (segments V and VIII). The posterior branch with an endoluminal diameter at the proximal portion of origin of 2 mm and a length 21.7 mm is distributed to the right lateral division of the liver (segments VI and VII) (Figure 1, A and B).

The morphological parameters of the kidneys are summarized in Table 1.

According with the protocol of Department of Anatomy and Embryology, for RA evaluation, for each RAs, we analyzed: (*i*) the endoluminal diameter at the origin from the AA; (*ii*) the arterial length; (*iii*) trajectory in the frontal plane (ascendant + or descendant –); (*iv*) the distance between the point of origin and the renal intra-parenchymal penetration point. For the right kidney, we also analyzed: (*v*) the distance between the extreme points of origin (upper and lower) of the right RAs from the AA; and the distance between the extreme points of penetration (upper and lower) into the renal parenchyma of the right RAs (Table 2).

Table 1 – ***Morphological parameters of the right and left kidneys***

Morphological parameters measured [cm or °]	Right kidney	Left kidney
Maximum length	11.19	12.65
Maximum width	6.73	5.24
Maximum thickness	5.26	5.44
Vertebral level of the upper pole	Lower 1/3 of L1 vertebral body	Lower 1/3 of L1 vertebral body
Distance between upper pole to the mediosagittal plane	6.3	8.16
Vertebral level of the lower pole	Upper 1/3 of L4 vertebral body	Lower edge of L4 vertebral body
Distance between lover pole to the mediosagittal plane	8.32	9.4
Distance between lower pole and the level of iliac crest	2.35	0.81
Angle of vertical kidney axis with the vertical axis of the body	42	55
Angle of renal hilum with the coronal plane	44	37

Table 2 – ***Morphological parameters of the renal arteries***

Morphological parameters measured [cm]	RRA1			
Right renal artery				
Vertebral level of renal arterial origin	Upper 1/3 of L2			
Intraluminal diameter at origin	0.62			
Arterial length	5.65			
Course (ascendant +; descendant –)	–			
Morphological parameters measured [cm]	**LRA1**	**LRA2**	**LRA3**	
Left renal arteries				
Vertebral level of renal arterial origin	Intervertebral disc L1/L2	Upper edge of L3	Lower 1/3 of L4	
Intraluminal diameter at origin	0.45	0.5	0.33	
Arterial length	6	6.22	5.27	
Course (ascendant +; descendant –)	–	+	+	
Distance between extreme points of origin at aortic level				10.61
Distance between extreme points of renal penetration				8.48

RRA1: Right renal artery 1; LRA1: Left renal artery 1; LRA2: Left renal artery 2; LRA3: Left renal artery 3.

In the right side, there is only one RA, the main (hilar) RA (RRA1). In the left part, for ease of location the RAs have been designated: LRA1 – the first right RA (the superior) was the main RA (hilar RA); LRA2 – the second left RA (the middle) was an AdRA (hilar RA); LRA3 – the third left RA (the inferior) was accessory extra RA (polar inferior RA) (Figure 3, A and B).

Consent

The patient was asked for two-signed informed consent, the first for angiographic examination by using a 64-slice MDCT system with the use of iodinated contrast agents, and the second for the use of data and images obtained in scientific research.

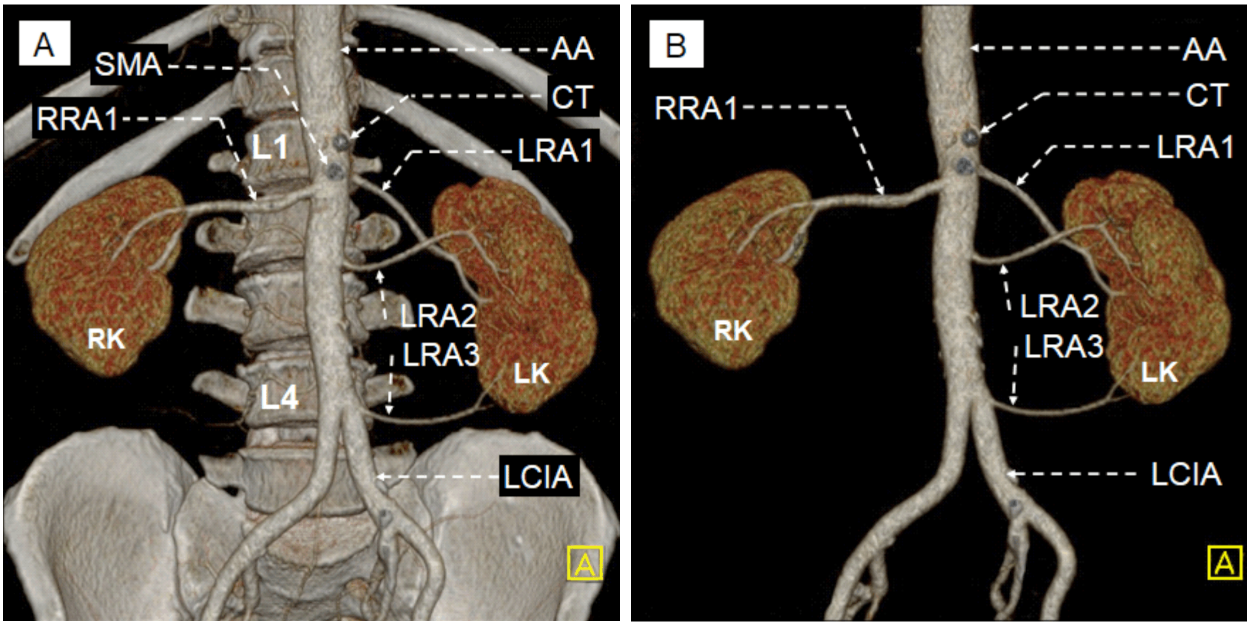

Figure 3 – ***MDCT angiographies with 3D reconstruction of the kidneys with the abdominal part of aorta and renal arteries – coronal aspect: (A) VRT image with the kidneys in situ and the relationship of the renal arteries to vertebral bodies and costal arches; (B) VRT image after subtraction of the bone structures. MDCT: Multidetector computed tomography; 3D: Three-dimensional; VRT: Volume rendering technique; RK: Right kidney; LK: Left kidney; AA: Abdominal part of aorta; CT: Celiac trunk; SMA: Superior mesenteric artery; LCIA: Left common iliac artery; RRA1: Right renal artery 1; LRA1: Left renal artery 1; LRA2: Left renal artery 2; LRA3: Left renal artery 3.***

Discussions

Embryology

Replaced right hepatic artery from inferior pancreaticoduodenal artery

The anatomical variations of the CT and SMA, as well as numerous anatomical variations at this level, are due to embryo-fetal remodeling in the abdominal ventral segmental arteries (VSAs) [2, 18, 19]. After fusion of the two dorsal aortae in the midline (the 4th and 5th weeks), the two VSAs (right and left) of the same metamer fuse also in the midline [20]. The first four abdominal VSAs (10th–13th) will participate through remodeling/resorption phenomena in edification of the unpaired branches of the AA. From top to bottom: the 10th abdominal VSA becomes LGA; the 11th becomes SA; the 12th becomes CHA, and the 13th becomes SMA. According with the theories of Tandler [21], these four primitive abdominal VSAs are connected to the "*longitudinal anastomosis*" placed in front of the AA.

In our case, with the presence of a CT in association with SMA arising independently from the AA, corresponding to the Morita type I, the process of resorption/retention of various portions of the longitudinal anastomosis and of the ventral segmental roots, is represented by: persistence of the longitudinal anastomosis between the 10th VSA (that becomes LGA), 11th VSA (that becomes SA), the 12th VSA (that becomes CHA); resorption of the longitudinal anastomosis between the 12th VSA (that becomes CHA) and the 13th VSA (that becomes SMA); regression of the 10th and 11th ventral segmental roots; persistence of the 12th ventral segmental root which will become the proximal part of the CT that connects the CT to the anterior aspect of AA; persistence of the entire 13th VSA (that becomes SMA) with the origin in the AA.

The fetal liver parenchyma is served by three primary hepatic arteries: (*i*) embryonic left hepatic artery (LHA), originating from the LGA services the left lateral division of the liver (segments II and III); (*ii*) embryonic middle hepatic artery, from the CHA (from CT) services the left and right medial divisions of the liver (segments IV, respectively V and VIII); (*iii*) embryonic right hepatic artery, from the omphalomesenteric artery (upcoming SMA) services the right lateral division of the liver (segments VI and VII). Subsequently, these three embryonic arteries are connected at the level of the hepatic hilum by the longitudinal anastomosis, and immediately afterwards), the right and left embryonic hepatic arteries regress. Due to these regression/remodeling phenomena, the hepatic parenchyma will be vascularized only through its HAP, from CHA, from CT [4, 20, 22, 23].

In our case, regresses only the embryonic LHA; the left part of the liver (the left medial and lateral divisions of the liver – segments II–IV) is served by the left branch of the HAP, from CHA, from CT. The right part of the liver (right medial and lateral divisions of the liver – segments V–VIII) is served by the RRHA arising from IPDA.

The origin of RRHA in the proximal portion of the SMA is considered as the usual one. In our case, the migration of RRHA from SMA to IPDA can occur, according to the theory of Bremer (1915), during the remodeling process of the periaortic arterial plexus, which before it disappears connects the origin of RRHA to IPDA, similar process to connecting the inferior phrenic arteries with the CT or its branches [24, 25].

Multiple right RAs

According with Felix [26], the urinary organs develop in three stages: (*i*) the pronephros, (*ii*) the mesonephros and (*iii*) the metanephros.

The transitory kidney (the mesonephros) develops between the 5th and 16th week of embryo-fetal life develops between the 5th and 16th week of embryo-fetal life, between the 6th cervical vertebrae and the 3rd lumbar vertebrae [27, 28].

During its evolution, the mesonephros is served on each side by a maximum of 30 temporary aortic branches. These temporary aortic branches are distributed in the entire mesonephric area (initially only to the mesonephros, but later also to the diaphragm, the adrenal bodies and the reproductive glands). This extension of the distribution territory of the mesonephric arteries causes even after the complete degeneration of the mesonephros some mesonephric arteries persist [27].

In the phase of complete degeneration of the mesonephros (18 mm long embryo) in the range from the 10th thoracic to the 3rd lumbar vertebra, remain only nine lateral mesonephric arteries. These nine pairs are placed in the space between the mesonephros and the metanephros. They were split by Felix [26] into three groups: (*i*) the cranial group (the 1st and 2nd lateral mesonephric arteries), located cranial to the CT, passing dorsal to adrenal body; (*ii*) the middle group (the 3rd to 5th lateral mesonephric arteries) vessels that passes towards metanephros to give rise to RAs; (*iii*) the caudal group (the 6th to 9th lateral mesonephric arteries) vessels that remain ventral to adrenal body; one of the these arteries usually persists and differentiates into the definitive gonadal artery [29–32].

Usually, the lateral mesonephric arteries from the middle group discards, except one that enlarged and becomes the permanent main RA (located at the level of the second lumbar vertebral body) [33, 34]. If in the transition period between mesonephros and metanephros, remain more than one mesonephric artery, will appear the AdRAs; because of this fact, the multiple RAs are considered persistent mesonephric arteries [28]. In case of presence of a greater number of three RAs for a kidney (one main RA and two AdRAs), AdRAs may occur due to the persistence of adjacent arteries from the other two groups of mesonephric arteries (cranial and caudal groups) [35].

The metanephros originates in the pelvic cavity, in front of the first or second sacral segment during the 4th and 5th weeks of intrauterine life, having the hila oriented anteriorly, and closer to one another vicinity of the pelvic medio-sagittal plane [36]. During the 6th and 9th weeks of intrauterine life, the metanephros ascends from the pelvic to lumbar level. During their ascent, the two kidneys rotate medially almost 90°, so that in the final position the renal hila are oriented medial or antero-medial [35].

Like other organs in development, the metanephros blood vessels are constantly changing during lumbar ascent [37]. Initially, at the pelvic level, the metanephros is served by branches of the middle sacral artery, and iliac arteries (internal and external). Subsequently, at lumbar level, the metanephros is served by branches of the common iliac artery and AA [27, 28, 36].

In the transition phase between the mesonephros and the metanephros, according with the Graves theory [37], in the space delimited: (*i*) laterally by the mesonephros, (*ii*) dorsally by the metanephros, and (*iii*) ventrally by the reproductive gland, the 5–9 mesonephric arteries form the *rete arteriosum urogenitale*. This arterial network connects the arterial vessels of the metanephros with the mesonephric arteries and the AA. The caudal extension of mesonephric elements extends to the level of L3 [27, 28]. If ascendant migration of the metanephros is arrested, the temporary metanephric arterial vessels will become permanent [35]. Because of this, renal arterial sources with the origin located lower than L3 level, should be considered as of metanephric origin.

In our case, the left kidney has three RAs: the main left RA arising from left lateral aspect off AA (at the level of inferior edge of L2 vertebral body); one AdRA from the left aspect of AA (at the level of intervertebral disc L2–L3); one AcRA from the left lateral aspect of the left common iliac artery (at the level of inferior edge of L4 vertebral body). To correlate the name of the various multiple RAs types with their origin, we used the description of Glodny *et al.* [38], which considered that the AdRA originating from the AA, and the AcRA originating from branches of the AA.

Anatomical variations and clinical implications

Replaced right hepatic artery from inferior pancreaticoduodenal artery

According with Staśkiewicz *et al.* [10], the vascular complications represent the most common cause of morbidity and mortality in patients with pancreatic or duodenal surgical pathology. The most affected arterial structure is RRHA. The variability of origin and pathways of RRHA may be morphological factors that may complicate surgery.

Reviewing literature, on 21 492 cases over 29 studies (Table 3), we highlighted the modal type of CT with a prevalence of 80.3% of cases, and the RRHA with a prevalence of 5.29% of cases [4.47% of cases RRHA originated from SMA, and 0.82% of cases RRHA originated from SMA in association with replaced left hepatic artery (RLHA) originated from LGA]. The prevalence RRHA originated from SMA (type III Michels) varies between 3.5% [39] and 17% [41], and prevalence of RRHA originated from SMA in association with RLHA originated from LGA varies between 0% [6, 39–46] and 5% [41].

Yamashita *et al.* [47], on 6588 cases from 10 studies, reveal the standard anatomy in 86.46% of cases, and the RRHA in 13.505% of cases. The authors highlight seven levels of origin of RRHA namely: SMA in 12.95% of cases; CT in 0.24%; AA in 0.15%; CHA in 0.15%; GDA in 0.045%; RA and LGA in 0.015%, respectively. Huang *et al.* [48], in an angiographic investigation on 553 patients, highlights in 23.8% of cases the presence of a common trunk of IPDA with an aberrant [replaced (R) or accessory (A)] RHA originated from SMA; in this case, the diameter in the proximal portion of the arterial trunk of the IPDA is significantly lower than that of R/A RHA.

Along with the level of origin, the course of the RRHA in relation to the pancreas is particularly important for the planning and performing of surgical interventions of pancreaticoduodenectomy. Jah *et al.* [49] classifies the RRHA pathway in three types: type I: RRHA has a postero-lateral tract to the pancreatic head; type II: RRHA has an intra-pancreatic tract (intraparenchymal) – traversing the head of pancreas; type III: RRHA has a path that crosses the superior mesenteric vein groove.

Table 3 – *Incidence of hepatic artery variation according to Michels classification as reported in large case series*

Michels type			I	II	III	IV	V	VI	VII	VIII	IX	X	Other**
Authors	***Year***	***No. of cases***	***Incidence [%]***										
Michels [8]	1966	200	55	10	11	1	8	7	1	2	4.5	0.5	0
Suzuki *et al.* [39]	1971	200	70.5	8	3.5	0	4.5	4	0	0	3	0	7.5
Chen *et al.* [40]	1998	381	80.31	7.87	4.99	0.79	1.31	1.57	0.52	0	1.58	0	1.05
Ferrari *et al.* [41]	2007	60	60	10	18.33	5	1.67	0	0	1.67	0	0	3.33
Iezzi *et al.* [42]	2008	524	72.14	5.91	9.35	0	0.19	0	0	0	3.63	0	8.78
Ugurel *et al.* [43]	2010	100	52	11	17	1	10	1	1	1	2	0	4
El-Badrawy [44]	2011	67	64.18	10.45	16.43	0	2.98	2.98	0	0	0	0	2.98
Osman & Abdrabou [45]	2016	1000	74.2	3	12.5	0	5.2	1.1	0.6	1	2.3	0	0.1
Keles *et al.* [46]	2016	150	63.33	6.67	8	2	4	2	0	2.67	1.33	0	10
Noussios *et al.** [7]	2017	18 810	81.56	2.96	3.77	0.87	3.15	1.64	0.2	0.35	1.3	0.03	4.17
Total	No. of cases	21 492	17 244	718	982	176	695	353	49	86	311	7	871
	%	100	80.3	3.35	4.47	0.82	3.23	1.64	0.23	0.4	1.48	0.03	4.05

*Reviewing 20 studies in the literature; **"Not otherwise described" in the literature.

Multiple right RAs

Usually, the multiple RAs arise from the lateral aspect of the AA (AdRAs [38]); in rare instances, they arise from the lateral aspect of iliac, lumbar, and suprarenal arteries, or from CT, superior and inferior mesenteric arteries, or middle sacral arteries [16] being considered AcRAs [38]. In our case, the superior right RA was the main RA; the middle left RA was an AdRA, and the inferior left RA was AcRA.

The presence of multiple RAs (AdRAs and AcRAs) complicates the procedures and extends the time of renal transplant achievement. If the distance between extreme points of origin of aortic level is small, the renal arterial pedicle can be harvested with an aortic patch [28]. Case analysis with bilateral triple [28] and bilateral quadruple [27] highlight on the left a distance between the extreme points of aortic origin of 2.4 cm respectively 8 cm. In our case, this distance is 10.61 cm. This value is due to the presence of inferior AcRA origin, of the left iliac artery to the lower level 1/3 of the L4 vertebral body.

In cases with multiple RAs [27, 28], the length of AdRAs is significantly greater than of the main RAs. In our case, AdRA (LRA2) has a length shorter than the left main RA; the AcRA (LRA3) has a shorter length than that of the main RA due to its origin at the level of left aspect of the common iliac artery, and the relatively early bifurcation of the arterial trunk, in vicinity of the inferior pole of the left kidney.

Conclusions

The authors presented in this paper an extremely rare case of a RRHA arising from IPDA, in association with left multiple RAs. All these vascular variations of the liver and the kidneys can be explained by considering the embryo-fetal development. Taking in account the hepatic and renal arterial variation is important to preparation and performing the vascular surgical procedures including hepatic and renal transplant surgery.

Conflict of interests

The authors declare that they have no conflict of interests.

References

[1] Matusz P, Miclaus GD, Ples H, Tubbs RS, Loukas M. Absence of the celiac trunk: case report using MDCT angiography. Surg Radiol Anat, 2012, 34(10):959–963.

[2] Matusz P, Iacob N, Miclaus GD, Pureca A, Ples H, Loukas M, Tubbs RS. An unusual origin of the celiac trunk and the superior mesenteric artery in the thorax. Clin Anat, 2013, 26(8):975–979.

[3] Standring S (ed). Gray's anatomy: the anatomical basis of clinical practice. 41st edition, Elsevier–Churchill Livingstone, Edinburgh, 2016, 1116–1117.

[4] Matusz P. Right/left symmetry of the intrahepatic distribution and terminology of the hepatic artery proper and the intrahepatic bile duct system: proposals to revise the *Terminologia Anatomica*. Surg Radiol Anat, 2011, 33(1):71–74.

[5] Hulsberg P, Garza-Jordan Jde L, Jordan R, Matusz P, Tubbs RS, Loukas M. Hepatic aneurysm: a review. Am Surg, 2011, 77(5):586–591.

[6] Winston CB, Lee NA, Jarnagin WR, Teitcher J, DeMatteo RP, Fong Y, Blumgart LH. CT angiography for delineation of celiac and superior mesenteric artery variants in patients undergoing hepatobiliary and pancreatic surgery. AJR Am J Roentgenol, 2007, 189(1):W13–W19.

[7] Noussios G, Dimitriou I, Chatzis I, Katsourakis A. The main anatomic variations of the hepatic artery and their importance in surgical practice: review of the literature. J Clin Med Res, 2017, 9(4):248–252.

[8] Michels NA. Newer anatomy of the liver and its variant blood supply and collateral circulation. Am J Surg, 1966, 112(3): 337–347.

[9] Hiatt JR, Gabbay J, Busuttil RW. Surgical anatomy of the hepatic arteries in 1000 cases. Ann Surg, 1994, 220(1):50–52.

[10] Staśkiewicz G, Torres K, Denisow M, Torres A, Czekajska-Chehab E, Drop A. Clinically relevant anatomical parameters of the replaced right hepatic artery (RRHA). Surg Radiol Anat, 2015, 37(10):1225–1231.

[11] Dandekar U, Dandekar K, Chavan S. Right hepatic artery: a cadaver investigation and its clinical significance. Anat Res Int, 2015, 2015:412595.

[12] Lee JM, Lee YJ, Kim CW, Moon KM, Kim MW. Clinical implications of an aberrant right hepatic artery in patient undergoing pancreaticoduodenectomy. World J Surg, 2009, 33(8):1727–1732.

[13] Gruttadauria S, Foglieni CS, Doria C, Luca A, Lauro A, Marino IR. The hepatic artery in liver transplantation and surgery: vascular anomalies in 701 cases. Clin Transplant, 2001, 15(5):359–363.

[14] Katagiri H, Sakamoto T, Okumura K, Lefor AK, Kubota T. Aberrant right hepatic artery arising from the celiac trunk: a potential pitfall during laparoscopic cholecystectomy. Asian J Endosc Surg, 2016, 9(1):72–74.

[15] Felli E, Vennarecci G, Santoro R, Guglielmo N, Ettorre GM. Right hepatic artery crossing the common hepatic artery: an unusual blood supply to the liver. Surg Radiol Anat, 2016, 38(3):359–360.

[16] Caruso F, Dondossola D, Fornoni G, Caccamo L, Rossi G. Right hepatic artery from splenic artery: the four-leaf clover of hepatic surgery. Surg Radiol Anat, 2016, 38(7):867–871.

[17] Braun MA, Collins MB, Wright P. An aberrant right hepatic artery from the right renal artery: anatomical vignette. Cardiovasc Intervent Radiol, 1991, 14(6):349–351.

[18] Çavdar S, Şehirli Ü, Pekin B. Celiacomesenteric trunk. Clin Anat, 1997, 10(4):231–234.

[19] Iacob N, Pusztai AM, Miclăuş GD, Pop E, Matusz P. An anomalous origin of the gastrosplenic trunk and common hepatic artery arising independently from the abdominal aorta: a case report using MDCT angiography. Rom J Morphol Embryol, 2018, 59(1):353–357.

[20] Douard R, Chevallier JM, Delmas V, Cugnenc PH. Clinical interest of digestive arterial trunk anastomoses. Surg Radiol Anat, 2006, 28(3):219–227.

[21] Tandler J. Über die Varietäten der *Arteria coeliaca* and deren Entwicklung. Mat Hefte, 1904, 25:473–500.

[22] Polguj M, Gabryniak T, Topol M. The right accessory hepatic artery; a case report and review of the literature. Surg Radiol Anat, 2010, 32(2):175–179.

[23] Alakkam A, Hill RV, Saggio G. Superior mesenteric origin of the proper hepatic artery: embryological and clinical implications. Surg Radiol Anat, 2016, 38(6):747–750.

[24] Miclaus GD, Matusz P, Loukas M, Ples H. Rare case of the trunk of the inferior phrenic arteries originating from a common stem with a superior additional left renal artery from the abdominal aorta. Clin Anat, 2012, 25(8):979–992.

[25] Matusz P, Loukas M, Iacob N, Ples H. Common stem origin of left gastric, right and left inferior phrenic arteries, in association with a hepatosplenomesenteric trunk, independently arising from the abdominal aorta: case report using MDCT angiography. Clin Anat, 2013, 26(8):980–983.

[26] Felix W. The development of the urogenital organs. In: Keibel F, Mall FP (eds). Manual of human embryology. Vol. II, J.B. Lippincott Co., Philadelphia, 1912, 752–979.

[27] Miclaus GD, Matusz P. Bilateral quadruple renal arteries. Clin Anat, 2012, 25(8):973–976.

[28] Miclăuş GD, Matusz P. Bilateral triple renal arteries. Rom J Morphol Embryol, 2015, 56(4):1507–1511.

[29] Paraskevas GK, Ioannidis O, Raikos A, Papaziogas B, Natsis K, Spyridakis I, Kitsoulis P. High origin of a testicular artery: a case report and review of the literature. J Med Case Rep, 2011, 5:75.

[30] Arévalo Pérez J, Gragera Torres F, Marín Toribio A, Koren Fernández L, Hayoun C, Daimiel Naranjo I. Angio CT assessment of anatomical variants in renal vasculature: its importance in the living donor. Insights Imaging, 2013, 4(2): 199–211.

[31] Miclaus GD, Pupca G, Gabriel A, Matusz P, Loukas M. Right lump kidney with varied vasculature and urinary system revealed by multidetector computed tomographic (MDCT) angiography. Surg Radiol Anat, 2015, 37(7):859–865.

[32] Prathap Kumar J, Kannan S, Shailaja S, Radhika PM. A study of variations in the origin of testicular arteries in adult human cadavers with embryological significance and clinical importance. Int J Anat Res, 2016, 4(2):2434–2439.

[33] Bayazit M, Göl MK, Zorlutuna Y, Tasdemir O, Bayazit K. Bilateral triple renal arteries in a patient with iliac artery occlusion: a case report. Surg Radiol Anat, 1992, 14(1):81–83.

[34] Halloul Z, Meyer F, Buerger T. Ectopic vascularization of the right kidney by a contralateral origin of the main renal artery from the left common iliac artery: report of a case. Surg Today, 2001, 31(4):371–373.

[35] Türkvatan A, Demir D, Olçer T, Cumhur T. Cake kidney: MDCT urography for diagnosis. Clin Imaging, 2006, 30(6): 420–422.

[36] Pupca G, Miclăuş GD, Bucuraş V, Iacob N, Sas I, Matusz P, Tubbs RS, Loukas M. Left crossed fused renal ectopia L-shaped kidney type, with double nutcracker syndrome (anterior and posterior). Rom J Morphol Embryol, 2014, 55(3 Suppl): 1237–1241.

[37] Graves FT. The arterial anatomy of the congenitally abnormal kidney. Br J Surg, 1969, 56(7):533–541.

[38] Glodny B, Tröbinger MG, Hofmann KJ, Rehder P, Trieb T, Petersen J. A right accessory renal artery arising from a left additional common renal artery stem. Cardiovasc Intervent Radiol, 2009, 32(4):804–806.

[39] Suzuki T, Nakayasu A, Kawabe K, Takeda H, Honjo I. Surgical significance of anatomic variations of the hepatic artery. Am J Surg, 1971, 122(4):505–512.

[40] Chen H, Yano R, Emura S, Shoumura S. Anatomic variation of the celiac trunk with special reference to hepatic artery patterns. Ann Anat, 2009, 191(4):399–407.

[41] Ferrari R, De Cecco CN, Iafrate F, Paolantonio P, Rengo M, Laghi A. Anatomical variations of the coeliac trunk and the mesenteric arteries evaluated with 64-row CT angiography. Radiol Med, 2007, 112(7):988–998.

[42] Iezzi R, Cotroneo AR, Giancristofaro D, Santoro M, Storto ML. Multidetector-row CT angiographic imaging of the celiac trunk: anatomy and normal variants. Surg Radiol Anat, 2008, 30(4):303–310.

[43] Ugurel MS, Battal B, Bozlar U, Nural MS, Tasar M, Ors F, Saglam M, Karademir I. Anatomical variations of hepatic arterial system, coeliac trunk and renal arteries: an analysis with multidetector CT angiography. Br J Radiol, 2010, 83(992): 661–667.

[44] El-Badrawy A, Denewer A, Kandiel T, Roshdy S, El-Etreby S, El-Badrawy ES, Shawky J. 64 Multidetector CT angiography in preoperative evaluation of hepatic artery. Egypt J Radiol Nucl Med, 2011, 42(2):133–137.

[45] Osman AM, Abdrabou A. Celiac trunk and hepatic artery variants: a retrospective preliminary MSCT report among Egyptian patients. Egypt J Radiol Nucl Med, 2016, 47(4): 1451–1458.

[46] Keles P, Yuce I, Keles S, Kantarci M. Evaluation of hepatic arterial anatomy by multidetector computed tomographic angiography in living donor liver transplantation. Biochem Genet, 2016, 54(3):283–290.

[47] Yamashita K, Hashimoto D, Itoyama R, Okabe H, Chikamoto A, Beppu T, Baba H. Accessory right hepatic artery branched from gastroduodenal artery. Surg Case Rep, 2015, 1:90.

[48] Huang Y, Li J, Qi H. Management of the accessory or replaced right hepatic artery (A/R RHA) during multiorgan retrieval when the inferior pancreaticoduodenal artery shares a common origin with A/R RHA. Transplant Proc, 2013, 45(1): 20–24.

[49] Jah A, Jamieson N, Huguet E, Praseedom R. The implications of the presence of an aberrant right hepatic artery in patients undergoing a pancreaticoduodenectomy. Surg Today, 2009, 39(8):669–674.

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