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ANCILLARY DETECTION OF ABDOMINAL VASCULAR VARIANTS ON MULTIDETECTOR COMPUTED TOMOGRAPHY

Radiology

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ABSTRACT

This article deals with the spectrum of incidence of various abdominal vascular variants, both arterial(abdominal aorta and its main branches) and venous (inferior vena cava and IVC) that help in better delineation of pre-operative anatomy due to great variability found in the vasculature of the abdominal organs.

Identification of these variations should be included in routine scans. The preoperative knowledge of these variants has tremendous surgical significance when laparoscopic procedures or liver surgery are planned due to limited vision of the surgical field. Moreover, recognition of the aberrant vessels can also be useful in trans catheter arterial chemoembolization and radio embolization, liver or kidney transplantation as well as interventional or diagnostic procedures.

Apart from the standard evaluation of transverse sections of the vessels, a very important element of the CTA examination is the three-dimensional reconstruction performed with high resolution.

KEYWORDS

CTA (CT angiography) , SMA(Superior mesenteric artery),IVC(Inferior vena cava),CHA(Common hepatic artery),RHA(Right hepatic artery),LHA(Left hepatic artery),LRV(Left renal vein),RLRV(Retroaortic left renal vein),CLRV(Circumaortic left renal vein)

MATERIALS AND METHODS:

The material included computed tomography studies of abdomen of 100 patients (42women and 58 men) performed between August 2016 and July 2017. The CT examinations were conducted with a 64-detector CT scanner at the Department of Radiology of LTMMC and LTMGH, Sion. Images were obtained during the arterial and venous phases and were analysed for the presence of potential anomalies of the branches of the abdominal aorta and IVC anomalies.

The examinations were carried out with the 64-detector CT scanner (Philips Brilliance V.2.6,Philips Healthcare, Netherlands) The examined area stretched from the *diaphragm domes* to the pelvis. In all cases, the s*lice thickness* was 1 mm, the pitch amounted to 1.3, and the average gantry rotation time to 0.5 sec. Contrast agent bolus was administrated using an automatic syringe. Vascular access was obtained with a 18G or a 20G needle inserted into the antecubital vein. The volume of the highly-iodinated contrast agent ranged from 80 to 130 ml, depending on the patient's body mass. The rate of the contrast agent administration was

3.0–4.0 ml/s. CT examinations were performed according to the described protocol: abdominal CT (multi-phase examination), depending on indications. The multi-phase examinations evaluated the early arterial phase only (after 30 seconds following contrast agent administration). The reconstruction thickness of the images was 2 to 5 mm and was performed on an Extended Brilliance Work Space workstation with the software Philips Brilliance for tomography. Image post processing techniques involved two- and three-dimensional reconstructions (Maximum Intensity Projection – MIP; Volume Rendering – VR). Only those images that were free from artefacts – i.e. where the arterial or venous phase was appropriately visualized and an adequate and comprehensive evaluation of the aortic branches or venous variants was possible – were used for the analysis.

RESULTS:

In this study, we have tried to analyse the spectrum of all possible arterial and venous variants found in our study group. **(Table 1)**

Arterial variants were more commonly found in our study group than venous variants.

TABLE 1

Type of Variants	N	%
Arterial	81	81.0%
Venous	19	19.0%
Total	100	100.0%

ARTERIAL

Renal arteries

The total number of the analysed renal vessels amounted to 200/100 patients. In 49/100 patients (37.1%), a typical renal vasculature was found, meaning: each kidney was supplied by a single renal artery. Renal vasculature anomalies were observed in 51/100 patients (63%), based on the presence of accessory renal arteries or anomalous origin of renal arteries. **Table 2**

TABLE 2

Renal Variants	N	%
Accessory Renal Artery – BL	6	11.8%
Accessory Renal Artery – Left	20	39.2%
Accessory Renal Artery – Right	23	45.0%
Right acc renal artery arising from Left CIA	1	2.0%
Left acc renal artery arising from Left CIA	1	2.0%
Total	51	100.0%

Among the accessory renal arteries, 2 groups were identified: renal polar arteries (superior and inferior) and hilar arteries.

The most frequently observed anomaly in our study, was the additional superior renal polar artery (Fig 1, 2), Table 3 – in 26 kidneys (50.9%). Second the most frequent anomaly was the presence of hilar arteries (Fig 3) – found in 18 kidneys (35.29%).Third was inferior renal polar artery (Fig 4) present in 7 kidneys (13.7%).

TABLE 3

Accesory renal artery types	N	%
Superior polar artery	26	50.9%
Hilar artery	18	35.3%
Inferior polar artery	7	13.7%
Total	51	100.0%

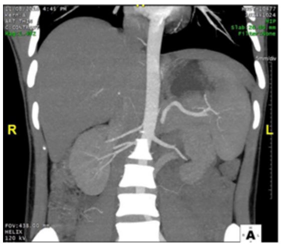


FIG 1

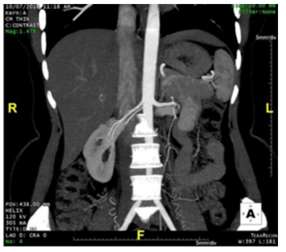


FIG 2

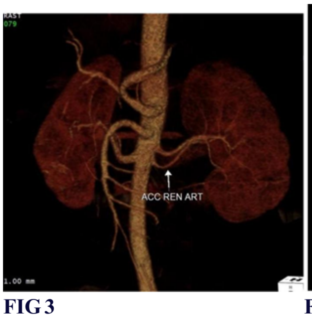


FIG 3

FIG 4

Right kidney vasculature anomalies were found in 45.1% (23/100) of patients, while the left-side anomalies in 39.2% (21/100) of patients.

Bilateral coexistence of additional arteries was observed in 7/100 (13.7%) cases.

Variants of renal vasculature (accessory arteries) were observed in 42/100 women and 58/100 men. Venous variants were observed more commonly in men(12/19) than women(7/19) Table 4.

TABLE 4

Gender	Type of Variant		Total
	Arterial	Venous	
Female	35	7	42
	83.3%inn	16.7%	100.0%
Male	46	12	58
	79.3%	20.7%	100.0%
Total	81	19	100
	81.0%	19.0%	100.0%

In additional renal arteries, few uncommon variants were observed in two patients with ectopic kidneys, in one patient accessory right renal artery was seen arising from left common iliac artery(Fig 5,6) and accessory left renal artery was seen arising from left common iliac artery.

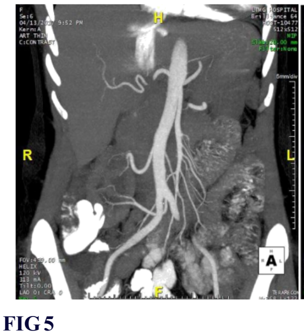


FIG 5

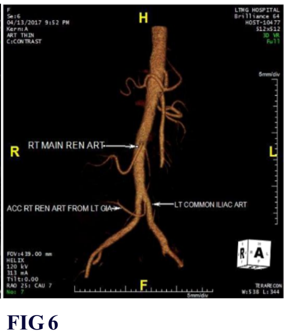


FIG 6

Accessory right renal artery arising from left CIA. Fig 5-MIP reconstruction. FIG 6- VR reconstruction.

Celiac trunk and superior mesenteric artery

Among 100 patients, a typical variant of the celiac trunk and superior mesenteric artery anomaly was found in 70 patients (Fig 7, 8). The typical variant was defined as: the celiac trunk located 1.1 cm above the superior mesenteric artery and splitting into 3 branches: left gastric artery, common hepatic artery and splenic artery.

Superior mesenteric artery branches typically from the anterior aortal wall, approx. 1 cm below the origin of the celiac trunk.

FIG 7

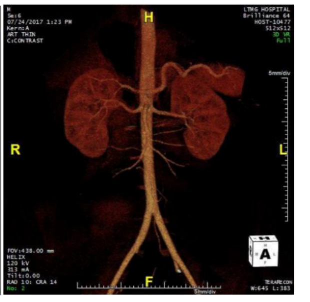


FIG 8

Celiac trunk and superior mesenteric artery, typical variant, MIP reconstruction.

Celiac trunk and SMA variants were found in 30/100 patients ,Table 5. Common origin of the celiac trunk and of the superior mesenteric artery – the celiac-mesenteric trunk – was observed in 5 patients (16.6%) (Fig 9). An independent orifice of the left gastric artery from aorta (splenohepatic trunk) was observed in 6/30 patients (24%).

In the case of hepatogastric trunk, the splenic artery was seen arising directly from aorta (3.3%).

FIG 9

FIG 10

Common origin of the celiac trunk and of the superior mesenteric artery **(Fig 9).** Common hepatic artery as a ramification of the superior mesenteric artery, MIP reconstruction. **(Fig 10)**

FIG 11

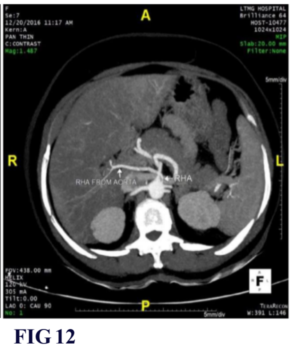


FIG 12

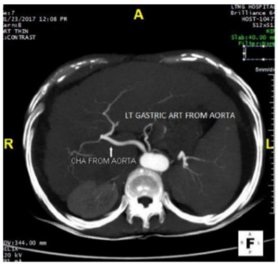
RHA directly arising from Aorta , MIP and VR reconstruction images (Fig 11,12)

The HAS varied in 18 cases (60%).Anomalous right hepatic artery location was the most frequently found anatomical variation seen in 8 cases (26.6%) noted originating from SMA (hepatomesenteric trunk)in one case as(hepatosplenic trunk) from SMA(3.3%) and in another seen directly arising from aorta(3.3%)(Fig 11,12).

In our study left hepatic abnormalities was found in just one patient wherein it was seen as direct branch of Aorta (3.3%).

Most common CHA variant observed was seen arising from SMA in 4 cases(13.3%)(Fig

10).This was followed by CHA arising as a separate branch of aorta i.e gastrosplenic trunk in patients(9.9%).In one case (3.3%) all three branches of celiac trunk are seen arising as separate branches from aorta(Fig 13,14).



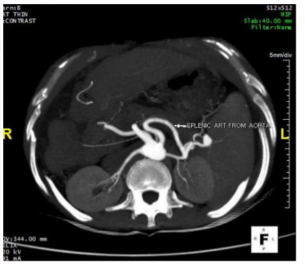


FIG 13 **FIG 14**

Left gastric,common hepatic and splenic arteries originating separately from Aorta(Fig 13,14)

TABLE 5 Prevalence of anatomical variants of celiac trunk and superior mesenteric artery, N=100.

Celiac and SMA Variants	N	%
CHA from Aorta	1	3.3%
CHA and Celiac SEP from Aorta	1	3.3%
CHA, Splenic and left Gastric artery from Aorta	1	3.3 %
Left Gastric Artery from Aorta	6	20.0%
RHA From Aorta	1	3.3%
RHA from Celiac & LHA from Aorta	1	3.3%
CHA from SMA	4	13.3%
RHA from SMA	8	26.6%
Common origin of celiac and SMA	5	16.6%
RHA and Splenic artery from SMA	1	3.3%
Splenic artery from SMA	1	3.3%
TOTAL	30	100.0%

Inferior mesenteric artery

In our study, no anomalies of the orifice of the inferior mesenteric artery were found. In all patients, it was a single vessel branching off independently in its typical location.

VENOUS

Most anomalies of venacava are accidental findings in routine thoracic & abdomen imaging.

Radiologists often encounter these anomalies unexpectedly. Anomalies of the IVC occur in less than 1% of patients and can be readily recognized on multidetector row CT and MR angiography.1 Among these, left IVC prevalence is 0.2%–0.5% and double IVC.2%–3%.

In our study, among 100 patients, a typical variant of the venacava was found in 81 patients. Venacaval anomalies were found in 19/100 patients Table 6.

Most common tributary of IVC showing variant anatomy was seen involving renal veins with circumaortic renal vein being the most commonly observed venous variant in our study accounting for 8/19 patients (42.1%) (Fig 22,23). This was followed by retro-aortic renal vein seen in 5/19 patients(26.3%) (Fig 21).Other less common variants found were double IVC in 3/19 patients (15.8%) (Fig 17,18) left IVC in 2/19 patients(10.5%) (Fig 15,16).

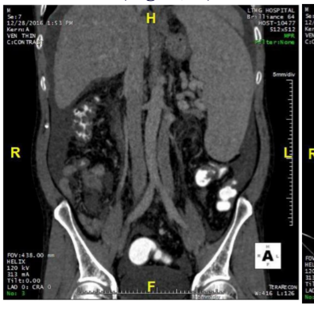
Another less common rare variant found was persistent left subcardinal vein seen in 1 patient (Fig 19 ,20).

TABLE 6

Venous Variants	Total	%
Retro-aortic	5	26.3%
Circum-aortic	8	42.1%
Double IVC	3	15.8%
Left Side IVC	2	10.5%
Left Sub-cardinal	1	5.3%
Total	19	100.0%

FIG 15 **Fig 16**

Lt sided IVC (Fig 15,16)



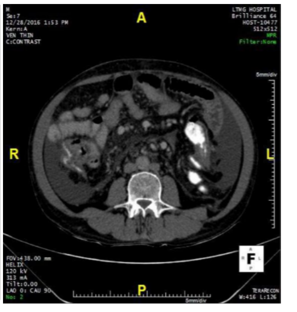
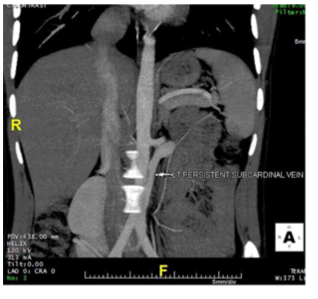


FIG 17 **FIG 18**

Double IVC



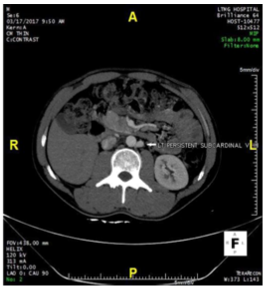


FIG 19 **FIG 20**

Persistent left subcardinal vein, MIP reconstruction images (Fig 19,20)

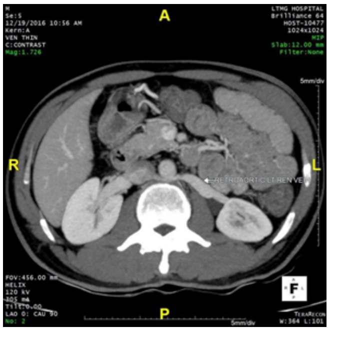


FIG 21

Retroaortic left renal vein

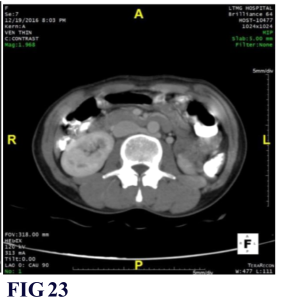


FIG 22 **FIG 23**

Circumaortic left renal vein

Our study aimed at determining the spectrum of various possible vascular anatomical

Our study aimed at determining the spectrum of various possible vascular anatomical variants in the study population with Multi-detector computed tomography (MDCT) along with multi-planar and multi-volume imaging with a resolution of less than 1 mm, covering large anatomical areas.. Other advantages of the CTA examination include imaging of the arterial phase of contrast enhancement along with the ability to analyse vessel wall and its lumen.

The examination results obtained with the 64-detector CT enabled us to analyse venacaval anomalies also along with anatomical relations of the arteries branching off from the abdominal aorta and and to distinguish a few types of such anomalies, and to determine their prevalence in the study population.

When evaluating vessels, we took into consideration the arterial and venous phases of contrast enhancement of a multi-phase examination. The analyzed CT examinations were performed for different medical indications as mentioned above. It should be noticed that in our study, only the main arteries originating from the abdominal aorta and all possible variants of IVC were subjected to the analysis – celiac trunk and its three main branches: common hepatic, left gastric and splenic artery, as well as the superior mesenteric artery, renal arteries and inferior mesenteric artery.

The main observation of our study was that developmental abnormalities of renal arteries originating from the abdominal aorta are frequent, and amounting to 63 % of the cases and in case of IVC anomalies, circumaortic left renal vein was the most common variant accounting for 42.1% cases.

Renal arteries

Among all abdominal aorta ramifications, renal arteries show the highest anatomical variability. In our study group, different variants of the renal arteries were significantly more frequent (63%) than the variants of the celiac trunk or of the superior mesenteric artery (30%).

Theories related to embryonic origin of the renal vasculature have been postulated as descibed. Vasculature development is strictly dependent on the cephalic migration of kidneys during embryogenesis. If their final location is atypical, renal vasculature may also be atypical, which can be explained by arterial vasculature adjustments to the location of the kidneys. In our study group, the atypical kidney location was observed in two patients, and thus the additional renal arteries were probably the remains of the mesonephric blood vessels, giving rise to the renal artery. During embryogenesis, there exists a genitourinary arterial system composed of a few mesonephric arteries supplying kidneys, adrenal glands and gonads. In the course of the embryonic development, the number of the kidney-supplying mesonephric arteries dwindles down to one, with the rest undergoing atrophy. Any abnormalities of this process may lead to a higher number of renal arteries [8].

We found no significant difference in the results of our study from those presented in the literature. In our opinion, there are two to three factors underlying the differences: number of the examined patients, study method and the race or the region of the world in which the study was conducted.

There is found a great variability and frequency in distribution of various anatomical variants of renal vasculature which demands studies in much larger populations to obtain repeatable and similar results. The study groups in the quoted papers were larger than our study population . The above mentioned studies were conducted in Asia, Africa or South America, and thus the race factor can be the underlying cause of the observed differences as well. This can cause differences in renal vasculature. The influence of the race on renal vasculature was well described in the paper by Satyapal et al., showing a significantly higher rate of additional renal arteries in Africans (37.1%) and Caucasians (35.3%) than in Indians (17.4%).

In our study, anomalies of the renal arteries were more frequent on the right (45% of right kidneys – 23/51) than on the left side (41% of left kidneys – 20/51). There was no statistically significant difference. The majority of authors did not present with similar results [5,7,16,15]. Other authors: Cicekcibasi et al. [14] and Ayuso et al.[17] described an opposite laterality of anomalies; this was also the case in the study by Tarzamni et al., who observed 32.47% of right-sided anomalies and 17.09% of left-sided anomalies, p=0.01 [18]. On the basis of our results and the data by other authors, it is now impossible to determinate a significantly dominant side; however, it is of a great clinical importance, because the left kidney is easier to collect laparoscopically (for transplantation purposes), due to the longer renal vein and to more convenient anatomical conditions [19].

In our study, bilateral anomalies were observed in 11% (6/51) of patients. In the literature, the prevalence of bilateral anomalies of the renal arteries ranged between 3.1% and 13% [5,3,15,18,20].

The prevalence of the superior renal polar artery accompanied by the hilar renal artery ranges, according to the study, from 4.3 to 7% of kidneys [5,10] or 3.3–7.5% of cases [3,14]. For the inferior renal polar artery, this is: 3–10.8% of kidneys [5,10] and about 10% of patients [14, 3]. Two hilar arteries were observed in 7–12.1% of kidneys [5, 10] and 11.1 in 19% of patients [3,14]. Such discrepancies between the results may have various causes: size of the study group, study method (autopsy examination [5,10,14], CT examination [3]) and the race of the examined patients [5]. It is worth noticing that the results of our study are similar to the results of the quoted papers, including the autopsy-based ones [3,5,7,10,14– 16,18,20].

Renal vasculature anomalies were observed in (42/100) of women and (58/100) of men. The difference was statistically significant (p=0.79). Satyapal et al. found that the prevalence of additional renal arteries is statistically significantly higher in men than in women [7]. Other studies did not show statistically significant differences between genders with respect to the prevalence of renal artery variants [15,18]. Cicekcibasi et al. showed that vasculature variants were more frequent in men, which was similar to our results [14].

Celiac trunk and superior mesenteric artery

Celiac trunk is the most superior branch of all three single branches of the abdominal aorta (Figure 5). It splits into 3 branches: left gastric, common hepatic and splenic artery. Normally, the left gastric artery arises just before the orifice of the common hepatic and the splenic artery, but it may also have a common origin with those vessels or it may be a splenic artery ramification or have separate orifice from aorta as was found in our study.

Typical celiac trunk division into three arteries was observed by us in 70 patients .Other authors, analyzing larger populations, reported a much lower prevalence of the typical celiac trunk division: in 378 patients (72.1%) and 875 patients (89.8%) [22,23]. However, the common origin of the celiac trunk and of the superior mesenteric artery was observed in %, of our patient, which is more frequent than in the literature – 0.4% [22] (Figure 6). In our study, the hepatosplenic trunk was present in 1.5% of the patients (Figure 7), and the gastrosplenic trunk in 0.5% (Figure 8). This was much less frequent than in other studies:

2.7–4.4% and 3.4–4.0%, respectively [22,23].

On the other hand, we did not find in our study any variants observed by Iezzi et al., such as the gastrohepatic trunk or the absence of the celiac trunk. This was probably due to the rareness of such variants and a larger study sample in report by Iezzi et al.

Venous

Embryology

Study of embryology of the inferior venacava allows for explaining its multiple anatomical variants .The inferior venacava originates between the 6th and 8th weeks from a dynamic process of development, regression, anastomosis, and replacement of the vitelline vein, subcardinal and supracardinal veins. The posterior cardinal vein appears first and disappears except for the distal segment that becomes the iliac bifurcation. During the fifth week the subcardinal veins, which drain the mesonephrons, are formed. The anastomosis between the subcardinal veins forms the left renal vein. The left subcardinal vein disappears and the right subcardinal vein becomes the renal segment of the IVC. One week later, during the sixth

week the supracardinal veins are formed. While the left supracardinal vein regress, the right supracardinal vein becomes the infrarenal portion of inferior vena cava. In the thorax supracardinal veins form azygos and hemiazygos veins. The right vitelline vein forms the hepatic segment of the IVC. It connects to the renal segment and the infrarenal segment and the IVC is complete.

The LRV has a longer and more complex embryological developmental process compared to the right renal vein. Posterior cardinal, subcardinal and supracardinal venous channel pairs play an important role in the developmental process of the IVC (6th–10th intrauterine weeks).

Congenital venous abnormalities in the retroperitoneal space are relatively infrequent but are of clinical importance to general, vascular, and transplant surgeons, urologists, and interventional radiologists.

LRV abnormalities are usually detected incidentally. Although such abnormalities are generally asymptomatic, there are papers reporting cases presenting with intermittent haematuria and blunt side pain with no pathology other than renal vein abnormality.

The rate of LRV abnormalities varies in different studies. Reed et al. [27] reported the frequency of RLRV abnormality as 1.8% and CLRV abnormality as 4.4% with CT scanning in 433 cases. In another study including 1014 cases by Trigaux et al. [28], RLRV was detected in 3.7% and CLRV abnormality in 6.3% of cases with CT scanning. In a study by Oyar et al. [29], the rate of RLRV abnormality was 0.4% and CLRV abnormality was 1.2% in 250 abdominal CT images. The frequencies of retro-aortic and circumaortic renal vein abnormalities in autopsy series were 1.5–3.4% and 1.8–16.8%, respectively [8]. Satyapal et al. [30] examined 1008 cases in their combined series of cadaver and clinical cases and reported RLRV abnormality in 0.5% and CLRV abnormality in 0.3% of cases.

In this study, the frequency of circumaortic was 42.1% (8/19 studies) and RLRV was 26.1% (5/19 CT studies) and furthermore quite divergent for left IVC 2/19 studies (10.5%), duplication of IVC was 15.8% 3/19 studies. In another study by Yesildag et al. [31], the rate of RLRV abnormality was 0.9% and CLRV abnormality was 2.3% in 1003 abdominal CT images. Our rates of retro-aortic and circumaortic renal vein abnormalities, respectively, are within the ranges reported in other studies

Renal vein and IVC abnormalities are valuable in surgery because a lack of knowledge on the existence of an abnormality may result in complications leading to haemorrhage, nephrectomy, or even death . In renal transplant donors, the left side is preferred due to the length of the LRV. Thus, knowing whether the LRV has a normal pre-aortic course is important.

Developmental anomalies of the accessory renal arteries branching from the abdominal aorta were frequent seen in our study(63%) revealing a great variability of variants, with the most common one being the presence of an additional superior renal polar artery. The study showed a statistically significantly higher number of vasculature anomalies of the right kidney in comparison to the left kidney. In our study group, renal vasculature anomalies were clearly more frequent in men, but the difference was not statistically significant.

Celiac trunk and superior mesenteric artery showed less anatomical variabilities and the prevalence of these arterial anomalies in our study group – 30/100 of the patients, respectively. No anomalies of the inferior mesenteric artery branching were observed.

Correlation between our study results and the literature data, confirms the sensitivity and precision of the presented diagnostic method, i.e. of the multi-detector computed tomography. The high rate of atypical anatomical variants of the arteries branching from the abdominal aorta, observed in our study, speaks for the necessity of presurgical vascular diagnostics in this respect. Evaluation of the renal vasculature seems especially important due to the frequency of the anomalies.

Prevalence of venous anomalies of renal veins especially circumaortic renal vein(8/19 patients) followed by retroaortic left renal vein (5/19 patients)were frequent in our study accounting for 42.1% and 26.1% cases.

Preoperative imaging diagnosis is one of the most important factors in avoiding inadvertent venous injury and bleeding during surgery. However, care must be taken in abdominal aortic surgery, particularly in emergency surgery when sufficient preoperative examination cannot be performed, it is necessary to always keep in mind this possibility and to be familiar with the anatomical features when performing surgery.

Summary

Abdominal vascular variants, both arterial(abdominal aorta and its main branches) and venous (inferior vena cava and IVC) are common, can be identified at multidetector CT angiography. This article describes their appearances and prevalences as encountered in our study.

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