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CELIAC TRUNK - HEPATIC ARTERIAL SYSTEM AND RENAL ARTERIES, ANATOMICAL VARIATIONS IDENTIFICATION, PREVALENCE AND ASSOCIATION : ANALYSIS USING MDCT

Radiodiagnosis

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ABSTRACT

AIMS AND OBJECTIVES:

- Aim of this study is to determine the anatomical variants of celiac trunk, hepatic arterial system and renal arteries , their pervasiveness with the use of contrast enhanced Multi detector computed tomography (MDCT) and post processing techniques like Multiplanar reconstruction (MPR), Maximum intensity projection(MIP) and Volume rendering technique (VRT).
- The variations are individually described and the association between occurance of renal artery and celiac-hepatic artery variations is statistically evaluated.

METHODS AND MATERIALS: We conducted a retrospective analysis in 521 patients referred to the Department of Radiodiagnosis from December 2016 to December 2017 for various abdominal pathologies.
The imaging (CE MDCT) was performed using GE Bright Speed Elite 16 Slice CT Scanner.
All the patients have undergone plain CT followed by triphasic CECT abdomen with multiplanar reconstruction, maximum intensity projection and volume rendering post processing.

RESULTS : In our retrospective study in 521 patients, comprising 276 (53%) men and 245 (47%) women between the age of 9 to 72 years (Mean age of 31.5 years) celiac trunk variations were present in 44 patients (8.4%), Hepatic artery variations were present in 128 patients (24.6%) and renal artery variations were seen in 232 patients (44.5%).
Celiac trunk and/or hepatic artery variation was present in 63 (21.8%) of 289 patients without renal artery variation and in 95 (40.9%) of 232 patients with renal artery variations.
There is an increased prevalence of celiac-hepatic artery variations in individuals with accessory renal arteries.

CONCLUSION : Prior evaluation of arterial variations is of paramount importance before abdominal interventional and surgical procedures.
Contrast enhanced MDCT with Multiplanar reformation (MPR), Maximum intensity projection (MIP) and Volume rendering technique (VRT) post processing is a noninvasive diagnostic technique of high preference holding prime importance in accurate detection and characterization of anatomical vascular variants of celiac trunk, hepatic artery and renal arteries.

KEYWORDS

Variations, Coeliac trunk, Hepatic artery, Renal arteries.

INTRODUCTION

Celiac trunk is the first ventral branch of the abdominal aorta and is the source of arterial supply for the entire foregut. Its branches are critical for the function of solid organs and hollow abdominal viscera of the foregut. With the advancement of computed tomography scanner technology, invasive angiography is no longer the sole method for evaluation of arterial pathologic conditions (1).

Knowledge about the anatomical variants of the coeliac trunk and hepatic arteries are of prime importance in laparoscopic cholecystectomy, pancreatic and hepatobiliary surgeries, radiological interventions and penetrating injuries to the abdomen due to increased chances of inadvertent / iatrogenic vascular injuries in the presence of aberrant anatomy.

A road map of the arterial vascularity of the donor and recipient are a prerequisite for liver transplant surgery (2).

With the advancement of endovascular treatment options for hemorrhage control and management of visceral artery aneurysms (VAA) along with leading edge of interventional procedures like transcatheter arterial chemoembolization (TACE), transarterial radionuclide therapy (TART), and placement of infusion pumps, recognition of these anatomical variants have gained paramount importance.

Knowledge of renal artery variants is significant in surgical management of reno vascular hypertension, renal transplantation and in interventional radiological procedures for renal artery stenosis, renal artery aneurysms, arterio-venous malformations, dissection and thrombosis, where it is important to know the origin, number and course of these renal arteries.

AIMS & OBJECTIVES:

- Aim of this study is to determine the anatomical variantions of celiac trunk, hepatic arterial system and renal arteries, their pervasiveness with the use of contrast enhanced Multi detector computed tomography (MDCT) and post processing techniques like Multiplanar reconstruction(MPR), Maximum intensity projection(MIP) and Volume rendering technique (VRT).

- To study the association between occurance of renal artery and celiac-hepatic artery variations, with statistical evaluation.

MATERIALS & METHODS:

Source of data: We conducted a retrospective observational study in 521 consecutive patients referred to the Department of Radio diagnosis for various abdominal pathologies from December 2016 to December 2017.

Sample size: 521.

Inclusion criteria:
Patients of all age groups and both sexes referred for CE MDCT abdomen for various indications.

Exclusion criteria :

1. Patients with a history of major upper abdominal surgery.
2. Patients with thrombosis of celiac, hepatic and renal arteries of various causes.
3. Any patient with extensive local pathological condition, which can alter the normal vascular anatomy.

Equipment: GE Bright Speed Elite 16 Slice CT Scanner.

CT Imaging protocol : Scans were performed in the axial plane, starting from the domes of diaphragm up to the pubic symphysis, first in plain followed by contrast multiphasic scans.

Post processing using Multiplanar reconstruction(MPR), Maximum intensity projection(MIP) & Volume rendering technique (VRT) was performed.

Scanning Parameters : Slice thickness: 5mm
Interslice increment: 5mm
Pitch: 1.375:1
kVp: 120
mAs(auto): 90-140
Gantry rotation Time: 0.8 sec
Matrix: 512 x 512

Contrast media : 80-100 ml (2-3 ml/Kg body weight) of Iodinated contrast (Iohexol) with Iodine concentration of 350 mg /ml, injected using automated power injector at the rate of 3-4ml/second.

Time of acquiring arterial phase: 25-30 seconds of start delay.

Retrospective Reconstruction Parameters: Slice thickness: 1.25 mm

IMAGE INTERPRETATION:

- The coeliac trunk, hepatic arterial system and renal arteries are analyzed individually and are recorded using standard classification systems.
- Uflacker's classification system is used for celiac trunk variations and hepatic arterial system is characterized using both Michel's and Hiatt's system of classifications.
- The renal arteries are assessed with respect to their origin, number and laterality.

Key definitions used in this study:

Typical celiac axis (6): Arterial trunk that gives rise to the common hepatic, left gastric, and splenic arteries.

Ambiguous celiac axis (6): Congenital absence of CHA or congenital presence of an anastomotic channel connecting the celiac axis and superior mesenteric artery (SMA) or anastomotic channel connecting the CHA to the celiac axis and the SMA.

CHA (6): Artery giving rise to RHA or LHA and the GDA, irrespective of its origin and course.

Replaced (7): Replaced origin of hepatic arteries refers to the arterial blood supply from an ectopic location.

Accessory (7): Accessory origin of hepatic arteries refers to the arterial blood supply from typical as well as ectopic branch.

TABLE 1: Coeliac trunk variations: Uflacker's classification (3)

Coeliac trunk variation	Uflacker's Classification	Description
Classic coeliac trunk	Type I	The CHA, SA and LGA have a common point of origin from the celiac trunk
Hepatosplenic trunk	Type II	CHA and SA have common trunk with the LGA arises separately from AA
Hepatogastric trunk	Type III	CHA and LGA have common trunk with the SA arises separately from the aorta or SMA
Hepatosplenicmesenteric trunk	Type IV	CHA, SA and SMA have common trunk with the LGA arises separately from the AA
Gastrosplenic trunk	Type V	LGA and SA have a common trunk with the CHA arises separately from the AA or SMA
Coeliac-mesenteric trunk	Type VI	Celiac and SMA have a common trunk
Coeliac-colic trunk	Type VII	The middle colic artery and the celiac have the same trunk
No coeliac trunk	Type VIII	No celiac trunk with the CHA, SA and LGA arises directly from the AA

TABLE 2: Hepatic artery variations: Michel's and Hiatt's classifications (4,5)

Hepatic artery variation	Michel's classification	Hiatt's classification
Normal anatomy	Type I	Type I
Replaced left hepatic artery originating from the left gastric artery	Type II	Type II
Replaced right hepatic artery originating from the superior mesenteric artery	Type III	Type III
Co-existence of Type II and III	Type IV	Type IV
Accessory left hepatic artery originating from the left gastric artery	Type V	Type II
Accessory right hepatic artery originating from the superior mesenteric artery	Type VI	Type III
Accessory left hepatic artery originating from the left gastric artery and accessory right hepatic artery originating from the superior mesenteric artery	Type VII	Type IV
Accessory left hepatic artery originating from the left gastric artery and replaced right hepatic artery originating from the superior mesenteric artery	Type VIII	Type IV
Common hepatic artery originating from the superior mesenteric artery	Type IX	Type V
Right and left hepatic arteries originating from the left gastric artery	Type X	NOD
Common hepatic artery directly originating from the aorta	NOD	Type VI

Abbreviations used in this study:
Abdominal aorta (AA)
Celiac trunk (CT)
Splenic artery (SA)
Left gastric artery (LGA)
Common hepatic artery (CHA)
Right hepatic artery (RHA)
Left hepatic artery (LHA)
Gastroduodenal artery (GDA)
Superior mesenteric artery (SMA)
Renal artery (RA)
Right renal artery (RRA)
Left renal artery (LRA)
Accessory renal artery (ARA)
Superior polar artery (SPA)
Inferior polar artery (IPA)
Multi detector computed tomography (MDCT)
Contrast enhanced computed tomography (CECT)
Multiplanar reformation (MPR)
Maximum intensity projection (MIP)
Volume rendering (VR)
Not otherwise described (NOD)

RESULTS

In retrospective study involving 521 patients, comprising 276 (53%) men and 245 (47%) women between the age of 9 to 72 years (Mean age of 31.5 years) celiac trunk variations were present in 44 patients (8.4%),Hepatic artery variations were present in 128 patients (24.6%) and renal artery variations were seen in 232 patients (44.5%).

Coeliac trunk variations: In accordance with Uflacker's classification 477(91.5 %) out of 521 patients showed type I anatomy, 14 patients (2.7%) showed type II variation, 2 patients (0.4%) showed type III variation, 3 patients (0.6%) showed type IV variation, 19 patients (3.6%) showed type V variation and 1 patient (0.2%) showed type VI variation.

Type III and type IV showed least incidence in our study group accounting for 0.4 % and 0.6 % respectively.

In our study group we did not come across type VII and type VIII variations, which are considered very rare according to literature.

5 (1.0%) out of 521 patients had three types of unclassified variants.

Three cases of quadrifurcation of CT were seen with absent common hepatic artery and branching into right hepatic, left hepatic, left gastric and splenic arteries. In these cases the gastroduodenal artery was noted to arise from right or left hepatic artery.

In two cases the common hepatic artery arose from the superior mesenteric artery (SMA) and the left gastric, splenic arteries originated separately from the aorta.

Hepatic artery variations: In accordance with Michel's classification, 393 (75.4%) out of 521 patients showed normal i.e type I anatomy, 39 patients (7.5%) showed type II variation, 26 patients (5.0%) showed type III variation, 6 patients (1.2%) showed type IV variation, 24 patients (4.6%) showed type V variation, 22 patients (4.2%) showed type VI variation and in 4 patients (0.7%) type IX variation was noted. None of the patients showed type VII, VIII and X variations.

In accordance with Hyatt's system of classification, 393 (76.5%) out of 521 patients showed normal type I anatomy, 63 patients (12.1%) showed type II variation, 48 patients (9.2%) showed type III variation, 6 patients (1.2%) showed type IV variation, 4 patients (0.7%) showed type V variation and 6 patients (1.2%) showed type VI variation.

One patient (0.2%) had a different anatomical variant of CHA, which could not be categorized using Michel's or Hyatt's system of classification which was, replaced right hepatic artery arising from the aorta.

Renal artery variations: In 521 patients, 289 patients (55.5 %) showed normal anatomy i.e. one renal artery on both sides and 232 patients (44.5 %) showed accessory renal arteries.

Among 232 patients, 174 patients (33.4 %) demonstrated unilateral accessory renal arteries and 58 patients (11.1 %) demonstrated bilateral accessory renal arteries accounting for 290 kidneys with accessory renal arteries.

Among the 290 kidneys with accessory renal arteries, 129 kidneys (12.4%) showed double hilar arteries, 38 kidneys (3.6%) showed triple hilar arteries, 51 kidneys (4.9 %) showed superior polar arteries and 72 kidneys (6.9%) showed inferior polar arteries.

Celiac trunk and/or hepatic artery variation was present in 63 (21.8%) of 289 patients without renal artery variation and in 95 (40.9%) of 232 patients with renal artery variations.

There is an increased prevalence of celiac-hepatic artery variations in individuals with accessory renal arteries which was statistically significant (chi-square test with $p < 0.05$).

TABLE 3: Coeliac trunk variations - Uflacker's classification

Classification	No. of Cases	Incidence(%)
Type I	477	91.5
Type II	14	2.7
Type III	2	0.4
Type IV	3	0.6
Type V	19	3.6
Type VI	1	0.2
Type VII	0	0
Type VIII	0	0
Others	5	1.0
TOTAL	521	100

TABLE 4: Hepatic artery variations

Michel's classification	Hyatt's classification	No. of patients	Incidence(%)
Type I	Type I	393	75.4
Type II	Type II	39	7.5
Type III	Type III	26	5.0
Type IV	Type IV	06	1.2
Type V	Type II	24	4.6
Type VI	Type III	22	4.2
Type VII	Type IV	0	0
Type VIII	Type IV	0	0
Type IX	Type V	04	0.7
Type X	NOD	0	0
NOD	Type VI	06	1.2
OTHERS		1	0.2
TOTAL		521	100

TABLE 5: Renal artery variations

	Number of Patients	Incidence
Single Renal Artery	289	55.5
Accessory Renal Arteries	232	44.5
Total	521	100

TABLE 6: Accessory renal arteries

	Number of Patients	Incidence
Accessory Right Renal Artery	130	56
Accessory Left Renal Artery	102	44
Total	232	100

TABLE 7: Accessory renal arteries

Renal Artery Variants	Number of Kidneys
Single Hilar Artery(normal)	752
Double Hilar Artery	129
Triple Hilar Artery	38
Superior Polar	51
Inferior Polar	72
Total	1042

DISCUSSION

CELIAC TRUNK

Celiac trunk, which is the first ventral branch of the abdominal aorta, is embryological derivation of vitelline vasculature, which along with SMA & IMA gets absorbed into ventral aspect of abdominal aorta.

The most superior of the three abdominal vitelline arteries, the celiac artery, initially joins the dorsal aorta at the seventh cervical level. This connection subsequently descends to the twelth thoracic level. The celiac artery gives branches that vascularize not only the abdominal part of the foregut, i.e the abdominal esophagus to the descending segment of the duodenum, but also the several embryological outgrowths of the foregut—liver, pancreas, and gallbladder (8).

Embryological tenth and thirteenth vitelline arteries persist and develop into the CT and the SMA, respectively. The eleventh and twelfth vitelline arteries and the longitudinal anastomosis bridging the four vitelline arteries regress, and remnants of the distal tenth, eleventh, and twelfth vitelline arteries join the tenth vitelline artery root to form the LGA, SA and CHA respectively (9,10).

Tandler in 1904, suggested that persistence of the longitudinal anastomoses of the vitelline arteries could result in celiac-mesenteric variants, and proposed embryological explanations for variations in the celiac trunk. There after, many variations of CT have been reported and classified.

In accordance with Uflacker's classification (3) six types of celiac axis anatomic variations were identified in our study. A total of 477 of the 521 patients had a normal celiac axis anatomy. Anatomic variations were seen in 8.5 % of patients. Ambiguous anatomy was seen in 5 patients (1%).

HEPATIC ARTERIES

Ishigami et al.(11) studied the significance of variant hepatic artery anatomy in liver transplant recipients and concluded that, small-caliber of CHA in a liver transplant recipient increases the risk of post-transplantation hepatic artery complications like stenosis and thrombosis.

In chemotherapy patients with normal arterial anatomy, the chemotherapy pump is placed in the hepatic artery after the origin of the gastroduodenal artery to avoid turbulence within the hepatic artery and maintain long-term patency and also reduces the chances of complications like extrahepatic misperfusion, chemotoxicity, chemical cholangitis, bleeding, duodenitis (12).

In surgeries for malignancies of head/uncinate process of the pancreas, knowledge about the presence or absence of a replaced RHA is critical, as the anomalous origin of RHA from the celiac axis or aorta is more prone to iatrogenic injury (12).

In 1955, Michel described the classification scheme for describing

anatomic variation in the hepatic arterial blood supply based on the results of dissecting 200 cadavers (13). In 1969, Vandamme et al. did extensive research on hepatic artery anomalies on 156 cadavers (14). Then, in 1971, Suzuki et al., published their series on 200 patients based on angiography study and also highlighted the importance of hepatic artery variations. (15). In 2010, Song et al., published the largest series of their work in celiac axis and hepatic artery variations in 5002 patients (6).

According to Michels textbook (13) the prevalence of a normal celiac axis anatomy is 89%. In our study, normal celiac axis anatomy was noted in 91.5%. The most common anatomic variation was Gastrosplenic trunk (type V) noted in 19 patients (3.6%). The next common anatomic variation in our study group was that of Hepatosplenic trunk (type II) noted in 14 patients (2.7%). These results were comparable with the studies (6,12,16).

Michels's classification of the hepatic arterial system described 10 variant subtypes (4). The accessory and replaced hepatic arterial systems were described separately within this classification. In Hiatt's classification, no such distinction was made because it was angiographically difficult to distinguish between accessory and replaced hepatic arterial structures, hence six subtypes were described (5). A normal hepatic arterial system has been reported in 51–80% of cases in most studies conducted using DSA (17, 18). In our study, this ratio was about 75.4%. In the literature, the most frequently encountered variation is Type III, present in between 6% and 15.5% of all cases (19, 20). The second most frequent variation, Type II, was reported in 2.5–10% of all cases (20, 21). In our study group, types II and III were the most commonly encountered hepatic artery variations accounting for 7.5 % and 5.0% respectively, which is also in close conjunction with Ugurel et al.(16). Types VII, VIII and X have only been reported very rarely. In our study group, we did not encountered Types VII , VIII and X types.

Our study revealed a frequency of 0.2% (1 in 521 patients) for unclassified variants, which is a replaced right hepatic artery, originating from the aorta, which was earlier reported by Koops et al (21) and Ugurel et al.(16).

RENALARTERIES

Definitive kidneys arise in the sacral region and migrate upwards to a lumbar site just below the suprarenal glands. As they migrate, they are vascularized by a succession of transient aortic branches. These arteries do not elongate to follow the ascending kidneys but instead degenerate and are replaced. The final pair of arteries in this series forms in the upper lumbar region and becomes the definitive renal arteries (8). Persistence of other arteries gives raise to accessory renal arteries.

The renal arteries typically arise from the aorta at the level of L2 below the origin of the superior mesenteric artery, with the renal vein being anterior to the renal artery at the renal hilum.

Variations in renal arteries have been called aberrant, supernumerary, supplementary or accessory. It is therefore necessary that the morphology and the nomenclature of these vessels be standardized. According to Sampaio and Passos (22) these arteries should be called multiple, since they are segmental vessels for the kidneys, without anastomoses between themselves and they should be named according to the territory supplied by them as hilar, superior polar and inferior polar.

The commonest variation noted in our study group is, double hilar arteries in 129 kidneys (12.4%). All the accessory arteries in our study population were seen originating from the abdominal aorta.

Multiple renal arteries are unilateral in approximately 33.4% of patients and bilateral in approximately 11.1%.

Accessory renal arteries where more common on right side (130 patients) than on the left side (102 patients).

According to Satyapal et al. (23) the prevalence of multiple renal arteries in the literature is between 9% and 76%. The incidence of multiple renal arteries is 44.5% in our study group. Our study was also in correspondence with the study done by Kornafel et al. (24) that reported 41.3% of prevalence of multiple renal arteries. There is a reported higher chance of renal transplant failure in patients with multiple renal arteries (25).

Celiac trunk and/ or hepatic artery variations were present in 89(26.6%) of 334 patients without renal artery variation & in 65(39.1%) of 166 patients with renal artery variations, which is a statistically significant correlation. Similar association has been reported by Ugurel et al. This study suggests that there can be a common etiological factor associated in causing variations in two different arterial systems arising from abdominal aorta during embryogenesis.

LIMITATION: Our study posed difficulty in interpretation of MIP images in cases of tortuous and thin caliber arteries.

And as this is a retrospective study, and dedicated protocol for specific angiograms was not performed, there is possibility having missed thin caliber branches.

CONCLUSION

- The anatomical variations of the celiac trunk, hepatic arterial system and renal arteries needs to be established at pre operative imaging to minimize the incidence of iatrogenic arterial injury that could occur during organ transplantation, laparoscopic surgery, radiological abdominal interventions, endovascular procedures, surgical treatment of penetrating injuries to the abdomen and in surgical treatment of renovascular hypertension.
- The prevalence of variations in the coeliac trunk and/or hepatic arteries is more common in people with accessory renal arteries, suggesting the need of careful examination of other arteries to rule out the possibility of anatomical variations, when one anatomical variant is identified.
- Contrast enhanced MDCT with Multiplanar reformation (MPR) , Maximum intensity projection (MIP) and Volume rendering technique (VRT) post processing is a noninvasive diagnostic technique of high preference, holding a paramount importance in near accurate detection and characterization of anatomical vascular variantions.

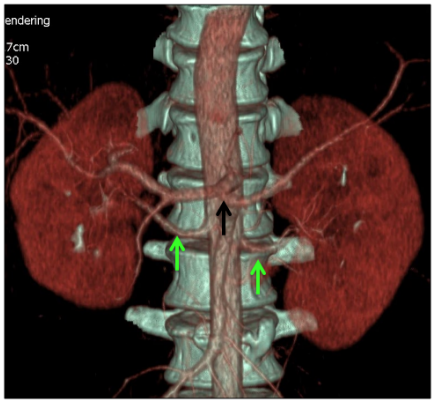

FIG 1A: 3D Reconstructed, Volume rendered CECT image showing normal CT (Black arrow) and normal bilateral single renal hilar arteries (Green arrows).

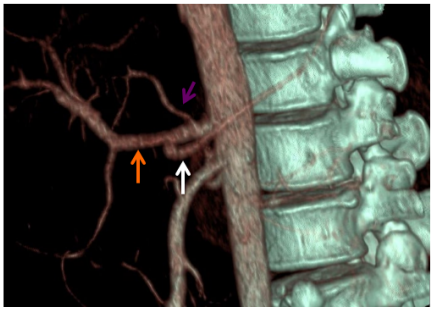

FIG 1B: 3D Reconstructed, VR oblique sagittal image showing normal non-classic pattern of type I CT with its three branches SA (White arrow), LGA (Purple arrow) and CHA (Orange arrow).

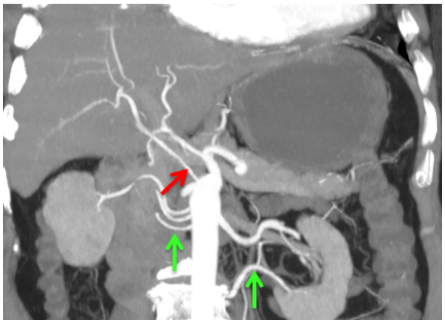

FIG 2A: MIP coronal oblique image showing replaced RHA (Red arrow) originating from SMA.
Also there are 2 accessory right renal hilar arteries and 1 accessory left renal inferior polar artery (Green arrows).

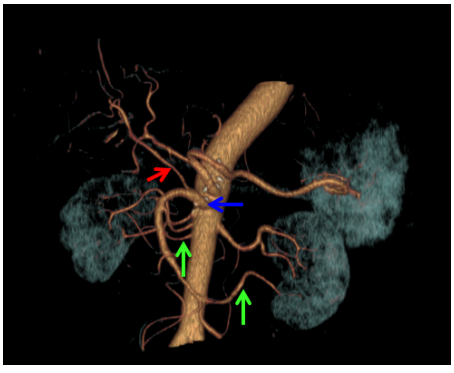

FIG 2B: 3D Reconstructed coronal oblique image showing replaced RHA (Red arrow) originating from SMA (Blue arrow).
Also there are 2 accessory right renal hilar arteries and 1 accessory left renal inferior polar artery (Green arrows).

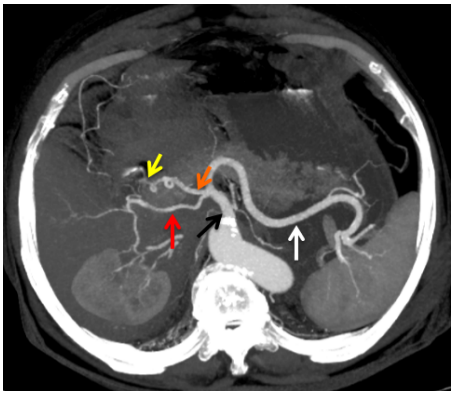

FIG 3: Axial MIP image show replaced RHA (Red arrow) directly originating from CT (Black arrow). LHA (Yellow arrow) is seen originating from CHA (Orange arrow). SA(White arrow).

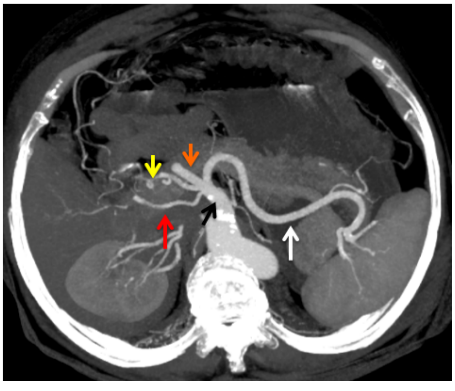

FIG 4: Axial MIP image shows accessory RHA (Red arrow) and LHA (Yellow arrow) originating from CT (Black arrow). CHA (Orange arrow) & SA (White arrow).

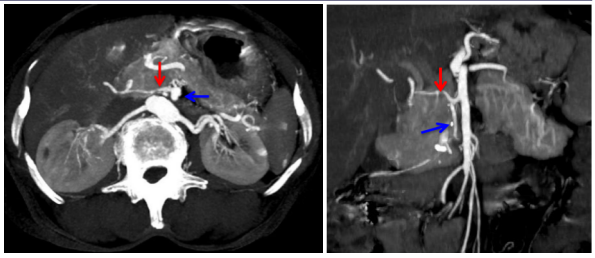

FIG 5A & B: Axial & coronal MIP images show accessory RHA (Red arrow) originating from SMA (Blue arrow).

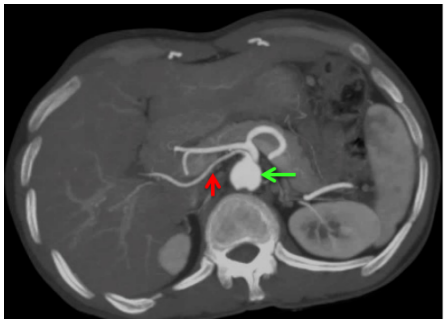

FIG 6: Axial MIP image show replaced RHA (Red arrow) originating directly from AA (Green arrow).

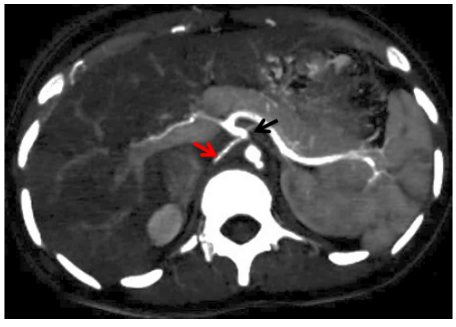

FIG 7: Axial MIP image show Replaced RHA (Red arrow) originating from CT (Black arrow).

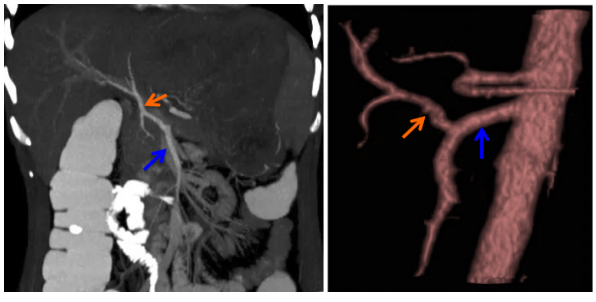

FIG 8A & B: Coronal oblique MIP image and sagittal oblique 3D Reconstructed image showing CHA (Orange arrow) originating from SMA (Blue arrow).

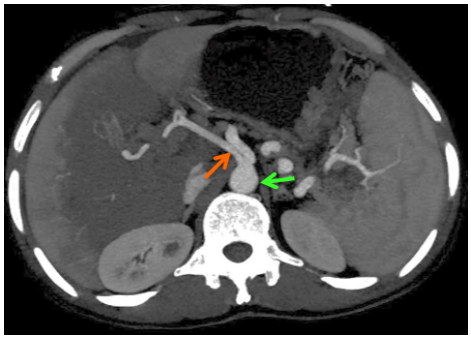

FIG 9A: Axial MIP image, show CHA (Orange arrow) originating directly from AA (Green arrow).

FIG 9B & C: Sagittal & Axial oblique 3D Reconstructed images respectively, showing CHA (Orange arrow) originating directly from AA. SMA (Blue arrow)

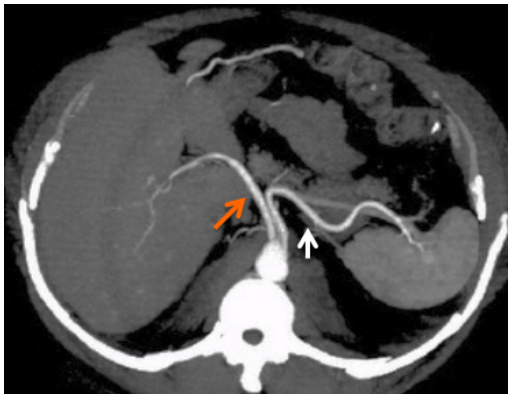

FIG 10: Axial MIP image shows separate origins of CHA (Orange arrow) and SA (white arrow) directly from AA at the same level. Agenetic celiac axis with Elephant-trunk (Sign of Rajul) course of common hepatic & splenic arteries.

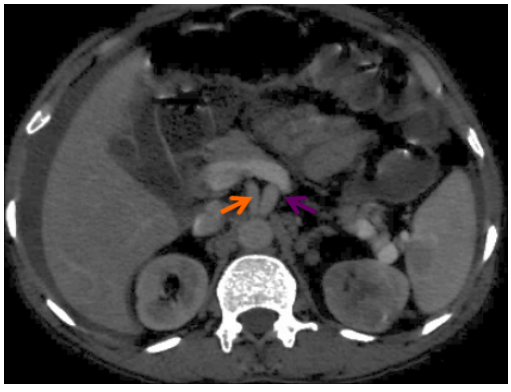

FIG 11: Axial MIP image show Type 5 coeliac artery division showing a common gastrosplenic trunk (Purple arrow) and separate origin of CHA(Orange arrow).

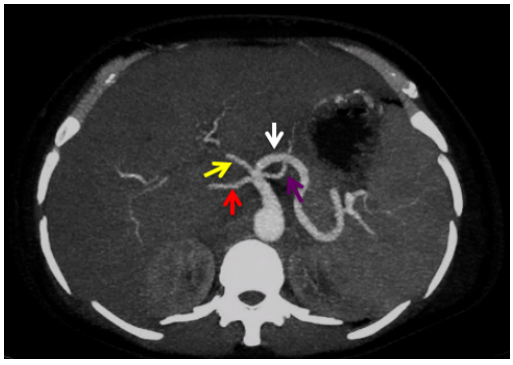

FIG 12: Axial MIP image show Quadrifurcation of celiac trunk into SA (White arrow), LGA (Purple arrow), RHA (Red arrow) & LHA (Yellow arrow)

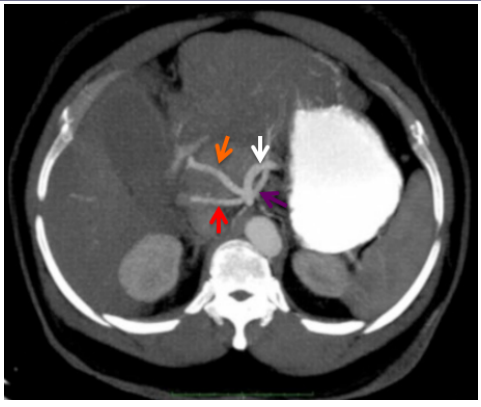

FIG 13: Axial MIP image show Quadrifurcation of celiac trunk into SA (White arrow), LGA (Purple arrow), CHA (Orange arrow) & RHA (Red arrow).

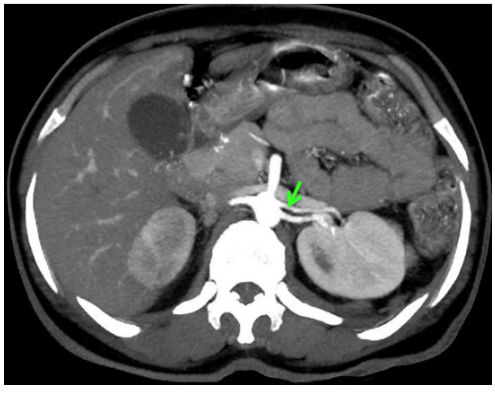

FIG 14: Axial MIP image show accessory left renal hilar artery (Green arrow).

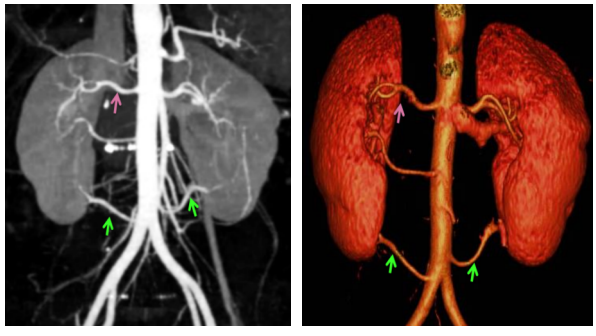

FIG 15A & B : MIP & 3D Reconstructed coronal images show Accessory bilateral renal inferior polar arteries (Green arrows) and Accessory right renal hilar artery (Pink arrow).

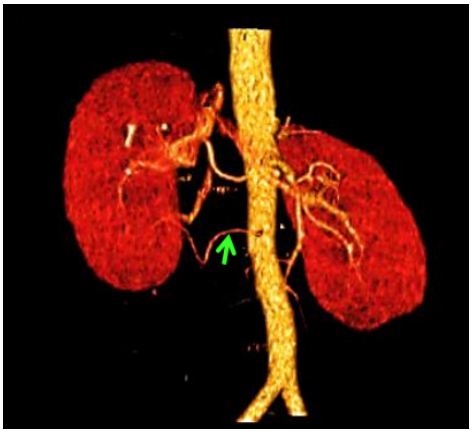

FIG 16: VR, 3D reconstructed coronal oblique image show an accessory right renal inferior polar artery (Green arrow).

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