Section: Radiodiagnosis

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Original Research Article

ASSESSMENT OF ANATOMICAL VARIATIONS IN MAJOR ARTERIAL BRANCHES OF THE ABDOMINAL AORTA USING 64-SLICE COMPUTED TOMOGRAPHY: A COMPREHENSIVE ANALYSIS

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Abstract

Background: The aim is to assess the anatomical variations of the main arteries branching from the abdominal aorta using 64-detector computed tomography. **Materials and Methods:** This Observational: cross sectional study was conducted in the Department of Radiodiagnosis, B.R.D. Medical College, Gorakhpur, Uttar Pradesh, India between 01/06/2023 to 31/05/2024 for a period of 12 months. **Result:** Out of the 110 patients, there were 56 females (50.9%) and 54 males (49.1%). The mean age of the patients was 40.87 ± 18.71 years. 98 patients (89.1%) were classified as type I (classic celiac trunk) Uflacker's type, 6 patients (5.5%) were classified as type II (hepato-splenic trunk), 4 patients (3.6%) were classified as type V(gastro-splenic trunk), 1 patient (0.9%) was classified as type VI(celiaco-mesenteric trunk) and 1 patient (0.9%) was classified as type VIII(absent celiac trunk). Majority of the patients showed normal left renal artery (63.6%), accessory left renal artery was observed in 16 patients (14.5%), left early branching was observed in 15 patients (13.6%), left upper pole aberrant artery was observed in 3 patients (2.7%), left lower pole aberrant artery was observed in 2 patients (1.8%) and left kidney was absent in 1 patient (0.9%). Right renal artery was normal in 80 patients (72.7%), accessory right renal artery was observed in 12 patients (10.9%), right early branching was observed in 12 patients (10.9%), right upper pole aberrant artery was observed in 3 patients (2.7%), right lower pole aberrant artery was observed in 2 patients (1.8%) and right kidney was absent in 1 patient (0.9%). **Conclusion:** In our study 10.9% of patients had celiac trunk developmental abnormalities, with the most prevalent variation—found in 5.5% of patients—being the left gastric artery originating from the aorta. Compared to the right renal artery, the left renal artery had more variation. The key variations encountered were the existence of an accessory renal artery and early branching renal artery.

INTRODUCTION

The thoracic aorta becomes the abdominal aorta just after going through the diaphragmatic haitus at the level of the T12 vertebra. The right & left common iliac arteries split off from the abdominal aorta at level of fourth lumbar vertebra. Blood vessels that supply the stomach, spleen, pancreas, duodenum, and liver are the left gastric artery, splenic artery and common hepatic artery(CHA). CHA extends forward and splits into the gastro-duodenal artery for the providing arterial supply to pancreas and duodenum and the proper hepatic artery supplying the liver. The left gastric artery follows the lesser curvature of the stomach, while the splenic artery winds its way towards the spleen.[1] The superior mesenteric artery (SMA) begins 1-2 cm below the celiac artery, as an anterior branch of the abdominal aorta, at first lumbar vertebra (L1) level. SMA is situated directly above the point at which the aorta gives off the renal arteries. As it enters the mesentery, SMA passes in posterior relation to the body of pancreas. It supplies blood to the distal part of duodenum, jejunum, ileum, and colon(from the cecum to the mid transverse area).[2] Recent developments in minimally invasive radiological abdominal interventions, laparoscopic surgery, liver and kidney transplantation have made it imperative to understand the normal changes in the blood flow of these organs. This knowledge is essential when discussing radiographic abdominal procedures, laparoscopic surgery, liver transplants, and the treatment of penetrating abdominal injuries. Variant anatomy of the arteries is sometimes seen.[3] An accidental or iatrogenic hepatic vascular damage is more likely when aberrant anatomy and variations are present.

The inferior mesenteric artery (IMA) origin lies few inches below origin of SMA. Beginning posterior to the D3 part of duodenum at L3 vertebral level, the artery runs laterally to the abdominal aorta. The distal third of the transverse colon, sigmoid colon, rectum, and upper portion of the anal canal receive arterial supply by the IMA, which supplies blood to the hindgut during the embryonic stage. Three branches frequently split out from the IMA. The superior rectal, the sigmoid and left colic artery make up the branches, arranged from distal to proximal. Straight blood arteries called arcades carry blood from the inferior mesenteric artery (IMA) branches to distal part of colon.[4]

In 1756, Haller documented the classical celiac trunk trifurcation, and Michels subsequently devised a categorization system using cadaveric dissection. As per the normal anatomical configuration, celiac trunk splits into three branches, the left gastric artery, common hepatic artery and splenic artery, right below its origin from the aorta. However, other studies, such as the one conducted by Mburu et al., emphasize the inconsistency in anatomical observations, since they found the trifurcation pattern in only 61.7% of cases.[5]

Studies have examined variations of the renal artery in various populations. Considerable differences in the reported prevalence of these abnormalitieshave found, with frequencies ranging from 4% to 61.5%. These variances exhibit significant variation among different ethnicities and even within the same population groups.[6,7]

A frequently available and affordable alternative to magnetic resonance angiography is multidetector computed tomography angiography (MDCTA), which is efficient and non-invasive. In many cases, digital subtraction angiography has been largely superseded by it.

MATERIALS AND METHODS

This Observational cross-sectional study was conducted in Department of Radiodiagnosis, B.R.D. Medical College, Gorakhpur, Uttar Pradesh, India between 01/06/2023 to 31/05/2024 for a period of 12 months.

Inclusion Criteria

- Patients coming to department of Radiodiagnosis at B.R.D Medical College for contrast enhanced abdominal CT examination for routine diagnostic and surgical conditions.
- All age group irrespective of sex.

Exclusion Criteria

- Patients not giving consent.
- Patients with history of severe contrast reaction.
- Patients with renal insufficiency.
- Patients with pregnancy.
- Patients having previous history of known abdominal vascular surgery, having pathological conditions affecting abdominal aorta and its branches anatomy.

After taking history, patient was instructed to drink 1000 ml of water as negative contrast media (unless contraindicated clinically). Patient was laying supine position with centering of gantry over abdomen and both arms were elevated over head. CT images were taken using 64-detector GE OPTIMA CT scanner with slice thickness range of 0.6-0.7mm and interval of 0.5 mm, a voltage of 120-140 kV, and 180-220 mA current, 0.33 s/rotation helical system. Scout image was taken followed by non-contrast images. 75-100 mL of non-ionic low osmolar contrast was given intravenously by bolus tracking technique. Patient was instructed to hold breath during image acquisitions. Arterial phase images were acquired of abdominal cavity and were examined using dedicated GE workstation to built multiplanar reconstructions in axial, coronal and sagittal plane along with maximum intensity projection (MIP). The images acquired were analyzed for the presence of potential anomalies of the main branches of the abdominal aorta. The variations of celiac trunk¸ superior mesenteric artery, renal artery and inferior mesenteric artery were studied. The variations of celiac trunk were distinguished using Uflacker’s classification system. For SMA, Celiaco-mesenteric trunk and Hepato-spleno-mesenteric trunk were variations considered. Accessory renal artery, early branching and aberrant renal artery were the variation studied for renal artery. Data collected was analysed using SPSS version 21.

RESULTS

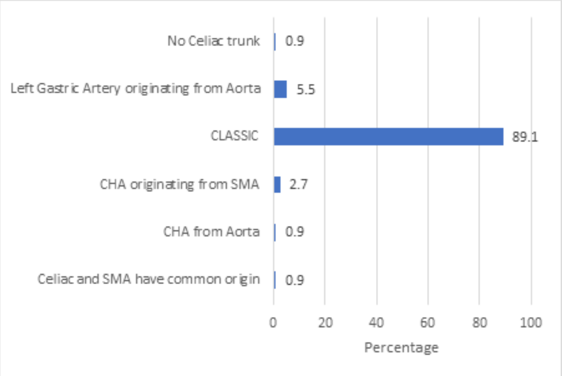
In our study, total sample size was 110. The mean age of the patients was 40.87 ± 18.71 years. The youngest patient was of 1yr age and eldest was of 85 yr.

In present study, 2 patients (1.8%) belonged to the age group of 0-10 years, 15 patients (13.6%) belonged to the age group of 11 to 20 years, 24 patients (21.8%) belonged to the age group of 21 to 30 years, 21 patients (19.1%) belonged to the age group of 31 to 40 years, 13 patients (11.8%) belonged to the age group of 41-50 years, 16 patients (14.5%) belonged to the age group of 51-60 years and 19 patients (17.3%) belonged to the age group of >60 years. The age group with maximum number of patients was that of 21-30 yrs comprising of 24 patients.

Inference: There were 56 females (50.9%) and 54 males (49.1%).

Out of 110 cases included in our study, Classical type of celiac trunk(Left gastric artery, common hepatic artery and splenic artery arising from common trunk) observed in 98 patients (89.1%) while 12 patients (10.9%) showed variant anatomy.

Classic configuration of celiac trunk(left gastric artery, common hepatic artery and splenic artery arising from a common trunk) was seen in 98 patients (89.1%), left gastric artery(LGA) originating from aorta was seen in 6 patients (5.5%), Common hepatic artery(CHA) originating from superior mesenteric artery(SMA) was observed in 3 patients (2.7%), celiac and SMA having common origin was observed in 1 patient (0.9%), Common hepatic artery(CHA) originating from aorta was observed in 1 patient (0.9%), and no celiac trunk(left gastric artery, common hepatic artery and splenic artery arising independently from aorta) was noted in 1 patient (0.9%).



Graph 1: Distribution of the subjects based on variations found in celiac trunk

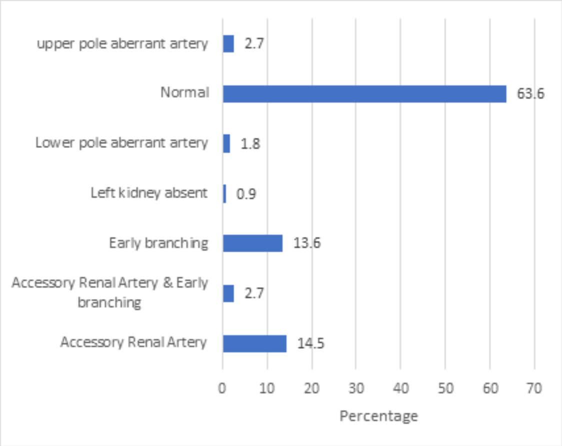
Based on Uflacker's classification, 98 patients (89.1%) were classified as type I(classic celiac trunk), 6 patients (5.5%) were classified as type II(hepato-splenic trunk), 4 patients (3.6%) were classified as type V(gastro-splenic trunk), 1 patient (0.9%) was classified as type VI(celiaco-mesenteric trunk) and 1 patient (0.9%) was classified as type VIII(absent celiac trunk).

Based on type of origin of superior mesenteric artery, 1 patient (0.9%) showed thatceliac and SMA have common origin while SMA was normal in majority of patients (99.1%).

Inference: Type of origin of Inferior mesenteric artery was normal in all patients (100%). No variant anatomy was observed.

out of 110 patients included in our study, right renal artery was normal in 80 patients (72.7%), accessory renal artery was observed in 12 patients (10.9%), early branching was observed in 12 patients (10.9%), upper pole aberrant artery was observed in 3 patients (2.7%), lower pole aberrant artery was observed in 2 patients (1.8%) and right kidney was absent in 1 patient (0.9%).

Left renal artery was normal in 70 patients (63.6%), accessory renal artery was observed in 16 patients (14.5%), early branching was observed in 15 patients (13.6%), upper pole aberrant artery was observed in 3 patients (2.7%), lower pole aberrant artery was observed in 2 patients (1.8%) and left kidney was absent in 1 patient (0.9%).



Graph 2: Distribution of the subjects based on variation observed in left renal artery.

Majority of the patients showed normal right renal artery (80%), accessory renal artery was observed in 12 patients (10.9%), early branching was observed in 12 patients (10.9%),upper pole aberrant artery was observed in 3 patients (2.7%), lower pole aberrant artery was observed in 2 patients (1.8%) and right kidney was absent in 1 patient (0.9%).

The association of variations observed in right renal artery with gender was statistically not significant in the present study. (p=0.17).

Majority of the patients showed normal left renal artery (63.6%), accessory renal artery was observed in 16 patients (14.5%), early branching was observed in 15 patients (13.6%), upper pole aberrant artery was observed in 3 patients (2.7%), lower pole aberrant artery was observed in 2 patients (1.8%) and left kidney was absent in 1 patient (0.9%).The association of variations observed in left renal artery with gender was statistically not significant in the present study. (p=0.92).

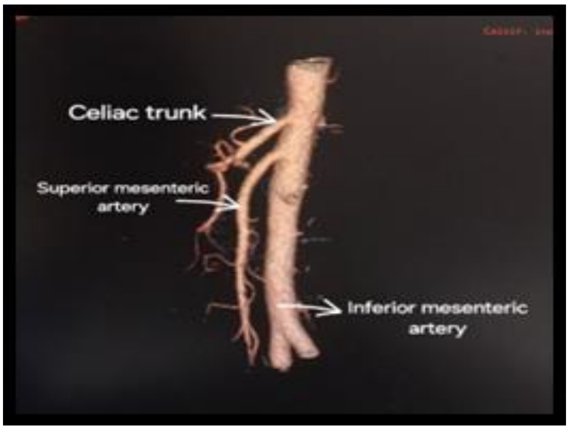


Figure 1: Computed tomography arterial phase images showing classical celiac trunk configuration (Uflacker's type I) with classical branching patterns of superior mesenteric artery and inferior mesenteric artery, (A) as viewed from front, (B) as viewed from lateral side

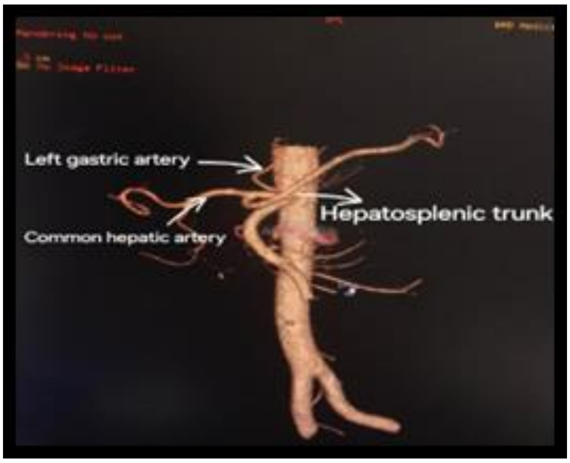


Figure 2: Computed tomography arterial phase images showing left gastric artery branching directly from abdominal aorta (Uflacker's type II)

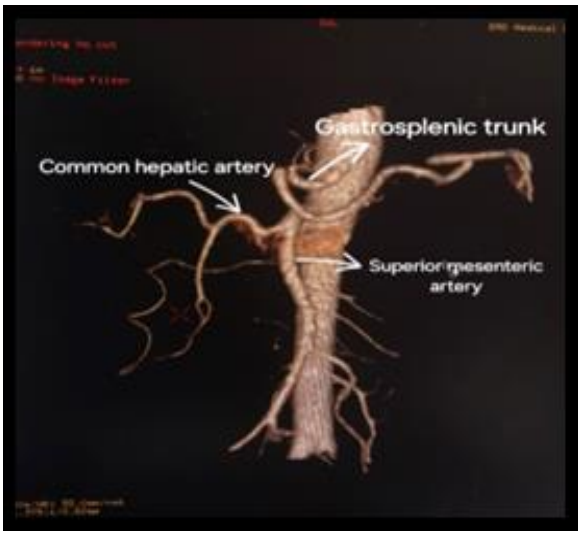


Figure 3: Computed tomography arterial phase images showing common hepatic artery originating from superior mesenteric artery(SMA) (Uflacker's type V), with a seperate Gastro-splenic trunk arising from abdominal aorta

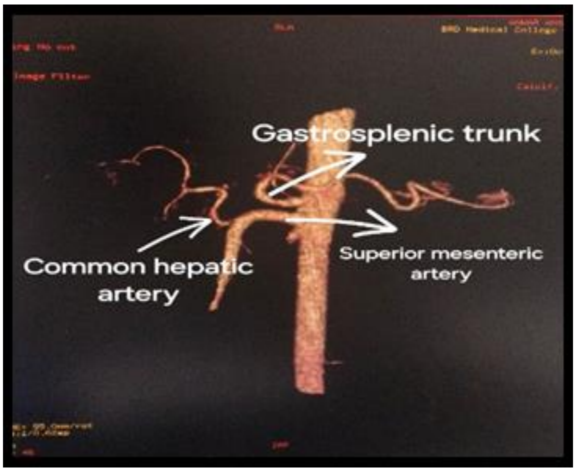


Figure 4: Computed tomography arterial phase images showing another case of Common hepatic artery arising from superior mesenteric artery(Uflacker's type V), with separate Gastrosplenic trunk arising from abdominal aorta

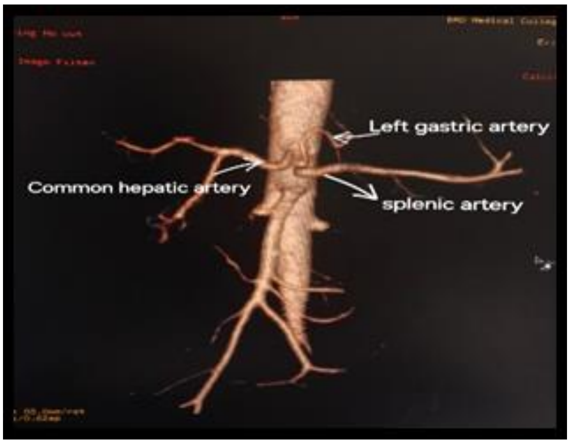


Figure 5: Computed tomography arterial phase images showing absent Celiac trunk (Uflacker's type VIII) with Left gastric artery, common hepatic artery and splenic artery each arising from aorta independently

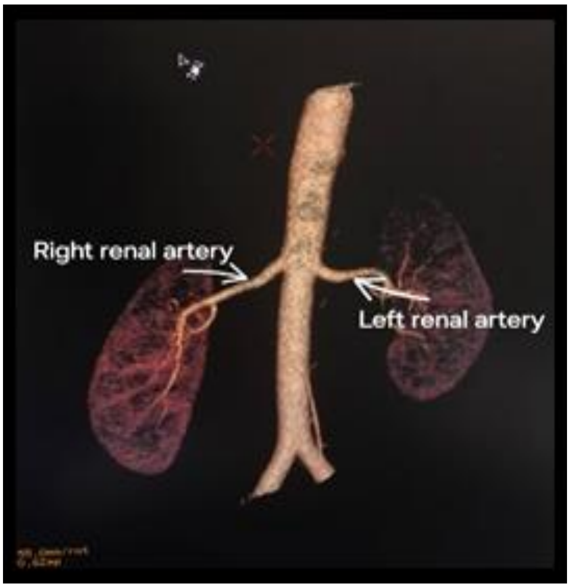


Figure 6: Computed tomography arterial phase images showing classical configuration of Renal artery, bilateral single renal artery

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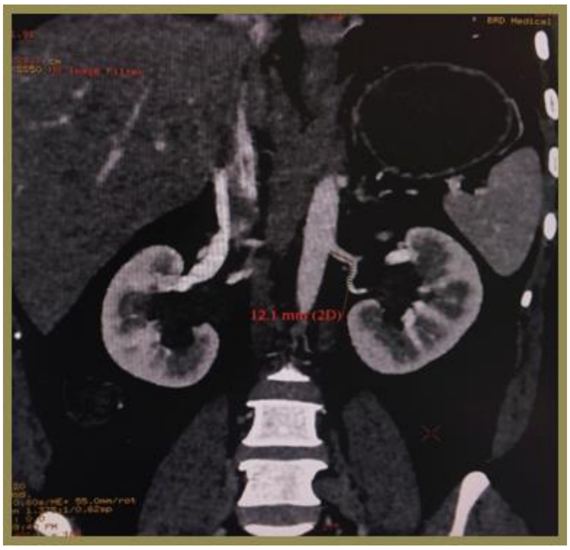

Figure 7: Computed tomography arterial phase images showing left early branching Renal artery

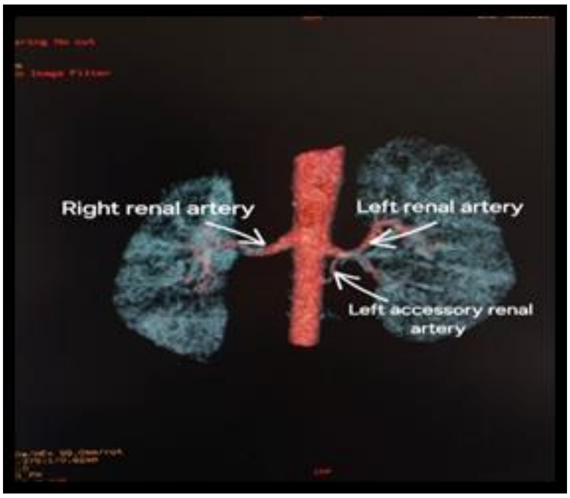

Figure 8: Computed tomography arterial phase images showing left accessory Renal artery, an extra renal artery entering the renal hilum

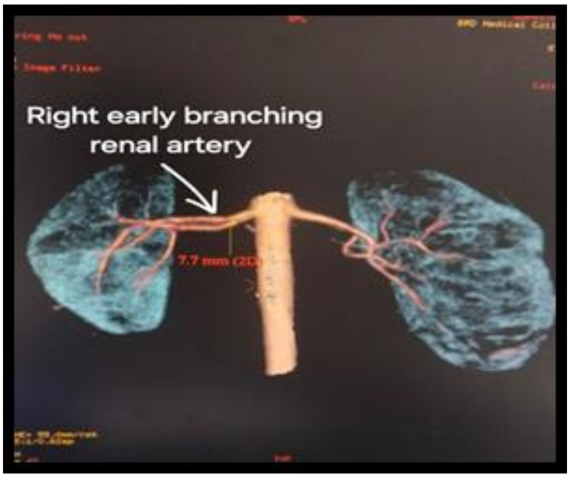

Figure 9: Computed tomography arterial phase images showing right early branching renal artery

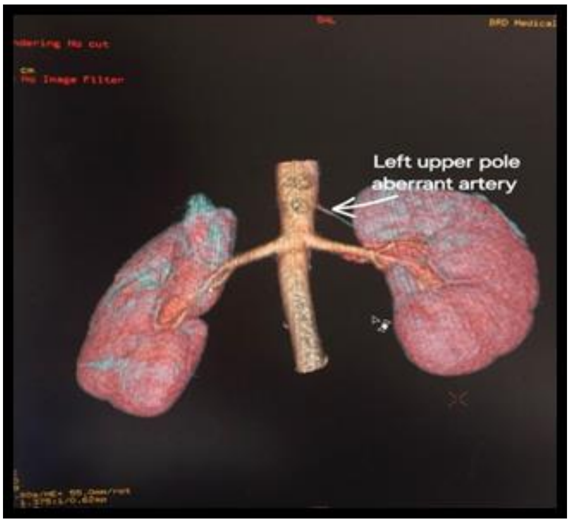

Figure 10: Computed tomography arterial phase images showing left upper pole aberrant renal artery

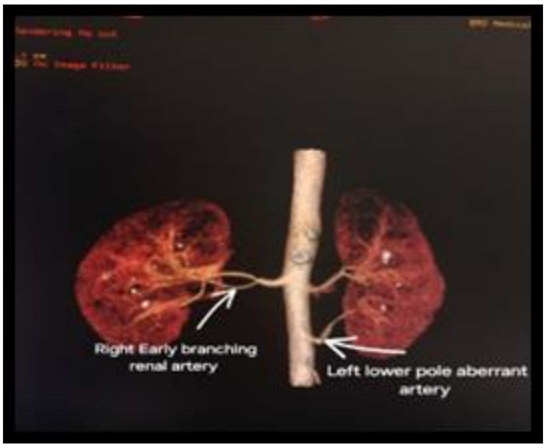

Figure 11: Computed tomography arterial phase images showing left lower pole aberrant renal artery with right early branching renal artery

Table 1: Mean Age Distribution of the Subjects.

	N	Minimum	Maximum	Mean	S.D
AGE	110	1.0	85.0	40.87	18.71

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Table 2: Distribution Of The Subjects Based On Age Groups

Age groups	Frequency	Percent
0-10	2	1.8
11-20	15	13.6
21-30	24	21.8
31-40	21	19.1
41-50	13	11.8
51-60	16	14.5
>60	19	17.3
Total	110	100.0

Table 3: Distribution Of The Subjects Based On Gender

Gender	Frequency	Percent
Females	56	50.9
Males	54	49.1
Total	110	100.0

Table 4: Distribution Of The Subjects Based On Types Of Celiac Trunk Observed

Types of Celiac Trunk Observed	Frequency	Percent
Classic	98	89.1
Variant	12	10.9
Total	110	100.0

Table 5: Distribution Of The Subjects Based On Variations Found In Celiac Trunk

Variations found in Celiac Trunk	Frequency	Percent
Celiac and SMA having common origin	1	.9
CHA originating from aorta	1	.9
CHA originating from SMA	3	2.7
CLASSIC	98	89.1
Left Gastric Artery originating from Aorta	6	5.5
NO Celiac trunk	1	.9
Total	110	100.0

Table 6: Distribution Of The Subjects Based On Uflacker's Classification

Uflacker's classification	Frequency	Percent
I	98	89.1
II	6	5.5
V	4	3.6
VI	1	.9
VIII	1	.9
Total	110	100.0

Table 7: Distribution Of The Subjects Based On Type Of Origin Of Superior Mesenteric Artery

Type of origin of superior mesenteric artery	Frequency	Percent
Celiac and SMA have common origin	1	.9
Normal	109	99.1
Total	110	100.0

Table 8: Distribution of The Subjects Based On Type Of Origin Of Inferior Mesenteric Artery

Type of origin of Inferior mesenteric artery	Frequency	Percent
Normal	110	100.0
Total	110	100.0

Table 9: distribution of the subjects based on variation observed in right renal artery.

Variation observed in right Renal Artery.	Frequency	Percent
Accessory Renal Artery	12	10.9
Early Branching	12	10.9
Lower pole aberrant artery	2	1.8
Normal	80	72.7
Right kidney absent	1	.9
upper pole aberrant artery	3	2.7
Total	110	100.0

Table 10: distribution of the subjects based on variation observed in left renal artery.

Variation observed in left Renal Artery.	Frequency	Percent
Accessory Renal Artery	16	14.5
Accessory Renal Artery & Early branching	3	2.7
Early branching	15	13.6
Left kidney absent	1	.9
Lower pole aberrant artery	2	1.8

normal	70	63.6
upper pole aberrant artery	3	2.7
Total	110	100.0

Table 11: Association Of Variations Observed In Right Renal Artery With Gender

Variation observed in right Renal Artery		**Gender**		**Total**
		Females	**Males**	
Accessory Renal Artery	Count	9	3	12
	%	16.1%	5.6%	10.9%
Early Branching	Count	6	6	12
	%	10.7%	11.1%	10.9%
Lower pole aberrant artery	Count	1	1	2
	%	1.8%	1.9%	1.8%
Normal	Count	36	44	80
	%	64.3%	81.5%	72.7%
Right kidney absent	Count	1	0	1
	%	1.8%	0.0%	.9%
upper pole aberrant artery	Count	3	0	3
	%	5.4%	0.0%	2.7%
Total	Count	56	54	110
	%	100.0%	100.0%	100.0%
Chi-square value- 7.76				
p value- 0.170				

Table 12: Association Of Variations Observed In Left Renal Artery With Gender

Variation observed in Left Renal Artery		**Gender**		**Total**
		Females	**Males**	
Accessory renal artery	Count	9	7	16
	%	16.1%	13.0%	14.5%
Accessory Renal Artery & Early branching	Count	1	2	3
	%	1.8%	3.7%	2.7%
Early branching	Count	8	7	15
	%	14.3%	13.0%	13.6%
Left kidney absent	Count	0	1	1
	%	0.0%	1.9%	.9%
Lower pole aberrant artery	Count	1	1	2
	%	1.8%	1.9%	1.8%
Normal	Count	35	35	70
	%	62.5%	64.8%	63.6%
Upper pole aberrant artery	Count	2	1	3
	%	3.6%	1.9%	2.7%
Total	Count	56	54	110
	%	100.0%	100.0%	100.0%
Chi-square value- 1.94				
p value- 0.924				

DISCUSSION

Assessments with isotropic resolution may be conducted using MD CT, particularly the contrast enhanced abdominal CT scan using fast 64-detector computed tomography. Owing to the ability to do imaging in multiple planes and acquiring volumetric data in a matter of seconds, covering huge anatomical regions with a resolution of less than 1 mm.[8] Regarding the assessment of the aorta and its branches, the ability to quickly visualize sizable sites using CT has significantly enhanced vascular diagnostics, enhanced patient comfort, and decreased the number of examination failures brought on, for instance, by motion artifacts.[9] Additional benefits of the CTA examination include the ability to see the vessel wall, lumen, and surrounding tissues as well as image the arterial phase of contrast enhancement. Additionally, the data from a single scan may be used to depict the artery architecture from all angles.

The arterial phase of contrast enhanced CT abdomen was considered for assessing anatomy of main vessels arising from abdominal aorta.

Gender and age: In the present study, the mean age of the patients was 40.87 ± 18.71 years with a female preponderance (50.9%). The age group of 21 to 30 years old accounted for the majority of the patients (21.8%). In contrast, the mean age of 58.4 with 45% female and 55% male were found in another research conducted by Kornafel O et al.[10] Another study by Malviya et al showed a higher female preponderance which was similar to our study findings.[11]

Type of celiac trunk observed: Out of the three single branches of the abdominal aorta, the celiac trunk is the most superior branch. The left gastric, common hepatic, and splenic arteries are its three branches. The left gastric artery normally emerges directly before the splenic and common hepatic artery orifices, although it can potentially have a shared origin with those arteries or be a ramification of the splenic artery.

Other studies by Omar et al. and Araujo-Neto et al. found 91.9% and 90% of cases with classical CeT configuration respectively ,consistent with our results.[8,12]

Uflacker's classification: In our study, based on Uflacker's classification, 98 patients (89.1%) were classified as type I. These findings were consistent with a research by Jalamneh B et al. that found 90.2% of patients were classified as type I.[13] These results were in concurrence with a study by Malviya KK et al which showed type I as the most common variant.[11] In a study conducted by Omar et al., Hepato-splenic trunk also known as class II Uflacker's was the most common non classical variant anatomical category observed (3%), similarly type II was most commonly encountered non classical celiac axis variation in our study (5.5%).[12] Similarly in a study conducted by Araujo-Neto et al. type II Uflacker's was the most commonly encountered variant configuration.=[8]

Type of origin of superior and inferior mesenteric artery

The roots of the celiac trunk, superior mesenteric artery, and inferior mesenteric artery emerge from the abdominal aorta at varying levels. During embryonic period, a longitudinal anastomotic vessel connects the roots and can either regress, separating the vessels and leaving normal anatomy, or persist, resulting in variations.[14] In the present study, based on type of origin of superior mesenteric artery, 1 patient (0.9%) showed that celiac and SMA have common origin and SMA was normal in majority patients (99.1%). An incidental case of celiaco-mesenteric trunk was encountered was Sangster et al.[2] Similarly Lagoutte et al encountered a case of celiaco-mesenteric trunk and highlighted its importance especially in patients undergoing aortic surgery.[15] In the present study, type of origin of inferior mesenteric artery was normal in all patients (100%). These findings were consistent with a research by Kornafel O et al. that revealed all patients had normal findings.[10]

Renal arteries: The renal arteries exhibited the most morphological variety of all the abdominal aorta ramifications. Regarding the renal vasculature's embryonic origins, there are a few notions. The formation of the vasculature is exclusively dependent on the kidneys' cephalic migration throughout embryogenesis. Renal vasculature may also be abnormal if their final placement is atypical, which may be explained by arterial vasculature adaptations to the kidneys' location.[16]

Variations observed in left Renal Artery: In the present study, left renal artery was normal in 70 patients (63.6%), accessory renal artery was observed in 16 patients (14.5%), early branching was observed in 15 patients (13.6%), upper pole aberrant artery was observed in 3 patients (2.7%), lower pole aberrant artery was observed in 2 patients (1.8%) and left kidney was absent in 1 patient (0.9%). Also reported by Ugurel et al. are two left accessory renal arteries.[17] We found two accessory renal arteries on both sides. In a study conducted by Johnson et al., accessory renal artery was the most common variation observed with greater incidence on left side, similar to our findings.[18]

Variations observed in right Renal Artery: Renal artery variants were examined by Budhiraja V et al. in 28 distinct ethnic groups; the frequency of changes varied from 4% to 59.5%.[19] In the present study, majority of the patients showed normal right renal artery (80%), accessory renal artery was observed in 12 patients (10.9%), early branching was observed in 12 patients (10.9%), upper pole aberrant artery was observed in 3 patients (2.7%), lower pole aberrant artery was observed in 2 patients (1.8%) and right kidney was absent in 1 patient (0.9%).

In a research done by Venkata Ramulu et al., most common variation observed was accessory renal artery (14%) entering the hilum of kidney, seen similar to our study(Right 10.9%, Left 14.5%).[20] In same study they encountered upper pole artery in 2% patients, which is similar to our findings(Right 2.7%, Left 2.7%). The incidence of lower pole aberrant artery was much higher (12%) than found in our study.

We found prevalence of variation in renal artery in our study to be (Right 20%, Left 36.4%). In a paper published by Gulas et al. the frequency of variations in renal artery was different in various population, 4% in Malaysian, 61% in Brazilian and 4-18.4% in Sothern Asian population.[21] More studies need to be conducted on renal artery variations in order to generalize the results to a larger population.

In a study conducted by Ozkan et al., single renal artery was seen in 76% of cases, which is in line to findings in the current study.[22]

Association of variation with gender: According to Satyapal et al., males are statistically substantially more likely than women to have accessory renal arteries.[16] Other research on the occurrence of renal artery variations did not find statistically significant gender differences. Similar to our findings, Cicekcibasi et al. demonstrated that variations in the vasculature were more common in males.[23] The association of variations observed in right and left renal artery with gender was statistically not significant in the present study. (p=0.17) (p = 0.92).

CONCLUSION

In our study 10.9% of patients had celiac trunk developmental abnormalities, with the most prevalent variation—found in 5.5% of patients—being the left gastric artery originating from the aorta. Compared to the right renal artery, the left renal artery had more variation. The key variations encountered were the existence of an accessory renal artery and early branching renal artery. Renal vascular abnormalities were evidently more common in females in our research group, but the difference was not statistically significant. Less anatomical variability was seen in the superior mesenteric artery and the celiac trunk. There were no abnormalities

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seen in the branching of the inferior mesenteric artery.

The therapeutic significance of anatomical variations of the celiac artery (CA), superior mesenteric artery (IMA), inferior mesenteric artery (SMA) and renal artery remained vitally important. In modern times with advances in minimally invasive techniques, in order to perform interventional and robotic procedures effectively, it is crucial to have a comprehensive understanding of the normal architecture and potential alterations of these arteries. Understanding these variances is crucial for a precise surgical approach, enabling surgeons and interventional radiologists to prevent any complications during procedures.

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