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VARIATIONS IN THE ORIGIN OF INFERIOR PHRENIC ARTERIES AND THEIR RELATIONSHIP TO CELIAC AXIS VARIATIONS ON CT ANGIOGRAPHY.

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ABSTRACT **Background:** The inferior phrenic arteries are the first branch of abdominal aorta. It is necessary to be familiar with the anatomy of the inferior phrenic arteries in surgical and traumatic vascular injuries, haemoptysis, especially due to pulmonary pathologies located in the lung base, and gastroesophageal haemorrhage from the gastroesophageal junction. It is the most common extra-hepatic supply of hepato-cellular carcinomas. TACE is the treatment of choice for unresectable and advanced hepatocellular carcinomas. Knowledge of the detailed arterial anatomy is required for successful embolization by TACE and to prevent complications. **Methods:** Data set consisted of 150 patients who underwent triple phase CT angiography in GI bleed protocol. The association of CA variation with common trunk, RIPA and LIPA, Chi-square test was used. **Results:** RIPA most commonly originated from abdominal aorta in 88 (58.7%) patients followed by celiac artery 45 (30%). LIPA most commonly originated from abdominal aorta in 77 (51.3%) patients followed by celiac artery 69 (46%). There was no statistical significance detected between the common truncus of IPA, RIPA & LIPA with celiac axis variations. **Conclusion:** The anatomy and variations in the origin of inferior phrenic arteries are clinically important and should be evaluated with CTA prior to the surgical or interventional management. In our study we did not find any relationship between the origin of the common trunk of IPA, LIPA and RIPA with celiac axis variations. The variations in the origin of inferior phrenic arteries and celiac axis variations can be explained by their embryological development.

KEYWORDS : Inferior phrenic artery (IPA), Right inferior phrenic artery (RIPA), Left inferior phrenic artery (LIPA), Hepatocellular carcinoma(HCC), Celiac axis (CA), CT Angiography (CTA).

INTRODUCTION-

Inferior phrenic arteries are the crucial source of arterial blood supply to the diaphragm, stomach and adrenal gland. They most commonly arise either from the aorta or from celiac artery.(1) The knowledge of the inferior phrenic artery origin is required in various clinical conditions. Due to excessive retching and vomiting in Mallory Weiss tears, rupture of small esophageal branches arising from inferior phrenic artery can lead to upper GI bleed. There are very few reported cases of pseudoaneurysms arising from inferior phrenic artery (2) (3) (4) (5) secondary to pancreatitis, gastrectomy and hepatobiliary surgery.

The most common non bronchial source of haemoptysis is inferior phrenic artery with chronic lung diseases resulting in fibrosis, bronchiectasis can lead to the development of transpleural systemic-pulmonary artery fistula causing haemoptysis (6).

IPA is the most common extra-hepatic supply of hepatocellular carcinomas. They especially supply HCCs situated in the peripheral segments of liver or bare area of liver. TACE is the treatment of choice for unresectable and advanced hepatocellular carcinomas. Knowledge of the detailed arterial anatomy is required for successful embolization by TACE and to prevent complications.(1)

The celiac artery is the first branch of abdominal aorta with its most common three branches: the left gastric artery, splenic artery and common hepatic artery.

Aslaner et al (7) in their study pointed out strong relationship between common truncus of IPA, RIPA and LIPA with celiac axis variations (p-value < 0.005).

The rationale of the study was to identify the IPA origins and assess the relationship between the origin of inferior phrenic artery and variations in celiac axis using CT Angiography, following the CT protocols used in our hospital so that it can aid in the management and surgical decision.

METHODS

Selection and description of participants:

Study setting:

Department of Radiology, Amrita Institute of Medical Sciences

Duration of study:

For two years duration starting from October 2019 to 2021 after obtaining approval from the thesis protocol review committee (Scientific, Ethical & Financial), Amrita Institute of Medical Sciences and Research Centre, Kochi, Kerala.

Sample Size:

Based on the results of proportion of variations in the Inferior Phrenic Artery (70.5) among patients who came for analysis of inferior phrenic artery and celiac axis variations observed in an earlier study (7) with 80% power and 95% confidence the minimum sample size comes to 150.

Technical Information

Primary Objective:

to prospectively assess the anatomic variation of inferior phrenic artery origin with CT angiography.

Secondary Objective:

to know the relationship between the origin of Inferior Phrenic Artery and celiac axis variations using CT Angiography.

CT imaging was performed after informed written consent with either Philips 256 slice iCT or Siemens Somatom Sensation 64 slice CT Terarecon volume calculation software using our standard GI bleed protocol. The contrast study was performed with 1.5ml/kg contrast followed by 30ml saline chase. The standard GI bleed protocol includes plain, 1st arterial phase, 2nd arterial phase and venous phase. After the plain phase the 3 phases are taken at 6 sec, immediately at 6 sec and at 30 sec respectively.

Image Interpretation:

Interpretation of data was be done by a radiologist. CT findings will assess the anatomic variation in the origin of inferior phrenic arteries and its relationship to celiac axis variations.

Statistics:

Statistical analysis was performed using IBM SPSS version 20.0

software. Categorical variables are expressed using frequency and percentage. To test the statistical significance of the association of CA variation with common trunk, RIPA and LIPA, Chi-square test was used.

RESULTS:

A total of 150 patients who fulfilled the inclusion and exclusion criteria and had undergone triple phase CT in GI bleed protocol were included in the study. Out of 150 patients, 33 patients (23.4%) had inferior phrenic arteries common trunk and 117 (76.6%) did not have a common trunk. Among those 33 patients, 20 patients (60.6%) had common trunk arising from aorta and 13 (39.3%) patients had from celiac artery.

RIPA most commonly originated from abdominal aorta in 88 (58.7%) patients followed by celiac artery 45 (30%), right renal artery 12 (8%), left gastric artery 3 (2%) and 1 (0.7%) respectively from accessory renal artery and splenic artery. LIPA most commonly originated from abdominal aorta in 77 (51.3%) patients followed by celiac artery 69 (46%) and 2 (1.3%) respectively from left gastric artery and splenic artery.

Among 150 patients, 77 patients (51.3%) had celiac axis variation and 73 (48.7%) did not have celiac axis variation. In cases with celiac axis variations, IPAs from the common trunk originated from aorta in 61.9% cases and 38.1% from celiac axis. The most common origin of RIPA was abdominal aorta seen in 59% and most common origin of LIPA was celiac axis seen in 50% cases. In cases without celiac axis variations, IPAs from the common trunk originated from aorta in 59% cases and 41% from celiac axis. The most common origin of RIPA was abdominal aorta seen in 57.3% and of LIPA was celiac axis seen in 50.8% cases.

As depicted in Table number 1, association between inferior phrenic artery common truncus and celiac axis variation with value of Fischer's exact test value 1. This signifies no statistically significant association between inferior phrenic artery common trunk and celiac axis variation.

As depicted in Table number 2, this table depicts the relationship between LIPA and celiac axis variation with p value 0.5. This signifies a non-significant relationship between LIPA and celiac axis variation.
As depicted in Table number 3, this table depicts the relationship between RIPA and celiac axis variation with p value 0.6. This signifies a non-significant relationship between RIPA and celiac axis variation.

DISCUSSION:

Inferior phrenic arteries are the crucial source of arterial supply to the diaphragm, stomach and adrenal gland. They most commonly arise either from the celiac artery or aorta. It can also originate from the splenic artery, left gastric artery, renal artery and common hepatic artery.

The celiac artery is one of the first branches of the abdominal aorta. The common terminal branches of the celiac artery are the left gastric artery, splenic artery and common hepatic artery. The most common termination is trifurcation of the celiac axis.

The recent advances in CT technology have improved its role in vascular imaging. The multiplanar reconstruction and fast imaging techniques help in detection of smaller vessels in various parts of the body. CT can depict the arterial anatomy of small vascular structures and its variations. This helps in planning transarterial procedures and choosing interventional hardwares and in turn reduces the procedure time, radiation exposure and contrast usage during interventions. The inferior phrenic arteries are millimetric arteries and it's not always easy to visualise these vessels. Few studies have shown that contrast enhanced images using bolus triggering techniques can help in better identification of these smaller arteries. Other than the arterial anatomy, the parenchymal structures can also be analysed through CTA.

Our sample was composed of patients who underwent CT angiography in GI bleed protocol. Basile et al(40)in their study evaluated the origin of inferior phrenic artery in 200 patients and classified it into 13 subtypes. Loukas et al (8) evaluated for origin of inferior phrenic artery in 300 human cadavers and classified into 5 groups.

In our study, the origin of inferior phrenic arteries and its relationship to celiac axis variations were assessed in 150 patients. We divided inferior phrenic arteries into two groups; those originating from a common trunk and those originating independently without a common trunk. The inferior phrenic artery originated from the common trunk in 33 (23.4%) patients. The common trunk originated from the aorta and celiac axis in the descending order. The trunk originated from aorta in 20 (60.6%) patients and from the celiac artery in 13 (39.3%) patients. We did not observe the common trunk originating from renal artery as reported by previous authors.(7)

Recent study by Aslaner et al (7) showed that 295 (29.5%) out of 1000 patients had IPA common trunk origin, with most common trunk origin being abdominal aorta (16.4%) followed by celiac artery (12.6%), right renal artery (0.4%) and left gastric artery (0.1%).

Young Ho So MD et al (9) in their study pointed out that 122 (21%) out of 580 patients had inferior phrenic artery common trunk, with most common origin being abdominal aorta (46.2%). This is in concordance with our observation.

In our series, the RIPA and LIPA originated independently in 117 (76.6%) patients. The most common origin of RIPA and LIPA was from abdominal aorta; with a frequency of 58.7% in RIPA and 51.3% in LIPA respectively. In our series, the IPA origin was between the diaphragm and renal arteries. It was found that in patients with IPA originating from the abdominal aorta, the origins were from lateral, anterior or posterior aspects of the abdominal aorta.

The other common sites of origin of the Inferior phrenic arteries were the celiac artery (RIPA- 30%, LIPA- 46%), right renal artery (RIPA- 8%), left gastric artery (RIPA- 2%, LIPA- 1.3%), splenic artery (RIPA- 0.7%, LIPA- 1.3%) and accessory renal artery (RIPA- 0.7%). In fact, the right inferior phrenic artery origin from accessory renal artery has not been reported in previous studies to the best of our knowledge. We found 1 case in which RIPA originated from accessory renal artery.

Most of the studies like Basile at al (10) and Chinmay et al (11) pointed out that the most common independent origin of IPA is from the abdominal aorta followed by the celiac artery. Basile at al (10) in their study detected 49% IPA originated from aorta and 41% IPA originated from celiac trunk. Chinmay et al (11) in their study pointed out the most common origin of RIPA is aorta (37.5%) followed by celiac artery (29.5%). These studies are in concordance with our observation.

But Aslaner at al (7) in their study showed that the most common independent origin of the IPA was from the celiac artery. 30.7% of RIPA and 40.3% of LIPA originated from the celiac artery followed by 25.2% of RIPA and LIPA from the abdominal aorta.

It is essential to understand the embryological development of inferior phrenic arteries to appreciate the logic behind the variations in IPA origin.

Various theories have been proposed to explain the variations in the origin of IPA. The primitive dorsale aorta gives off three branches: ventral, dorsal and dorsolateral. The ventral splanchnic arteries persist and supplies through the celiac artery, superior mesenteric artery and inferior mesenteric artery to foregut, midgut and hindgut. The dorsolateral arteries persist as lumbar arteries and intercostal arteries.

According to Felix ladder theory (12) IPAs are formed by the lateral splanchnic arteries. This could explain the variation in origin between other lateral arteries such as renal artery and gonadal arteries. However, to explain the origin of IPAs from the abdominal aorta and celiac artery which is seen in the majority of cases, other theories have been made. During fetal development most of the primitive arteries from lateral, dorsal and dorsolateral groups disappear. Persistence of longitudinal channels between ventral, dorsal and dorsolateral vessels can explain the origin of IPAs from celiac artery or abdominal aorta.(13)

Another theory by Isogoi et al proposed that adrenal primordium is supplied by some branches from abdominal aorta and/or gonadal arteries by day 14 of embryonic life. By day 15 of the embryonic life these adrenal arteries which are prospective IPAs develop adult branching pattern. This theory can explain the origin of IPA from celiac trunk and common trunk origin from abdominal aorta. (14)

In our study the most common celiac axis anatomy was the classical trifurcation into the left gastric artery, splenic artery and common

hepatic artery seen in 48.7% cases.

Celiac axis variations were classified according to recent classification as described in the study by Soon-Young Song (9). They divided into 15 different categories. Song et al (12) pointed out in their study that most common variation is trifurcation of left gastric artery, splenic artery and common hepatic artery seen in 89.1% cases. Another study by Aslaner et al (7) also showed trifurcation of celiac axis as the most common variation, seen in 89% cases.

Among patients with celiac axis variations 16% had a hepato-splenic truncus, 12% had hepato-splenic mesenteric truncus, 0.05% had gastrosplenic trunk, 0.02% had hepatomesentric trunk and 0.006% had hepatogastric trunk. Aslaner et al in their study pointed out that the most common celiac axis variation is hepato-splenic truncus. This is also in concordance with our observation.

Aslaner et al (7) in their study pointed out strong relationship between common truncus of IPA, RIPA and LIPA with celiac axis variations (p-value < 0.005). In contrast, in our series, we didn't find any relationship between the common truncus of IPA and celiac axis variations (p-value 1) as well between the RIPA origin and celiac artery variations (p-value 0.6) and LIPA origin and celiac artery variations (p value 0.5).

The relationship between IPA origin and celiac axis variations can be explained by their embryological development. The primitive aorta gives off three branches- ventral, dorsal and dorsolateral. Any persistence or regression in ventral segmental roots results in anatomical variations of the celiac axis. Variations in IPA origin can also be explained through the variations in ventral segmental roots.

Strengths and limitations

Strengths:

There have been very less studies done to study the relationship between variation of inferior phrenic artery origin and celiac axis variations.

Limitations: Our sample size was 150 and a larger sample size is required to study the relationship between IPA origin and celiac axis variations. Improper contrast bolus triggering might have occurred due to severe atherosclerotic calcifications in the aorta resulting in poor depiction of some of the IPAs making their analysis difficult.

CONCLUSION:

The anatomy and variations in the origin of inferior phrenic arteries are clinically important and should be evaluated with CTA prior to the surgical or interventional management. The most common origin of IPA was from the Abdominal Aorta as a common trunk. RIPA and LIPA also originated most commonly from Abdominal Aorta in those patients without a common trunk. In our study we did not find any relationship between the origin of the common trunk of IPA, LIPA and RIPA with celiac axis variations. The variations in the origin of inferior phrenic arteries and celiac axis variations can be explained by their embryological development.

Tables: Table 1 depicting association between origin of Inferior Phrenic Artery common trunk and Celiac Axis Variation

Association between origin of Inferior Phrenic Artery common trunk and Celiac Axis Variation			
Celiac axis variation	Inferior Phrenic Artery common trunk		p value
	Aorta	Celiac axis	
Yes (21)	13 (61.9%)	8 (38.1%)	1.000
No (12)	7 (58.3%)	5 (41.7%)	

Table 2 depicting association between origin of Left inferior phrenic artery and celiac axis variation

Association between Left Inferior Phrenic Artery and Celiac Axis Variation				
Celiac axis variation	Origin of LIPA			P-value
	Aorta	Celiac axis	Other arteries	
Yes (77)	41 (53.2%)	33 (42.9%)	3 (3.9%)	0.509
No (73)	36 (49.3%)	36 (49.3%)	1 (1.4%)	

Table 3 depicting association between origin of Right inferior phrenic artery and celiac axis variation

Association between Right Inferior Phrenic Artery and Celiac Axis Variation				
Celiac axisvariation	Origin of LIPA			P-value
	Aorta	Celiac axis	Other arteries	
Yes (77)	46(59.7%)	24 (31.2%)	7 (9.1%)	0.669
No (73)	42 (57.5%)	21 (28.8%)	10 (13.7%)	

Figures:

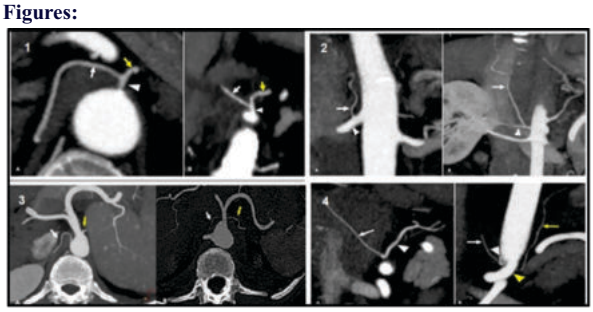

Figure 1: To depict variations in the origin of inferior phrenic arteries.

1. CT angiography maximum intensity projection (MIP) images show right IPA (A, B white arrow) and left IPA (A, B yellow arrow) originating from aorta (A arrowhead) and Coeliac artery (B arrowhead) as common trunk.
2. CT angiography maximum intensity projection (MIP) images show right inferior phrenic artery (RIPA A, B white arrow) originating separately without truncus. A. RIPA originates from right renal artery (white arrowhead) B. RIPA originate from accessory superior right renal artery (white arrowhead).
3. CT angiography maximum intensity projection (MIP) images show right inferior phrenic artery (RIPA, white arrow) and left inferior phrenic artery (LIPA, yellow arrow) originating separately without truncus. A. RIP originates from aorta (white arrow) and LIPA from coeliac artery (yellow arrow). B. Both RIPA and LIPA (white and yellow arrow) originate from celiac artery.
4. CT angiography maximum intensity projection (MIP) images show right IPA (A, B white arrow) originating from the left gastric artery (A, B white arrowhead) and left IPA (B, yellow arrow) originating from coeliac artery (B yellow arrowhead).

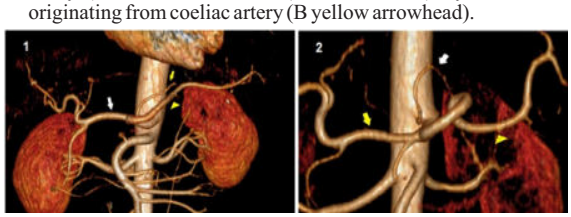

Figure ii: To depict celiac axis variations.

1. 3D reconstructed images shows normal celiac axis trifurcation into common hepatic artery (white arrow), left gastric artery (yellow arrow) and splenic artery (yellow arrowhead).
2. 3D reconstructed images shows hepatosplenic trunk and left gastric artery arising from aorta; common hepatic artery (yellow arrow), left gastric artery (white arrow) and splenic artery (yellow arrowhead).

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