Section: Anatomy

Original Research Article

ANATOMICAL STUDY ON VARIATIONS IN CELIAC TRUNK & ITS CLINICAL SIGNIFICANCE

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Abstract

Background: The celiac trunk is the first unpaired branch of abdominal aorta arising at the level between T12 & L1 vertebrae. Out of three ventral branches of abdominal aorta being the artery of foregut, celiac trunk is more prone to display many variations. It has a short forward course before dividing into three branches. The celiac trunk gives off left gastric, common hepatic & splenic arteries. Many variations in the branching pattern of celiac trunk were found and reported in literature. Knowledge of these variations is important for radiologists & surgeons while performing oncological resections, laparoscopic surgeries, kidney transplantations & radiological interventions. This study aimed to identify Celiac trunk branching pattern & its variations in cadaveric specimens. **Materials and Methods:** The study design is of descriptive and retrospective type. Thirty formalin fixed wet cadaveric specimens of both of sexes were collected from Anatomy department which were dissected for about 4 years. The celiac trunk and their branches were carefully traced out and followed till their termination and were analyzed for normal and abnormal patterns in each specimen. Celiac trunk with intact branches will be included in both cadaveric specimens. Damaged Celiac trunk and its branches were excluded. **Result:** We found variations in seven specimens of celiac trunk among thirty specimens. We found Celiac trunk was found to be divided into five branches (pentafurcation) in one specimen - Left gastric artery, common hepatic artery, splenic artery, omental branch below the left gastric artery and artery from celiac trunk joined with gastroduodenal artery. Celiac trunk was found to be divided into four branches (quadrifurcation) in four specimens. We found renal artery originating from celiac trunk in one specimen. We found accessory hepatic artery in three specimens. We found cystic artery originating from common hepatic artery in one specimen and from superior mesenteric artery in the another specimen. **Conclusion:** Knowledge of such variations is essential for gastrectomy, biliary reconstruction, pancreaticoduodenectomy, liver and pancreas transplantation, radiological associated interventions, laparoscopic surgeries and in trauma of the abdomen. Vascular variations of the abdominal aorta and its branches play a significant role in performing kidney transplantation and oncological resections.

INTRODUCTION

The Celiac trunk or celiac artery is the first anterior branch and arises just inferior to the aortic hiatus, usually at the level of the vertebral body of the twelth thoracic vertebra. It is 1 -3cm long and passes almost horizontally anteriorly and slightly to the right superior to the body of the pancreas and splenic vein. In most individuals, it trifurcates into left gastric, common hepatic and splenic arteries. Left gastric artery is the smallest branch that arises and ascends near cardioesophageal junction and it supplies lower/abdominal part of esophagus, lesser curvature of the stomach and terminates by anastomosing with

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Right gastric artery. Splenic artery is the largest branch running tortuous along the superior border of pancreas which supplies the hilum of spleen, pancreas, fundus of stomach. Common hepatic artery gives two major branches- Hepatic artery proper and gastroduodenal artery which supplies liver, gall bladder and duodenum. Further gastroduodenal artery divides into supraduodenal artery, posterior superior pancreatico duodenal artery, right gastro omental artery and anterior superior pancreatico duodenal artery. Variations reported include a separate origin of left gastric artery from the abdominal aorta, one or both inferior phrenic artery arising from the celiac trunk and the superior mesenteric artery or one or more of its branches arising in common with the celiac trunk. Rarely Celiac trunk can be compressed by a median arcuate ligament (Dunbar syndrome) resulting in visceral ischemia and abdominal pain.[1] The paired renal arteries branch laterally from the aorta at the right angles just below the origin of superior mesenteric artery. A single renal artery to each kidney is present in approximately 70% of individuals. Accessory renal artery is common (in approximately 30% of individuals) and usually arise from abdominal aorta above or below (most commonly below) the renal artery and follow it to the hilum. Rarely accessory renal artery arises from celiac trunk or superior mesenteric artery near the aortic bifurcation or from common iliac artery.[1] The Common hepatic artery gives off the the right gastric and gastroduodenal arteries. After originating from the celiac trunk, it passes anteriorly and laterally above the superior border of the pancreas, to the superior aspect of first part of duodenum. It is subdivided into the common hepatic artery from celiac trunk to the origin of gastroduodenal artery and proper hepatic artery from that point to its bifurcation. Both parts ascend anterior to the portal vein and medial to the bile duct within the free margin of lesser omentum. Anatomical variations of hepatic artery have been found in about one third of individuals which are relevant to surgical and interventional radiological procedures. An artery that supplies part of liver in addition to the normal artery supplying that part is defined as accessory artery. A replaced hepatic artery is an artery that does not originate from its usual position which provides the sole supply to that part of the liver. The most common anatomical variations are a replaced artery or accessory left hepatic artery that arises from left gastric artery or a replaced artery or accessory right hepatic artery that arises from superior mesenteric artery both occurring in 10 -20% of individuals.[1] The cystic artery usually (approximately 80%) arises from right hepatic artery and most often passes posterior to the common hepatic duct within cystohepatic triangle where it lies superior to the cystic duct. On reaching the superior aspect of neck of the gall bladder, it divides into superficial and deep branch that anastomose over the surface of the body and fundus. The origin of cystic artery is variable. The most common variant is its origin from the proper hepatic artery and it crosses anterior to the bile or common hepatic ducts to reach the gall bladder. Rarely this artery may arise from the celiac trunk or left hepatic artery, gastroduodenal artery, superior pancreaticoduodenal artery, right gastric artery, superior mesenteric artery. In these cases, the celiac artery might not traverse the cystohepatic triangle.[1] About 70-90% of individuals have the classical presentation of celiac artery, and in rest of the population there could be variation in the celiac artery branching pattern. This variation in branching pattern can potentially lead to several complications like increasing risk of accidental injury to artery during surgeries, which might cause ischemia to supplying organs, compression syndrome, development of aneurysm in celiac artery and its branches may occur and atypical appearance will lead to diagnostic errors in imaging studies too. Hence enhanced understanding of these variations can lead to better results, which is the main motive of this research.

MATERIALS AND METHODS

The study design is of descriptive and retrospective type. Thirty formalin fixed wet cadaveric specimens of both of sexes were collected from Anatomy department after getting ethical clearance from Institutional ethical clearance. The specimens were collected for the period of four years which were dissected for the first MBBS students. Intact celiac trunk and its branches were included in the study. Damaged celiac trunk or specimens with any damaged branch of celiac trunk was excluded. The celiac trunk and its branches were dissected till their termination and were analysed their course and branching pattern.

RESULTS

We found variations in seven specimens of celiac trunk among thirty specimens. We found the origin of right gastric artery from common hepatic artery in all the specimens. Inferior phrenic artery was originating from the abdominal aorta in all the specimens.

Specimen 1: Accessory hepatic artery originating from the proper hepatic artery and was divided in to the right & left branches to the right and left lobes of the liver. This artery also gave a branch to the lesser omentum. Left gastric artery, common hepatic artery, splenic artery originated from the celiac trunk.

Specimen 2: Celiac trunk was found to be divided into four branches (Quadrifurcation) - Left gastric artery, common hepatic artery, splenic artery and renal artery. Renal artery was found to enter the hilum of left kidney above the accessory left renal artery originating from aorta. Renal artery gave branch to left suprarenal gland. Left accessory renal artery entered into the lower pole of the left kidney.

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Specimen 3: Celiac trunk was found to be divided into five branches (Pentafurcation) - Left gastric artery, common hepatic artery, splenic artery, omental branch above the left gastric artery and artery from celiac trunk joined with gastroduodenal artery. Common hepatic artery was trifurcated into right hepatic artery, left hepatic artery and gastroduodenal artery. Proper hepatic artery was not found.

Specimen 4: Separate origin of left gastric artery was present from the celiac trunk. Hepatosplenic trunk was found from which common hepatic artery & splenic artery were originated. Common hepatic artery was trifurcated into right hepatic artery, left hepatic artery and gastroduodenal artery. Proper hepatic artery was not found.

Specimen 5: Coeliac trunk was found to be divided into four branches(Quadrifurcation) - Left gastric artery, common hepatic artery, splenic artery and a branch to pancreas. Common hepatic artery was divided into four branches – gastroduodenal artery, right hepatic artery, left hepatic artery and cystic artery. Cystic artery arising from the common hepatic artery and ran under the left hepatic vein.

Specimen 6: Celiac trunk was found to be divided into four branches(Quadrifurcation) - Left gastric artery, common hepatic artery, splenic artery and omental branch below the left gastric artery. Common hepatic artery was trifurcated into Proper hepatic artery, accessory hepatic artery and gastroduodenal artery. Common hepatic artery also gave two pancreatic branches.

Specimen 7: Celiac trunk was divided into four branches - Left gastric artery, common hepatic artery, splenic artery and accessory hepatic artery. Common hepatic artery gave gastroduodenal artery, right gastric artery, two branches to right lobe of liver and two branches to left lobe of liver. Accessory hepatic artery gave a branch to lesser omentum. It ran along with the hepatic artery and was divided near the inferior surface of liver into two branches to right lobe & two branches to left lobe of liver. Cystic artery was found to originate from superior mesenteric artery. Cystic artery ran behind the pancreas, gastroduodenal artery and common hepatic duct before reaching the gallbladder.

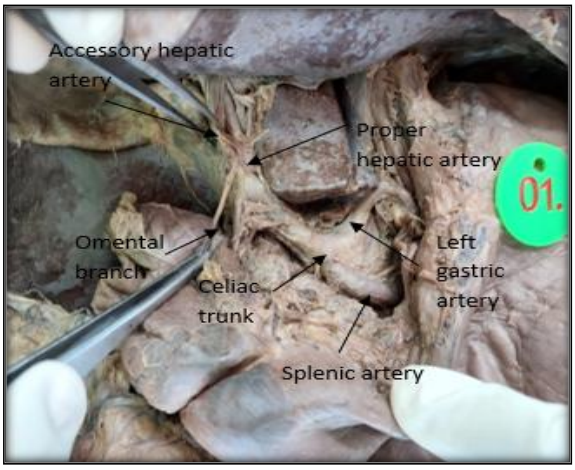

Figure 1: Showed Accessory Hepatic Artery from Proper Hepatic Artery, Omental Branch Originated from It

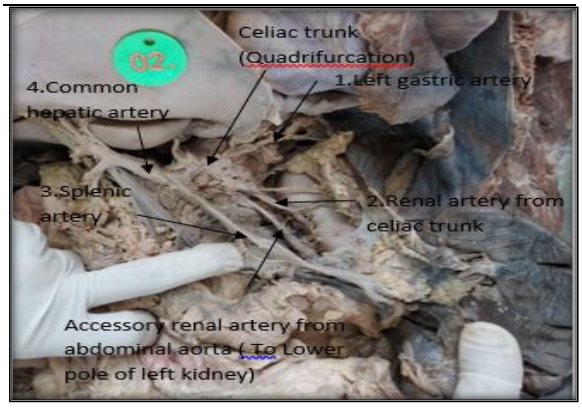

Figure 2: Showed Quadrifurcation of celiac trunk, Renal artery originated as a fourth branch

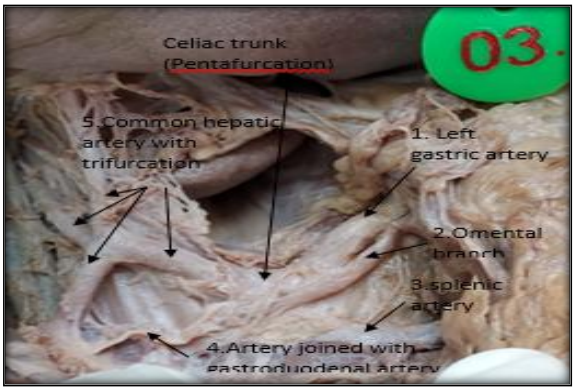

Figure 3: Showed Pentafurcation of celiac trunk, Trifurcation of common hepatic artery

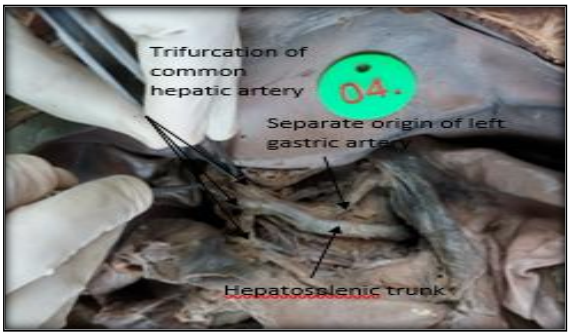

Figure 4: Showed Hepatosplenic trunk, Trifurcation of common hepatic artery

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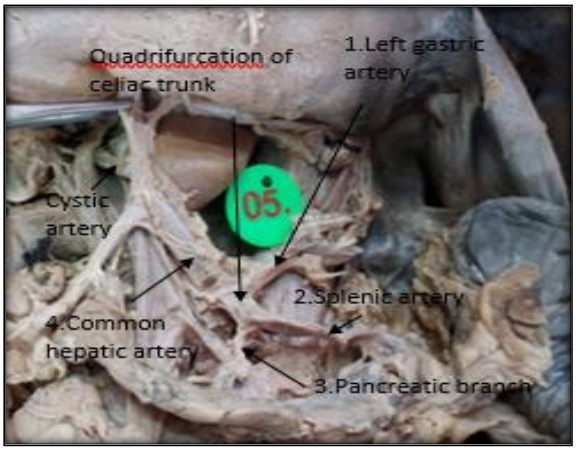

Figure 5: Showed Quadrifurcation of celiac trunk, Quadrifurcation of common hepatic artery

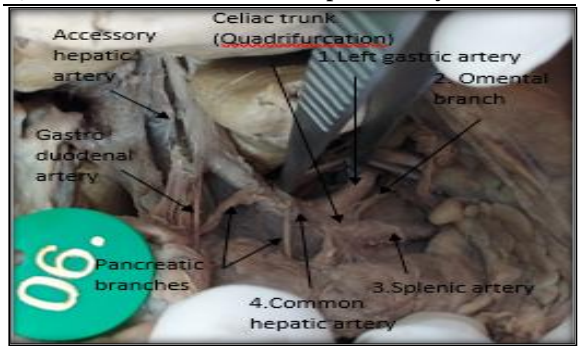

Figure 6: showed Quadrifurcation of celiac trunk, Pancreatic branches and accessory hepatic artery from Common hepatic artery

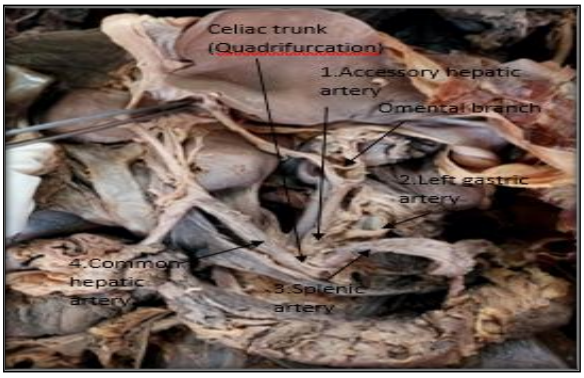

Figure 7: Showed Quadrifurcation of celiac trunk and Cystic artery originating from superior mesenteric

Table 1: Adachi's classification of variations of celiac trunk.

Classification Number	Branching pattern
1.	Hepatogastrosplenic trunk
2.	Hepatosplenic trunk
3.	Hepatosplenomesenteric trunk
4.	Celiacomesenteric trunk
5.	Gastrosplenic and Hepatomesenteric trunks
6.	Gastrosplenic trunk, Common hepatic artery arising from superior mesenteric artery

Table 2: Michel's[8] classification of variations of celiac trunk

Type	Branching pattern
I	Classic Celiac trunk
II	Hepatosplenic trunk
III	Hepatogatric trunk
IV	Hepatosplenomesenteric trunk
V	Splenogastric trunk
VI	Celiacomesenteric trunk

Table 3: Panagouli's[9] classification of variations of celiac trunk

Type	Form	Branching pattern
I		Trifurcation of CT into LGA,CHA,SA
	1	True Tripod – Common origin of LGA,CHA,SA
	2	False tripod – division into two branches
	2a	LGA is the first branch
	2b	CHA is the first branch
	2c	SA is the first branch
II		Bifurcation of CT
	1	Hepatosplenic trunk, LGA arising from AA
	2	Hepatosplenic trunk, no normal LGA
	3	Hepatosplenic trunk and gastromesenteric trunk
	4	Splenogastric trunk, CHA arising from AA
	5	Splenogastric trunk, CHA arising from SMA
	6	Splenogastric trunk and hepatomesenteric trunk
	7	Hepatogatric trunk, SA ariing from AA

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	8	Hepatogatric trunk, SA arising from SMA
	9	Hepatogatric trunk and Splenomesenteric trunk
CT: Celiac Trunk, LGA: Left gastric artery,CHA: Common hepatic artery, SA: Splenic artery, AA: Abdominal aorta and SMA: Superior mesenteric artery		

Figure 8: Showed Cystic artery originating from superior mesenteric artery

DISCUSSION

According to Gray,[1] the ventral splanchnic arteries are originally paired (vitelline) vessels which form capillary plexus in the wall of the yolksac. After fusion of dorsal aortae, they merge as unpaired trunks that are distributed to the increasingly defined and lengthening primitive digestive tube. Longitudinal anastomotic channels connect these branches along the dorsal and ventral aspects of the tube, forming dorsal and ventral splanchnic anastomoses. The dorsal splanchnic anastomosis persists in the gastroomental, pancreaticoduodenal and primary branch of colic artery whereas the ventral splanchnic anastomosis forms the right and left gastric and the hepatic artery. Below the diaphragm, the ventral splanchnic arteries are reduced to three: the celiac trunk, superior mesenteric artery and inferior mesenteric artery. As the viscera supplied descend into the abdomen, their origins migrate caudally by differential growth. Thus the origin of celiac trunk is transferred from the level of C7 to the level of T12, the superior mesenteric artery from T2 to L1 and the inferior mesenteric artery from T12 to L3.

Unequal growth of dorsal and ventral walls of aorta may leads to positional change of celiac trunk, superior mesenteric artery and inferior mesenteric artery.[2] Because of extensive orchestration of splanchnic vessels, variation may occur in any vessel or its branches.

Tandler J,[3] stated that the multiple anatomical variations of the celiac trunk might be a result of unusal regression or persistence of the primitive embryonic arterial system (primitive splanchnic arteries). With the folding of the embryo, the right and left vitelline plexus merge to generate several main arteries which are anastomosed with the ventral surface of the dorsal aorta. A series of unpaired segmental and ventral splanchnic arteries developed at the end of fourth week. These ventral segmental arteries are connected with longitudinal anastomosis running parallel to the abdominal aorta forming dorsal and ventral segmental (splanchnic) anastomosis. Ventral longitudinal anastomosing channels link these arteries. Many ventral splanchnic branches vanish and three trunks – the celiac, superior mesenteric artery and inferior mesenteric artery remain. Any modification to this longitudinal anastomosis may alter the branching pattern of celiac trunk.

In further development, first, second and third roots coalesce to form celiac trunk whereas single fourth root gives origin for the superior mesenteric artery and they still remain connected through the ventral longitudinal anastomosis. Separation of the ventral longitudinal anastomosis occurring at unusual level results in displacement of origin of celiac trunk branches and superior mesenteric artery.[4]

In general, the embryonic left hepatic artery, middle hepatic artery and the right hepatic artery originate respectively from the left gastric artery, the celiac axis and the superior mesenteric artery. After that, the embryonic left hepatic and right hepatic arteries regress while the middle hepatic artery remains as the proper hepatic artery supplying the whole liver as shown in the adult. In the case where failures in the regression of these embryonic arteries may lead to abnormal branching pattern of hepatic arteries. Furthermore, the branching variations of celiac trunk are usually caused by the remaining ventral splanchnic branches of dorsal aorta. According to previous studies, an appearance of additional right hepatic artery originates from superior mesenteric artery, and an additional left hepatic artery originates from left gastric artery.[5]

Coeliac trunk trifurcates into 3 major branches: Left gastric artery, Splenic artery and Common hepatic artery, this presentation of celiac artery is the classical presentation called “TRIPUS HALLERI” (Haller’s tripod) as this was described by Albert von Haller.[6] This pattern is observed in 77% of specimens in the present study.

The anatomical variations of coeliac trunk were classified to the first time by Adachi,[7] in 192,[8] According to the type, we found Hepatosplenic trunk (classification number -2) in one specimen. We did not find any other types. We had Type –II & Form1 in a specimen according to this classification.[9]

Ariyanachi Kaliappan et al,[10] observed variations in two specimens. Absence of right gastric artery with presence of three hepatic branches originating from the common hepatic artery - two hepatic branches to the right lobe and one hepatic branch to the left lobe of the liver in a specimen. In the second specimen, presence of hepatosplenic trunk, absence of right gastric artery and an additional branch to left triangular ligament of liver from celiac trunk were found. Presence of Hepatosplenic trunk in a specimen was similar to our study.

Hemamalini,[11] conducted a study on twenty specimens of celiac trunk and observed Hepatosplenic trunk in three specimens. This was

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similar to the present study. She observed total absence of celiac trunk with a hepatomesenteric trunk and a branch to transverse colon from splenic artery. We did not have the similar findings in the present study. She also observed Quadrifurcation of Celiac trunk with middle colic artery arising from it in one specimen and Quadrifurcation of Celiac trunk with dorsa pancreatic branch arising from it in the other specimen. We found Quadrifurcation of Celiac trunk with a branch to pancreas in a specimen. This was similar to the present study. We found Quadrifurcation of Celiac trunk in three more specimens which were not similar to the previous study.

Shivarama C.H.et al,[12] reported multiple variations in abdominal aorta in a cadaver. The left gastric artery originated from abdominal aorta just above the celiac trunk with presence of hepatosplenic trunk and other variations. Presence of hepatosplenic trunk was similar to the present study. We did not find the other variations.

Sandhya Vikas Yatagiri et al,[13] observed Quadrifurcation of Celiac trunk in a specimen. Celiac trunk was divided into left gastric artery, splenic artery, right hepatic artery and left hepatic artery. We found Quadrifurcation of Celiac trunk in four specimens which were not similar to the above presentation. We had omental branch as fourth branch in a specimen, pancreatic branch as fourth branch in a specimen, accessory hepatic artery as fourth branch in a specimen and Renal artery as a fourth branch in a specimen.

Mugurel Constantin Rusu et al,[14] found Quadrifurcation variants of celiac trunk in fifteen angiograms among 112 CT angiograms and classified it into five types. We could not find any of the type of Quadrifurcation of celiac trunk in the present study.

A Juszczak e al,[15] conducted a study on fifty cadavers and they observed hepatosplenic trunk in eight cadavers. Presence of hepatosplenic trunk was similar to the present study. Other variations were not similar to the present study.

K. Torres et al,[16] studied 1569 CT angiograms of celia trunk. They found Hepatosplenic trunk in2.2% of angiograms, Gastrosplenic trunk -4.1% of angiograms, Hepatogastric trunk in 0.2% of angiograms, Celiacomesenteric trunk in 0.5% of angiograms and absence of celiac trunk in 0.1% of angiograms. We found Hepatosplenic trunk in 3.3% in our study. We did not find the other trunks and absence of celiac trunk.

Prakash et al,[17] observed left gastric artery originating from celiac trunk proximal to bifurcation into common hepatic and splenic artery in 7.6% of specimens. The study was conducted on fifty specimens. Presence of hepatosplenic trunk is similar to the present study.

Chitra,[18] reported branching pattern of celiac trunk into four, five and six branches in her study. She found hepatosplenic trunk with origin of both inferior phrenic arteries as a common trunk from hepatosplenic trunk in a specimen. This was similar to the present study. We did not have origin of both inferior phrenic arteries as a common trunk from hepatosplenic trunk. She observed Quadrifurcation of Celiac trunk in two specimens. Fourth branch of celiac trunk was found to be Gastroduodenal artery and Middle colic artery in those specimens. This was not similar to our study. We found Quadrifurcation of Celiac trunk in three specimens. We had omental branch, pancreatic branch and renal artery in those specimens. She observed pentafurcation of celiac trunk in a specimen. Middle colic artery and right inferior phrenic artery were the additional branches in those specimens. We found pentafurcation of celiac trunk in a specimen. Omental branch and a branch joining the gastroduodenal artery were the additional branches in the present study.

Raeesa Omar et al,[19] performed a study on CT abdominal angiograms for a period of one year and found hepatosplenic trunk in 3% among the total angiogram pictures. Celiac trunk and/ or hepatic artery variation was found in 39.7% of the 58 patients with normal renal artery and 68% of the 42 patients with accessory renal artery. Variant or anomalous anatomy of hepatic artery was found in 20.9% of patients. He found replaced hepatic artery in an angiogram picture. We had hepatosplenic trunk in 3.3% of specimens. Presence of hepatosplenic trunk is similar to the present study.

Rachanee chanasong,[20] observed accessory hepatic artery from celiac artery in a cadaver among twenty three cadavers. This artery entered the fissure for ligamentum venosum and no branches were found along its course. We found accessory hepatic artery in the present study in two specimens. In both the specimens, the accessory hepatic artery was divided into right and left branches to right and left lobes of the liver.

Sukhendu Dutta & Bilamalendu Mukerjee,[21] performed a study on eighty four cadavers and found accessory hepatic artery in six cadavers. In five cadavers, the artery entered the fissure for ligamentum venosum and the artery ran along with the hepatic artery and entered into the porta hepatis in one cadaver. This was similar to the present study. We had accessory hepatic artery passed along with the hepatic artery and was divided into right and left branches to right and left lobes of the liver.

Tomiko Yahura et al,[22] observed Cystic artery arising from superior mesenteric artery in a cadaver. They found celiac trunk tetrafurcated into right hepatic artery, left hepatic artery, Splenic artery and left gastric artery. Cystic artery ran along the dorsal side of portal vein through calot's triangle to gall bladder. This was similar to the present study.

Sunil kumar,[23] reported the origin of right renal artery from the celiac trunk. He found superior renal artery from celiac trunk which supplied upper half of the kidney. Inferior renal artery from abdominal aorta supplied lower half of the kidney. We found left renal artery originating from celiac trunk which was similar to his study.

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Flors L et al,[24] reported that the greatest diameter of the artery is considered as renal artery and the remaining artery is named as accessory renal artery, if two arteries were found to supply the kidney with separate origin. The accessory renal artery is seen in up to 30% of the population. In the present study, Renal artery originating from abdominal aorta entered the lower pole of left kidney. As both the renal arteries were same diameter, the renal artery which was originating from celiac trunk was considered as main renal artery due to the entry into the hilum of the left kidney.

Nachiappan S,[25] Garti I& Meiraz,[26] found a single main ectopic renal artery arising from celiac trunk. This study was not similar to the present study. We found two arteries – renal artery originating from the celiac trunk and accessory renal artery originating from abdominal aorta.

Gillapie et al,[27] reported upper polar accessory renal artery arising from celiac trunk. This was not similar to the present study. We found renal artery originating from celiac trunk which entered into the hilum of the left kidney.

CONCLUSION

The knowledge of the anatomy of celiac trunk and its branching pattern is important for surgeons and radiologists to plan for the surgeries and interventional procedures. Radiologists should be accurate in the interpretation of the images and the procedures. Investigation of upper gastrointestinal bleeding requires CT catheterization of celiac trunk & subsequent catheterization of left gastric, common hepatic and splenic arteries. They should be cautious during endovascular procedures on the liver such as radio or chemoembolisation procedures. Embolization of the artery is an option when active bleeding is observed. In Transarterial chemoembolisation (TACE) or radioembolisation of hepatic malignancies and metastasis, it is essential to aware about hepatic and extrahepatic perfusion in order to prevent iatrogenic post procedural complications such as radiation induced ulcers in the stomach and duodenum or pancreatitis. In hepato biliary and pancreatic surgery, the surgeon should know the detailed anatomy of the celiac trunk branches in order to dissect them during liver or pancreas resections any variation could result in vascular damage which may lead to intraoperative and postoperative haemorrhage. In total gastrectomy and esophagogastric resections require ligation of left gastic artery. Hence surgeons should aware about the origin, course and variations in the branching pattern of left gastric artery. The knowledge of variations in the origin of the hepatic arteries is important during surgery like Pancreatico –duodenectomy, liver transplant as well as during hepatic artery infusion chemotherapy. Preoperative imaging may be helpful to prevent complications during intraoperative and postoperative periods. The branches of hepatic arteries supplying the liver are essentially end arteries and awareness regarding accessory hepatic artery should be known to the surgeons before planning liver transplantation and whipple procedure. Ligation of accessory hepatic artery may lead to ischemia to the area of liver supplied by the accessory hepatic artery. Hence such variation should be ruled out preoperatively by angiography. Before doing ligation of cystic artery in open or laparoscopic cholecystectomy, surgeon should confirm the origin of cystic artery - whether it is originating from the right hepatic artery or from superior mesenteric artery. If it is from superior mesenteric artery, have to look for the another artery which may originate from right hepatic artery which also needs ligation during the surgery.

Knowledge of such variation of renal artery from celiac trunk is crucial before doing nephrectomy, renal transplantation, surgical therapy of renal artery stenosis, liver or pancreatic surgeries to prevent injury to renal artery.

In repair of thoracoabdominal aneurysms, either open or endovascular with stent prosthesis if planned, celiac trunk and its branching pattern awareness is required. Any variations regarding the branches of celiac trunk that originate directly from the aorta or a common trunk with the superior mesenteric artery could complicate the procedures.

In planning bariatric procedures such as left gastric artery embolization or sleeve gastrectomy, celiac trunk and its branching pattern should be known to the surgeons.

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