The Egyptian Journal of Radiology and Nuclear Medicine 47 (2016) 1451–1458

Contents lists available at ScienceDirect

The Egyptian Journal of Radiology and Nuclear Medicine

journal homepage: www.sciencedirect.com/locate/ejrnm

Original Article

Celiac trunk and hepatic artery variants: A retrospective preliminary MSCT report among Egyptian patients

Ahmed M. Osman MD *, Ahmed Abdrabou MD

Radiology Department – Faculty of Medicine, Ain Shams University, Cairo, Egypt

ARTICLE INFO

Article history:
Received 3 July 2016
Revised 3 September 2016
Accepted 10 September 2016
Available online 24 September 2016

Keywords:
Celiac trunk (CT)
Common hepatic artery (CHA)
Multi-slice CT (MSCT)

ABSTRACT

Objective: To evaluate the feasibility of MSCT angiography of the celiac trunk and hepatic artery variants with a non-tailored protocol among Egyptian patients.

Patients and methods: 1285 Egyptian patients were retrospectively analyzed in our Radiology Department – Ain Shams University came for triphasic CT or CT aortic angiography. The celiac trunk origin and its main branches mainly the common hepatic artery were identified. The incidence of different celiac and hepatic artery anomalies was calculated depending on Uflacker's and Michel's classifications.

Results: About 90.5% of the patients showed normal trifurcation pattern of the celiac trunk (Uflacker type I) with the commonest variant was gastro-splenic trunk (Uflacker type V) with 4.3% incidence. The bifurcation pattern was representing 7.7% of cases. Regarding the hepatic artery, 74.3% of the cases showed normal origin of the hepatic arteries (Michel type I) with the commonest anomaly was Michel type III with 12.5% incidence. Some cases are discovered not previously described by either Uflacker's or Michel's classifications.

Conclusion: In our preliminary reports, Good imaging quality of MSCT angiography has proved effectiveness in depicting different celiac trunk and hepatic artery variants. This is important pre-interventional or pre-surgical to decrease the complications and the morbidity rates.

1. Introduction

The celiac trunk (CT) is the first ventral branch of the abdominal aorta arising at T12/L1 vertebral body level. It measures 1.5–2 cm in average length passing forward dividing into left gastric artery (LGA), common hepatic artery (CHA) and splenic artery (SA) which is the classic trifurcation pattern [1,2]. This classic pattern represents 86–89% of cases in several studies [3–5] and first described by Haller since 1756, so some times defined as Tripus Halleri [6]. CHA is recently defined as an arterial trunk containing at least one segmental hepatic artery and the gastroduodenal artery (GDA) irrespective of its origin and course and this definition facilitates the study of different CHA anomalies [7].

Superior mesenteric artery (SMA) is the second ventral branch of the abdominal aorta arising 1–20 mm below the level of the celiac trunk. It gives inferior pancreaticoduodenal artery (PDA), middle colic, right colic, ileo-colic, jejunal and ileal branches [8].

Identification of the course of the hepatic artery and their origin is very important before hepatic surgeries, liver

Peer review under responsibility of The Egyptian Society of Radiology and Nuclear Medicine.

* Corresponding author.
E-mail address: Dr_osman80@yahoo.com (A.M. Osman).

http://dx.doi.org/10.1016/j.ejrnm.2016.09.011

transplantation and laparoscopic maneuvers to avoid or minimize serious hepatic vascular complications [9–14].

Also, in interventional radiology, pre-procedure identification of the celiac and hepatic arteries is very important and very helpful especially before intra-arterial management of hepatic tumors and cases of bleeding [15,16].

The purpose of this study was to evaluate the feasibility of MSCT angiography of the celiac trunk and hepatic artery variants with a non-tailored protocol among Egyptian population.

2. Patients & methods

2.1. Patients

This is a retrospective study included a total number of 1285 patients that were referred to the Radiology Department - Ain Shams University to do either triphasic CT (which includes arterial phase) for liver assessment or CT angiography for aortic assessment during the period from February 2014 to March 2016. Agreement to use the backup data was taken from the ethical committee.

2.2. Exclusion criteria

- Any patient with pathological condition may alter the normal vascular anatomy.

2.3. CTA technique

- *CT machine:* High speed 16 slice CT machine – GE (general electric).
- *Technique:* the patient was in supine position with timing bolus technique used. Scan direction was craniocaudal in all patients. Scout was taken starting from above the level of the diaphragm down to the pelvis.
- *CT parameter:* (Table 1).
- *Contrast media:* we used 80 ml non-ionic contrast media injected via injector (MED TRONAG) at a rate of 4–5 ml/s.
- *Image processing:* The axial images were transferred to the work station where multi-planar reformatted images (MPR) were done as well as Maximum intensity projection (MIP), and 3D volume rendering (VR) images were also processed.

2.4. Image interpretation and statistical analysis

The celiac trunk origin and the origin of its main branches namely the LGA, CHA and SA as well as the origin of the SMA and its branches mainly the PDA were identified and recorded for statistical analysis to calculate the incidence of different variants. The variants of the celiac trunk were classified according to Uflacker's classification (Table 2) [17] while the hepatic artery variants were classified depending on Michel's classification (Table 3) [18,19]. The analysis data were done using IBM SPSS (Statistical Program for Social Science version 22.0, IBM Corp., USA, 2013).

Table 2
Illustrate the Uflacker's classification of celiac trunk anomalies.

Type	Description
Type I = trifurcation	
Classic pattern:	The CHA, SA and LGA have a common point of origin from the celiac trunk
Non classic pattern:	CHA and SA have a common point of origin with the LGA demonstrates a variable points of origin
Type II = hepato-splenic trunk	CHA and SA have common trunk with the LGA arises separately from aorta
Type III = hepato-gastric trunk	CHA and LGA have common trunk with the SA arises separately from the aorta or SMA
Type IV = hepato-spleno-mesenteric trunk	CHA, SA and SMA have common trunk with the LGA arises separately from the aorta
Type V = gastro-splenic trunk	LGA and SA have a common trunk with the CHA arises separately from the aorta or SMA
Type VI = celiaco-mesenteric trunk	Celiac and SMA have a common trunk
Type VII = celiaco-colic trunk	The middle colic artery and the celiac have the same trunk
Type VIII = no celiac trunk	No celiac trunk with the CHA, SA and LGA arises directly from the aorta

Table 3
Illustrates the Michel's classification for hepatic artery variants.

Type	Description
Type I	Hepatic artery originates from the CHA and bifurcates into the RHA and LHA
Type II	Replaced LHA arising from the LGA
Type III	Replaced RHA arising from the SMA
Type IV	Replaced RHA and LHA arising from the LGA
Type V	Accessory LHA arising from LGA
Type VI	Accessory RHA arising from SMA
Type VII	Accessory RHA arising from SMA and accessory LHA arising from LGA
Type VIII	Replaced RHA and accessory LHA or replaced LHA and accessory RHA
Type IX	CHA arising from SMA
Type X	CHA arising from LGA

3. Results

285 patients were excluded from the study because of gross lesions causing derangement of the target vascular area (112 cases had pancreatic lesions, 107 had gastric lesions, 56 had biliary and duodenal lesions, and the rest

Table 1
Illustrate the different parameters used in CT technique either in the arterial phase of the triphasic study or in the CT aortic angiography.

Thickness (mm)	Interval (mm)	Matrix	Pitch no.	Speed	Rotation time	kV	mA (auto)	FOV
1.25	0.625	512 × 512	1.75:1	35 mm/rot.	0.5 s.	120	150–400	Large

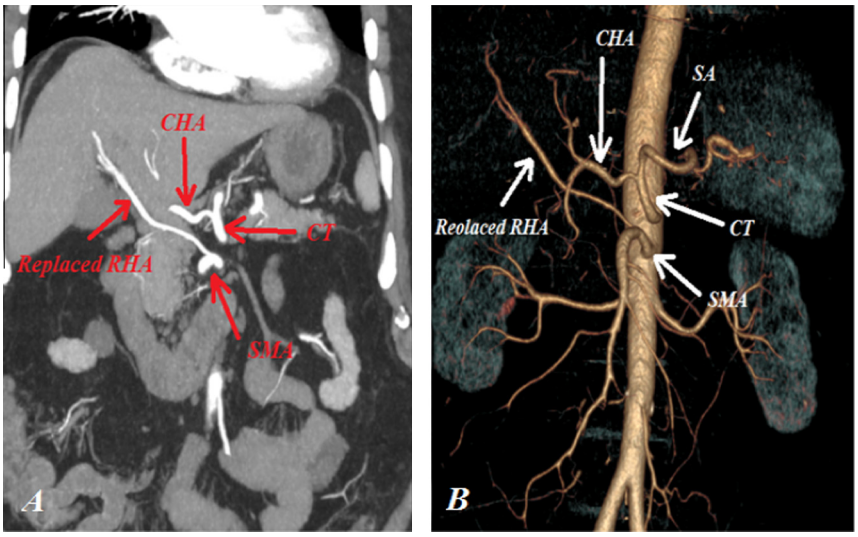

Fig. 1. (A) Coronal MPR and (B) 3D VR images show trifurcation of the celiac trunk into CHA, LGA and SA classified as Uflacker type I. This case is also classified as Michel type III with the replaced RHA arising from the SMA.

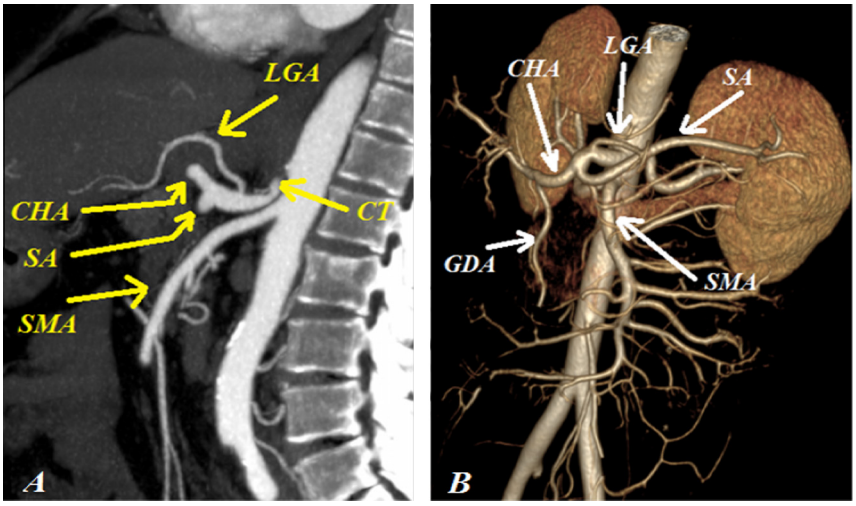

Fig. 2. (A) Sagittal MPR and (B) 3D VR images show non-classic form of Uflacker type I. Notice the origin of the LGA directly from the CT and then the trunk bifurcates into the CHA and SA.

10 had previous operation at the target area representing 39.4%, 37.5%, 19.6%, and 3.5% of the excluded cases respectively).

Regarding the celiac trunk, 905 cases showed normal trifurcation pattern of the celiac trunk (Uflacker I) representing 90.5% of the remaining 1000 included cases with 638 patients showed classic trifurcation form (Fig. 1) while 267 patients showed non-classic form with the LGA arising from any place along the celiac trunk or from the SA or the CHA course (Figs. 2 and 3). Type V Uflacker in the form of gastro-splenic trunk was found to be the most common anomaly representing 4.3% of cases (Figs. 6 and 7) followed by Uflacker type II found in 2.8% of cases (Fig. 4). Uflacker types III and VI were the least with 0.6% incidence for each (Figs. 5 and 9). Uflacker types IV and VII were not detected between our study population (Table 4).

Anomalies origin of the RHA from the SMA was the commonest anomaly regarding the hepatic artery variant representing Michel type III found in 12.5% of cases (Figs. 1 and 7). This is followed by Michel type V found in 5.2% of cases (Figs. 3, 4 and 7). Michel type IV and X were not detected between the study population (Table 4).

We had noted additional unclassified celiac trunk variant which was previously observed by Song et al. [7] and defined as ambiguous celiac axis. This variant was characterized by the presence of persistent anastomotic channels through the pancreaticoduodenal arcades and/or through vertical anastomosis and absent CHA owing to separate

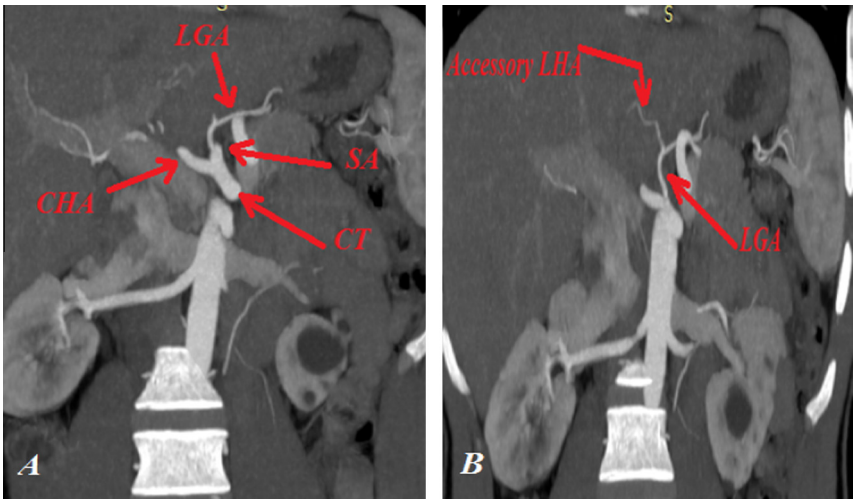

Fig. 3. Coronal MPR images show non-classic form of Uflacker type I. Notice the origin of the LGA from the SA. This case is also classified as Michel type V with accessory LHA arising from the LGA (image B).

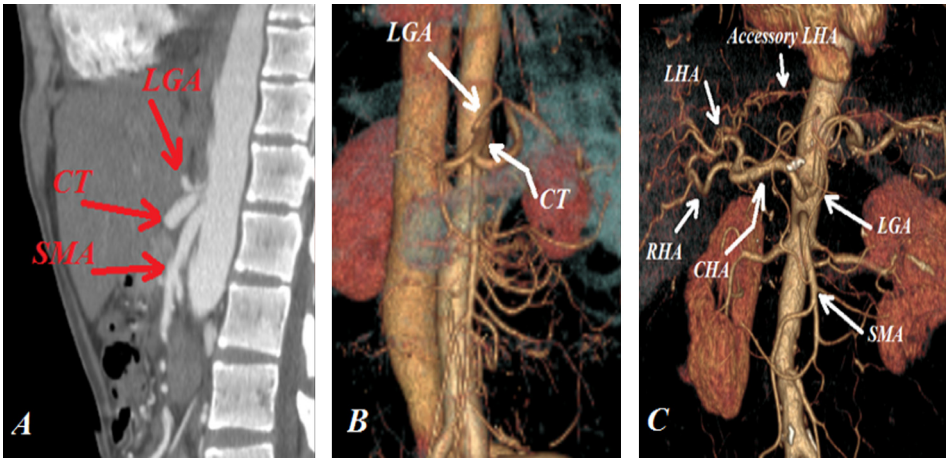

Fig. 4. (A) Sagittal MPR, (B and C) 3D VR images. A and B show celiac trunk bifurcation anomaly in the form of hepato-splenic trunk with separate origin of the LGA directly from the aorta close to the celiac trunk origin. The case is classified as Uflacker type II. C image is for another case showing also Uflacker type II anomaly yet with the LGA arising from the SMA. The same case C shows accessory LHA arising from the LGA which is classified as Michel type V.

origin of the hepatic and gastroduodenal artery. Such variant was detected in 2 cases only (Fig. 10).

Also, one hepatic variant detected in one case was not identified by Michel and not mentioned in other studies in the form of replaced RHA from the SMA and replaced LHA from the LGA with accessory branches arising from the CHA (Fig. 8).

Schematic diagrams were designed to illustrate different types of celiac trunk variants demonstrated in our study as seen in Fig. 11.

4. Discussion

Celiac trunk and hepatic artery variations and anomalies are uncommon and usually asymptomatic [20]. Digital subtraction angiography (DSA) is the gold standard in evaluation of vascular structures; however, it is invasive and carries a lot of risks and complications for patients [8].

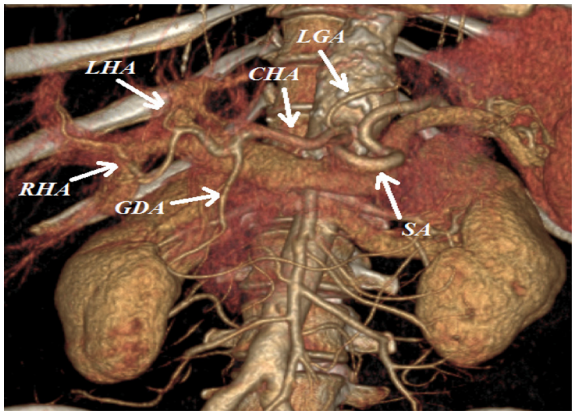

Fig. 5. 3D VR image showing abnormal bifurcation pattern of celiac trunk in the form of hepato-gastric trunk with the SA arising directly from the aorta in close to the hepato-gastric trunk which is classified as Uflacker type III.

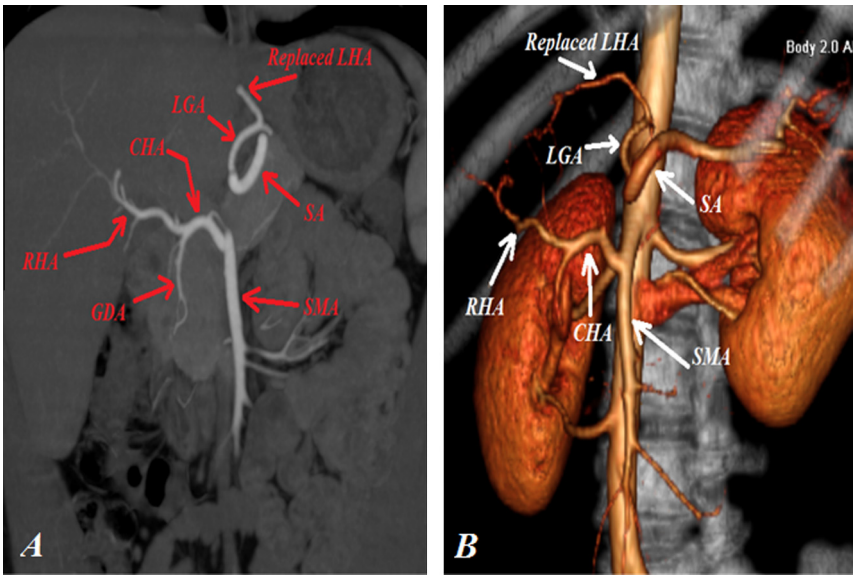

Fig. 6. (A) Coronal MPR and (B) 3D VR images show anomalies pattern of the celiac trunk in the form of spleno-gastric trunk with anomalies origin of the CHA from the SMA which is classified as Uflacker type V and Michel type IX. Notice also the presence of replaced LHA arising from the LGA which is classified as Michel type II.

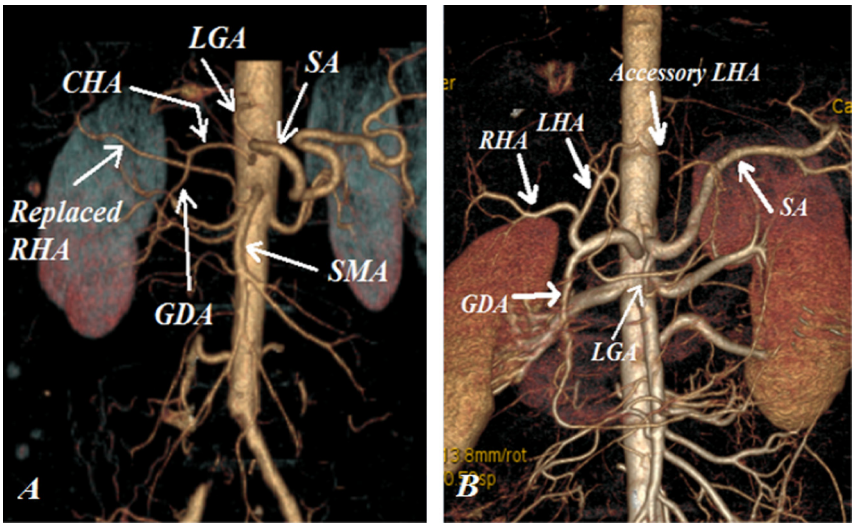

Fig. 7. 3D VR images show anomalies pattern of the celiac trunk in the form of spleno-gastric trunk with the CHA arising directly from the aorta which is classified as Uflacker type V. In case A there is replaced RHA from the SMA which is classified as Michel type III while in case B there is accessory LHA arising from the LGA which is classified as Michel type V.

The development of MSCT machines allows us to obtain thin thickness images with high spatial and temporal resolution in a very short time. Subsequently, it replaces the conventional angiography in assessment of the vascular structures as preoperative evaluation of the hepatic vasculature [9,21–23]. Also, it allows 3D views for the vessels with high sensitivity and specificity in detection of small vessels.

Recent trends in surgical procedures are more toward the minimally invasive surgeries and this is raising the need and the importance to know the normal vascular anatomy and to detect any anomalies and variants before the surgical interference [20]. The identification of celiac and hepatic artery variants is very important before laparoscopic and interventional procedures for the treatment of benign and malignant disease originating from the foregut and midgut as well as liver transplantation surgeries and aortic vascular surgeries [14,24,25].

Various studies and authors tried to classify the celiac trunk anomalies and variants based on the branching pattern. First classification was done in 1917 by Lipshutz. The most recent one done by Uflacker in 1997 classifying the

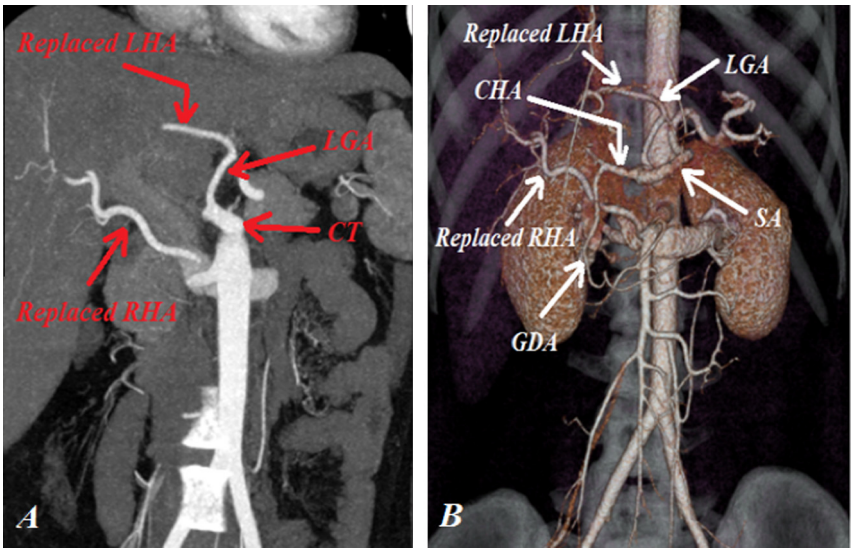

Fig. 8. (A) Coronal MPR and (B) 3D VR images reveal normal trifurcation pattern of the celiac trunk which is classified as Uflacker type I. There is replaced LHA arising from the LGA and replaced RHA arising from the SMA with CHA giving accessory hepatic branches. This variant is not classified in Michel classification (combination of Michel type II and III).

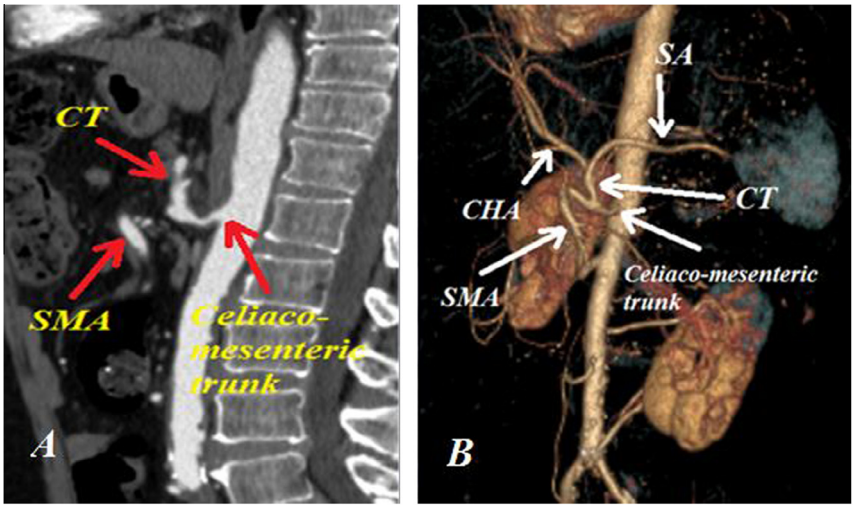

Fig. 9. (A) Sagittal MPR and (B) 3D VR images reveal the presence of common trunk from which celiac trunk and SMA originate which is classified as Uflacker type VI.

celiac trunk into eight types is demonstrated in Table 2 [17,18,26,27].

Many studies all over the world were done to identify the incidence of the celiac trunk and hepatic artery anomalies and variants.

All these studies showed that Uflacker type I is the commonest form which is consistent with our study. The incidence of Uflacker type I among Egyptians was 90.5% which is close to the results by Matsuki et al., Chen et al., Song et al., Ugurel et al. and Gumus et al. [5,7,19,28,29].

The commonest variant was Uflacker type V with gastro-splenic trunk and anomalies origin of the CHA from either the SMA and/or the aorta representing 4.3% and this is similar to Ugurel et al. [29]. Also, Gumus et al. found type V to be the highest anomalies but to a lesser incidence than been in our study (2.6%) [19].

This is contradictory to Lipschutz, Chen et al., and Mburu et al., who found Uflacker type II the commonest celiac trunk variants while type V was the second common variants yet with close numerical incidence to our study [5,26,30].

Song et al., discovered new non-classified form and called as ambiguous celiac trunk which was detected in 2 cases between our study populations (Fig. 10) [7].

The current study showed that Michel type I is the commonest form with an incidence about 74.2% which is close to the results of Koops et al. Type III was the commonest anomaly in our study with replaced RHA from the SMA

Table 4
Illustrate the incidence of different types of celiac trunk and hepatic artery variants among the study population according to Uflacker and Michel classification.

Celiac trunk variants			Hepatic artery variants		
Type	No. of patients	Incidence	Type	No. of patients	Incidence
Type I =	905	90.5%	I	742	74.2%
Classic pattern: (Fig. 1)	638	63.8%			
Non classic: (Figs. 2 and 3)	267	26.7%			
Type II = hepato-splenic trunk (Fig. 4)	28	2.8%	II (Fig. 6)	30	3%
Type III = hepato-gastric trunk (Fig. 5)	6	0.6%	III (Figs. 1 and 7)	125	12.5%
Type IV = hepato-spleno-mesenteric trunk	0	0	IV	0	0
Type V = gastro-splenic trunk (Figs. 6 and 7)	43	4.3%	V (Figs. 3, 4 and 7)	52	5.2%
Type VI = celiaco-mesenteric trunk (Fig. 9)	6	0.6%	VI	11	1.1%
Type VII = celiaco-colic trunk	0	0	VII	6	0.6%
Type VIII = no celiac trunk	10	1%	VIII	10	1%
Bifurcation form	77	7.7%	IX (Fig. 6)	23	2.3%
			X	0	0
Non classified (Fig. 10)	2	0.2%	Non classified (Fig. 8)	1	0.1%

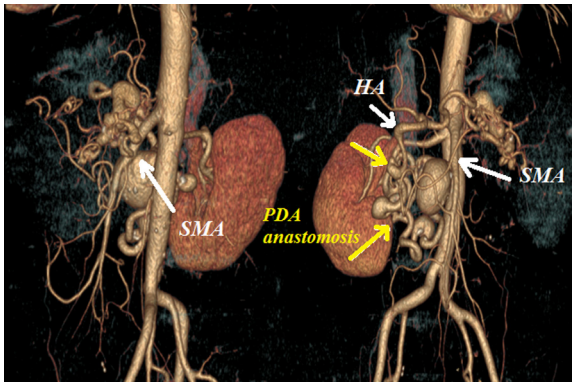

Fig. 10. A case with ambiguous celiac trunk with no celiac trunk seen arising from the aorta with the HA as well as the SA is refilled via pancreaticoduodenal arcades and anastomotic channels. This variant is not classified in Uflacker classification.

representing about 12.5% and this is consistent with Koops et al., De Cecco et al. and Gumus et al. with variable incidences [19,31,32]. However, Covey et al., Stemmler et al. and Cokun et al. found that Michel type V was the commonest between their study population [33–35].

Also, we found a new hepatic artery variant which is not previously described in the form of replaced RHA and LHA from the SMA and LGS respectively with the CHA giving rise to accessory branches (Fig. 8).

Accordingly this thesis may add a modified classification for the celiac and hepatic artery variants "Ain Shams Egyptian classification" which is similar to Uflacker and Michel yet with adding the newly discovered variants. Type IX adding to the Uflacker classification in the form of ambiguous celiac trunk as well as Type XI adding to the Michel's classification replaced RHA from SMA and replaced LHA from the LGA with accessory branches from the CHA.

5. Conclusion

Knowledge of the celiac trunk and hepatic artery variants and anomalies is very important pre-surgical, prelaparoscopic or even pre-interventional and this can be achieved using MSCT to minimize and avoid the major vascular complications and decrease the morbidity of patients.

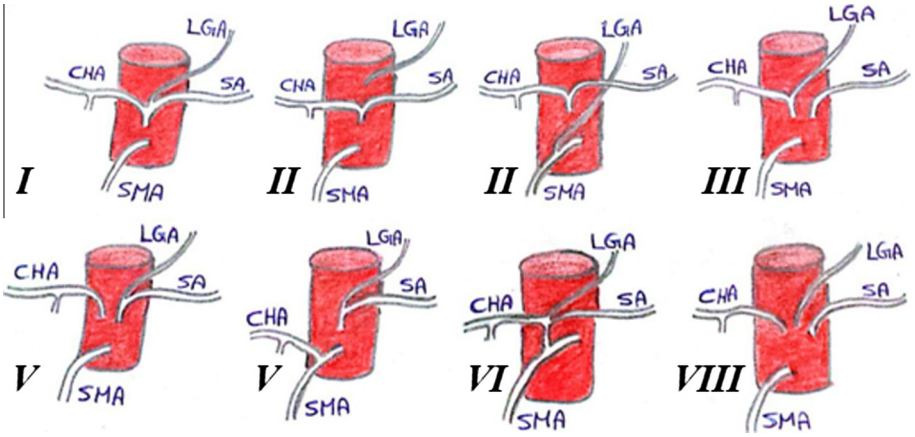

Fig. 11. Schematic diagram of the different types of celiac trunk variants detected in our study following Uflacker classification.

Conflict of interest

The authors declare that there are no conflicts of interest.

References

[1] Williams PL, Bannister LH, Berry MM, et al. Gray's anatomy. 38th ed. Edinburgh London: Churchill Livingstone; 1995. p. 1548–58.
[2] Vandamme JB, Bonte J. The branches of the celiac trunk. Acta Anat (Basel) 1985;122:110–4.
[3] Pamidi N, Verma S, Vollala VR. Anomalous branching pattern of celiac trunk. Int J Anat Var (IJAV) 2008;1:8–9.
[4] Bergman RA, Afifi AK, Miyauchi R. Illustrated encyclopedia of human anatomic variation: opus II: cardiovascular system: arteries: abdomen, celiac trunk arteries. <http://www.anatomyatlases.org/anatomicVariants/Text/Arteries/Celiactrunk.Shtml> [accessed February 2011].
[5] Chen H, Yano R, Emura S, et al. Anatomic variations of celiac trunk with special reference to hepatic artery patterns. Ann Anat 2009;191(4):399–407.
[6] Venara A, Pittet O, Lu T, et al. Aberrant right hepatic artery with a prepancreatic course visualized prior to pancreaticoduodenectomy. J Gastroint Surg 2013;17(5):1024–6.
[7] Song SY, Chung JW, Yin YH, et al. Celiac axis and common hepatic artery variations in 5002 patients: systematic analysis with spiral CT and DSA. Radiology 2010;255(1):278–87.
[8] Rubin GD, Rofsky NM. CT and MR angiography: comprehensive vascular assessment.. Wolters Kluwer/Lippincott Williams & Wilkins; 2009. p. 782.
[9] Nghiem HV, Dimas CT, McVicar JP, et al. Impact of double helical CT and three dimensional CT angiography on surgical planning for hepatic transplantation. Abdom Imag 1999;24(3):278–84.
[10] Rygaard H, Forrest M, Mygind T, et al. Anatomic variants of the hepatic arteries. Acta Radiol Diagn (Stockh) 1986;27(4):425–7.
[11] Suzuki T, Nakayasu A, Kawabe K, et al. Surgical significance of anatomic variations of the hepatic artery. Am J Surg 1971;122(4):505–12.
[12] Curley SA, Chase JL, Roh MS, et al. Technical considerations and complications associated with the placement of 180 implantable hepatic arterial infusion devices. Surgery 1993;114(5):928–35.
[13] Douard R, Ettorre GM, Sommacale D, et al. A two-step strategy for enlargement of left arterial branch in a living related liver graft with dual arterial supply. Transplantation 2002;73(6):993–4.
[14] Munshi IA, Fusco D, Tashjian D, et al. Occlusion of an aberrant right hepatic artery, originating from the superior mesenteric artery, secondary to blunt trauma. J Trauma 2000;48:325–6.
[15] Lee KH, Sung KB, Lee DY, et al. Trancatheter arterial chemoembolization for hepatocellular carcinoma: anatomic and hemodynamic considerations in hepatic artery and portal vein. Radiographics 2002;22(5):1077–91.
[16] Liu DM, Salem R, Bui JT, et al. Angiographic considerations in patients undergoing liver-directed therapy. J Vasc Interv Radiol 2005;16(7):911–35.
[17] Uflacker R. Atlas of vascular anatomy: an angiographic approach. Baltimore: Williams & Wilkins citied in the British Journal of Anatomy; 2010, vol. 83. p. 661–7.
[18] Michels NA. Newer anatomy of the liver and its variant blood supply and collateral circulation. Am J Surg 1966;112(3):337–47.
[19] Gumus H, Bukte Y, Ozdemir E, et al. Variations of the celiac trunk and hepatic arteries: a study with 64-detectors computed tomography angiography. Eur Rev Med Pharmacol Sci 2013;17:1636–41.
[20] Babu D, Khrab P. Celiac trunk variations: review with proposed new classification. Int J Anat Res 2013;1(3):165–70.
[21] Winter TC, Nghiem HV, Freeny PC, et al. Hepatic arterial anatomy: demonstration of normal supply and vascular variants with three dimensional CT angiography. Radiographics 1995;15(4):771–80.
[22] Takahashi S, Murakami T, Takamura M, et al. Multi-detector row helical CT angiography of hepatic vessels: depiction with dual-arterial phase acquisition during single breath hold. Radiology 2002;222(1):81–8.
[23] Lee SS, Kim TK, Byun JH, et al. Hepatic arteries in potential donors for living related liver transplantation: evaluation with multi-detector CT angiography. Radiology 2003;227(2):391–9.
[24] Kimura W, Han I, Furukawa Y, et al. Appleby operation for carcinoma of the body and tail of the pancreas. Hepatogastroenterology 1997;44:387–93.
[25] Rela M, McCall JL, Karani J, et al. Accessory right hepatic artery arising from the left: implications for split liver transplantation. Transplantation 1998;66:792–4.
[26] Lipshutz B. A composite study of the celiac axis artery. Ann Surg 1917;65:159–69.
[27] Das Adachi B, der Japaner Arteriensystem. Verlag der kaiserlich-Japan Univ zu Kyoto 1928;2:18–71.
[28] Matsuki M, Kani H, Tatsugami F, et al. Preoperative assessment of vascular anatomy around the stomach by 3D imaging using MDCT before laparoscopy assisted gastrectomy. AJR 2004;183(1):145–51.
[29] Ugurel MS, Battal B, Bozlar U, et al. Anatomical variations of hepatic arterial system. Celiac trunk and renal arteries: an analysis with multi-detector CT angiography. Br J Radiol 2010;83:661–7.
[30] Mburu KS, Alexander OJ, Hassan S, et al. Variations in the branching pattern of the celiac trunk in a Kenyan population. Int J Morphol 2010;28(1):199–204.
[31] Koops A, Wojciechowski B, Broering DC, et al. Anatomic variations of the hepatic arteries in 604 selective celiac and superior mesenteric angiographies. Surg Radiol Anat 2004;26:239–44.
[32] De Cecco CN, Ferrari R, Rengo M, et al. Anatomic variations of the hepatic arteries in 250 patients studied with 64-row CT angiography. Eur Radiol 2009;19:2765–70.
[33] Covey AM, Brody LA, Maluccio MA, et al. Variant hepatic arterial anatomy revisited: digital subtraction angiography performed in 600 patients. Radiology 2002;224:542–7.
[34] Stemmler BJ, Paulson EK, Thornton FJ, et al. Dual-phase 3D MDCT angiography for evaluation of the liver before hepatic resection. AJR Am J Roentgenol 2004;183:1551–7.
[35] Cokun M, Kayahan EM, Ozbek O, et al. Imaging of hepatic arterial anatomy for depicting vascular variations in living related liver transplant donor candidates with multidetector computed tomography: comparison with conventional angiography. Transplant Proc 2005;37:1070–3.