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## Case Report

# Vascular anomalies of the celiac trunk and implications in treatment of HCC with TACE.

## Description of a case and review of the literature

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## ABSTRACT

Knowledge of the vascular anatomy of the upper abdomen is important in the daily practice of surgeons specialized in the hepatobiliary and pancreatic area, and for general surgeons and radiologists, mainly those involved in interventional radiology. Since anatomical variants of the celiac axis and hepatic arteries are common, an accurate description of vascularization is required before procedures to avoid iatrogenic vascular changes.

We reported a case of a young male patient with HBV related cirrhosis, who came to our institution for the treatment of 2 HCC nodules. The preprocedural contrast-enhanced CT examination showed combined variations of celiac trunk, hepatic arteries, gastroduodenal artery, and right inferior phrenic artery. The careful pre- and intraprocedural evaluation of vascularization allowed us to perform transarterial chemoembolization of the 2 nodules without complications.

The incidence and developmental and clinical significance of this variation is discussed with a detailed review of the literature. Knowledge of such a case has important clinical significance in abdominal operations or invasive arterial procedures.

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## Introduction

The first anatomical description of celiac trunk trifurcation and of hepatic artery (HA) was made by Albert Haller in 1756 [1].

Subsequently several anatomical variants were described in literature [2–4].

Michels in 1966 provided a first classification of the 10 most common variants of arterial blood supply to the liver [4], which was simplified, in 1994, into 6 variants by Hiatt et al [5].

The knowledge of these variants is fundamental especially for surgeons and interventional radiologists who perform procedures in the hepatobiliary and pancreatic area.

We report a rare case of combined variations of celiac trunk, hepatic arteries, gastroduodenal artery, and right inferior phrenic artery (RIPA).

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## Case report

A 23-year-old patient from Senegal, followed by the infectious diseases department for newly diagnosed liver Hepatitis B virus (HBV) related cirrhosis was presented to a multidisciplinary team of hepatologists, surgeons, and interventional radiologists after the finding of 2 Hepatocellular carcinoma (HCC) nodules localized to segment II and segment V. The diagnosis was made based on the typical hallmarks of HCC shown on multiphase CT. His past medical history was unknown due to the presence of language barriers. Laboratory tests showed a slightly increased alpha-fetoprotein (10 IU/mL) and a reduced platelet count (131.0000/mm<sup>3</sup>), the remaining parameters of liver function were in the reference range. The Child-Pugh class of disease was A5.

The multidisciplinary team decision was to perform a transarterial chemoembolization (TACE) while waiting for liver transplantation.

A preprocedural contrast-enhanced CT examination was performed by a 64-slice CT scanner (Lightspeed; General Electric Healthcare, Waukesha, WI). The protocol included a non-contrast CT scan, with 5 mm of thickness, and dynamic acquisition at 30, 70 and 180 seconds after administration of iodine contrast medium (Iomeprolo 350 mgI/mL; volume: 90 mL; flow rate: 3 mL/s, slice thickness: 2.5 mm).

Upon review of the images, an anatomical anomaly of the celiac circulation was detected with origin of the RIPA, the splenic artery, 2 hepatic arteries for the right hepatic segments, left gastric artery from which the left HA originated, and the gastroduodenal artery directly from the celiac trunk.

The RIPA, with a diameter of 1.2 mm at its origin, arose from the anterior wall of the celiac trunk at the right of the mediosagittal plan at the level of upper edge of the L1 vertebral body (Fig. 1a).

Four millimeters away from the RIPA, the first HA originated from the celiac trunk with a diameter of 2.1 mm at its origin, it developed anteriorly to the vena cava, heading toward the right hepatic lobe.

A second HA arose from the anterior wall of the celiac trunk, at the level of the upper one-third of the L1 vertebral

body, 3.8 mm above the origin of the first one. It ran anteriorly to the portal vein and to the right liver lobe.

The left HA originated from left gastric artery, with a diameter of 2.3 mm at its origin, running upward to the left, superolaterally and after a trajectory of 37.6 mm, it split its branches to the left lobe.

Finally the gastroduodenal artery arose from the inferior wall of the celiac trunk (diameter at the origin of 3 mm and a length of 13 mm); it divided into 2 branches, the right gastroepiploic artery and the superior pancreaticoduodenal artery, supplying blood to the head of the pancreas, the proximal part of duodenum and the distal part of the stomach (Figs. 1 and 2).

TACE was performed in the angiography suite. Under local anesthesia, the common femoral artery in the right groin was punctured. By Seldinger's technique, interventional radiologist placed an arterial sheath (Terumo 4 Fr) in the artery and inserts a catheter through the sheath. Then the catheter (Terumo C1 Fr) was manipulated, guided by a wire, through the abdominal aorta into the celiac trunk under imaging guidance. The preliminary arteriographic examination confirmed the vascular anomaly and the 2 areas of neoangiogenesis in the V and II liver segments. The right HA supplying the lesion of the V segment was selectively catheterized by using a 2.7 coaxial catheter (Progreat Boston Scientific) and TACE was performed. Subsequently, the artery supplying the lesion of the II segment was selectively catheterized, taking into account the position of the left gastric artery and chemoembolization was performed. Degradable Starch Microspheres (Embocept 50 micron) and doxorubicina (25 mg) were used in both sites.

The intraoperative and postoperative treatment showed optimal success in the absence of complications (Figs. 3–5).

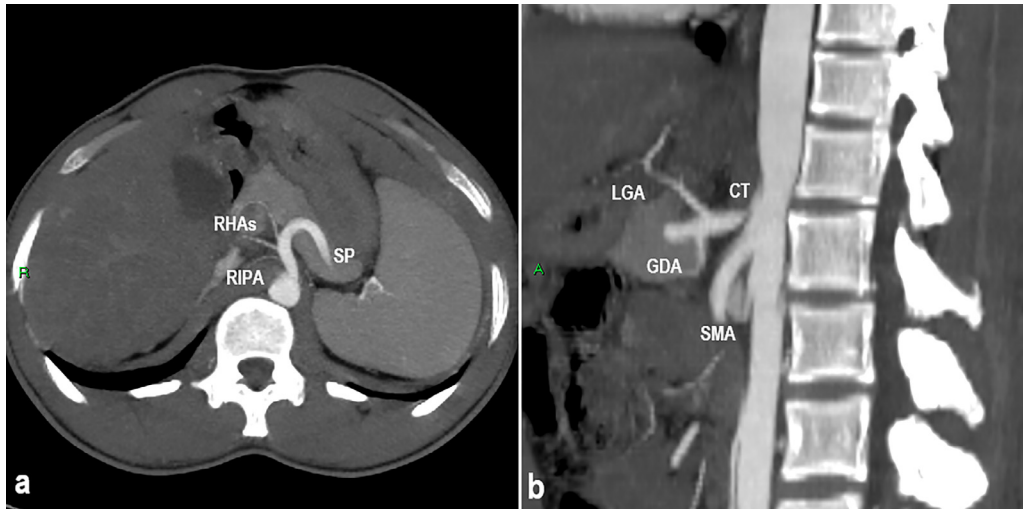
The patient subsequently underwent a liver transplant.

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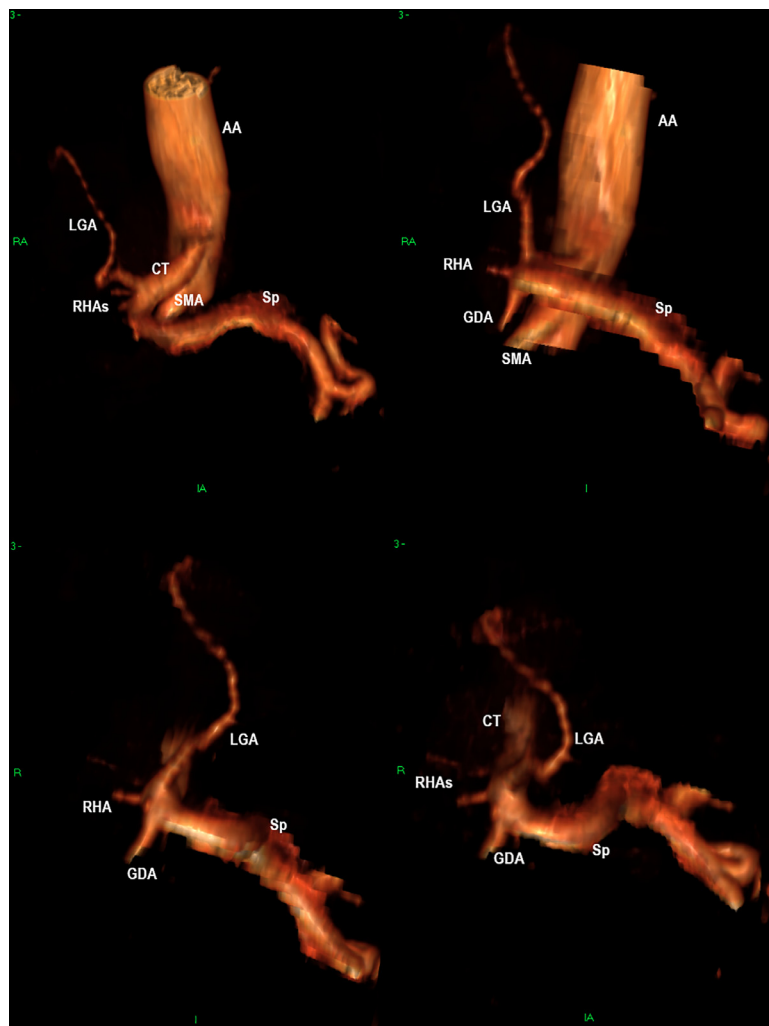
## Discussion

The celiac trunk is the first branch of the abdominal aorta, typically originating at the level of T12/L1 vertebra and, in most cases, it presents 3 terminal branches: left gastric artery, that runs along the small gastric curvature; splenic artery, that presents a tortuous course along the posterosuperior margin of the pancreas up to the spleen; and common HA (CHA), which divides into a gastroduodenal artery for pancreas and duodenum vascularization and proper HA for hepatic vascularization. This condition was highlighted in the literature between 72.29% and 90.78% [6–8].

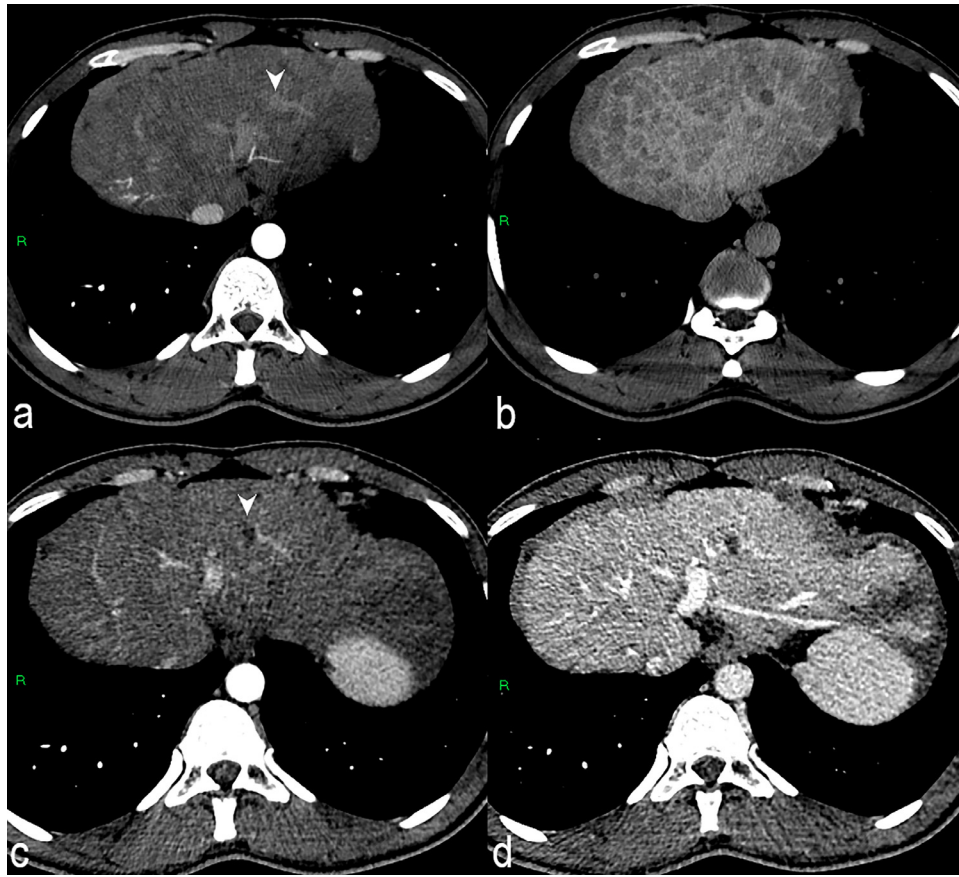
Numerous anatomic variants of the celiac trunk and of hepatic arteries are described in literature and awareness of this is important; especially when planning endovascular or surgical intervention of the upper abdomen. In particular, their precise identification is crucial for the success of procedures such as orthotopic liver transplantation [9–11] and endovascular treatment of unresectable malignant liver tumors [2,12–15]. We presented a rare case of vascular anomalies of the celiac trunk. Our patient had an ambiguous celiac axis; since the CHA was absent and he had 2 hepatic arteries for the right lobe that originated directly from the celiac trunk. He also presented a type II variant according to the classification



**Fig. 1** – CT images on the axial (a) and sagittal (b) planes of the celiac trunk. CT, celiac trunk; GDA, gastroduodenal artery; LGA, left gastric artery; RHAs, right hepatic arteries; RIPA, right inferior phrenic artery; SMA, superior mesenteric artery; Sp, splenic artery.



**Fig. 2** – 3D reconstruction of the celiac trunk. AA, abdominal aorta; CT, celiac trunk; GDA, gastroduodenal artery; LGA, left gastric artery; RHA, right hepatic artery; SMA, superior mesenteric artery; Sp, splenic artery; .



**Fig. 3** – HCC nodule localized to segment II, characterized by arterial phase hyperenhancement (a) and wash-out on portal venous phase (b). Fig. 3c and d show the complete response to the TACE treatment in the arterial (c) and portal venous (d) phases.

of Michels and Hiatt [4,5], with the left HA originating from the left gastric artery. In addition, this patient presented the gastroduodenal artery and the RIPA originating directly from the celiac axis. The 2 lesions localized to the V and II liver segments were respectively supplied by a HA to the right lobe and by the left HA originating from left gastric artery. Despite the anatomical variants present, chemoembolization was performed without complications thanks to a careful both pre- and intraprocedural evaluation of vascularization. In particular, it was possible to perform TACE of the lesion located to the II segment, avoiding involvement of the left gastric artery that could have caused ischemic suffering to the stomach. To our knowledge in literature, there are no other cases with all of these variants combined and in which TACE was performed without complications and with complete response to the treatment.

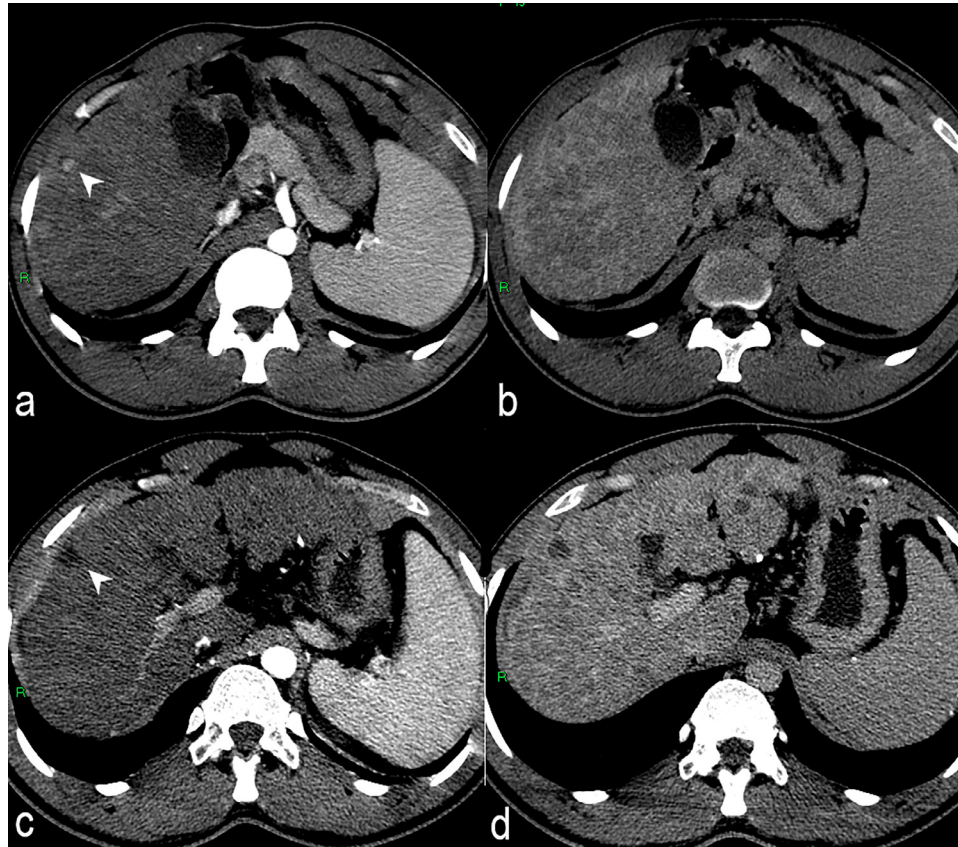
Song et al [11] retrospectively analyzed the CT and digital subtraction angiography of 5002 patients, finding a normal celiac axis in 89.1% of cases and 12 types of celiac axis variations in 9.64% of patients. In 1.26% of cases, the celiac axis was classified as ambiguous because the CHA was absent or persistent anastomotic channels were present. Sureka et al [3] in a study on 600 patients identified 6 types of celiac axis variations in 5.5% of cases and an ambiguous celiac axis in 3.5% of patients.

Natsis et al reported a case of a 74-year-old male cadaver which did not present a CHA with the gastroduodenal artery originating from celiac trunk, but in their case a proper HA, arising from superior mesenteric artery, was present [16].

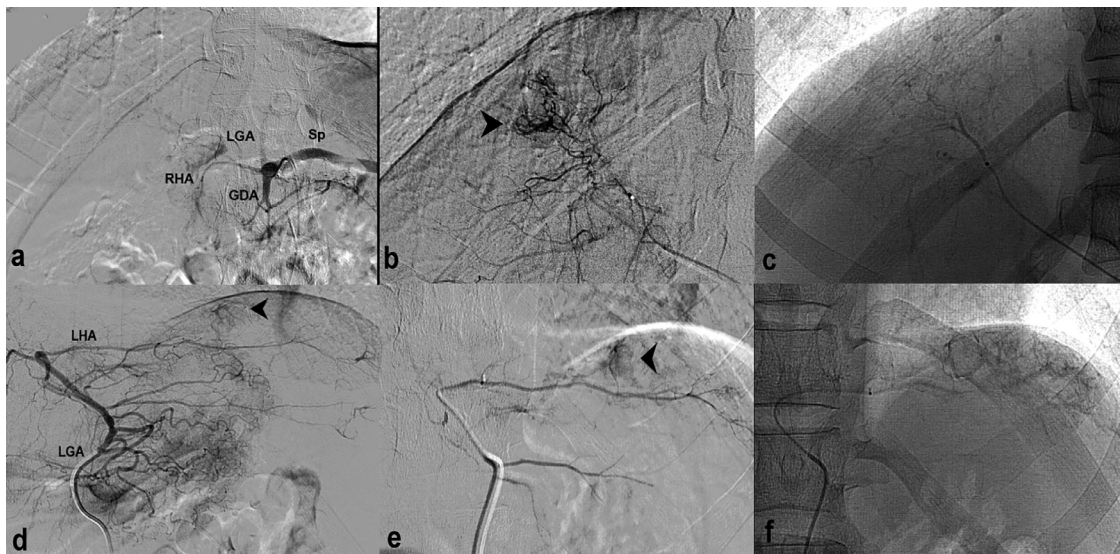
Kimura et al [17] and Basile et al [18] showed that the most common origin of RIPA was from the abdominal aorta and the second most frequent origin was from the celiac trunk. For Loukas et al [19] and Aslaner et al [20] instead the most frequent origin type of RIPA was the celiac axis followed by the abdominal aorta.

It is important to evaluate the vascular anatomy of the inferior phrenic arteries, because in addition to the main vascularization of the diaphragm they could form collateral circulation. In particular, some studies have shown that RIPA is the most common collateral circulation supplying liver cancer [21,22]. This can have important clinical implications, for example, in the planning of liver chemoembolization procedures, specifically for peripheral lesions.

Based on the anatomy of 200 cadaver livers, Michels described the 10 most common variants of arterial blood supply to the liver. The full classification with its frequency of occurrence is as follows: Type I (normal pattern)—81%; type II (a replaced LHA from the left gastric artery) 3%; type III (a replaced RHA from the superior mesenteric artery) 3.7%; type IV (replaced RHA and LHA) 0.8%; type V (an accessory LHA) 3.2%;



**Fig. 4** – HCC nodule localized to segment V, characterized by arterial phase hyperenhancement (a) and wash-out on portal venous phase (b). **Fig. 4c** and **d** show the complete response to the TACE treatment in the arterial (c) and portal venous (d) phases.



**Fig. 5** – Preliminary arteriographic examination shows the celiac trunk anomaly (a) and the origin of the left hepatic artery from the left gastric artery (d). Arrowheads indicate the 2 areas of neoangiogenesis in the V (b) and II (d and e) liver segments. **Fig. 5c** and **f** show the complete response after TACE treatment. GDA, gastroduodenal artery; LGA, left gastric artery; LHA, left hepatic artery; RHA, right hepatic artery; Sp, splenic artery.

type VI (an accessory RHA) 1.6%; type VII (accessory LHA and RHA) 0.2%; type VIII (a replaced LHA or RHA with the other HA being an accessory one) 0.35%; type IX (the hepatic trunk as a branch of the superior mesenteric artery) 1.2%, and type X (CHA branched from the left gastric artery) 0.04% [4]. This classification by Michels was later simplified into 6 variants by Hiatt et al in a study on 1000 liver [5].

Hiatt classification is frequently applied when the analysis is performed using angiographic studies, since it is considered difficult to distinguish between angiographically ancillary substitute or vascular structures.

Based on Michels classification, the most frequent change according to the literature is the type III present in 6%–15.5% of cases. It is also the most important to identify as it can significantly influence the success of surgical procedures [23].

The second most common is type II, reported in literature between 2.5% and 10%. Type IV is described with an incidence of 1% and 7.4%. The types VII, VIII, IX, and X are rarely described in literature [9].

However, as anatomical variations may occur due to genetic aberrations in the embryonic period, no detailed classification can cover all types [2].

According to Tandler et al [24] during embryogenesis 4 ventral branches arise from the abdominal aorta interconnected with each other by an anastomotic channel. Their persistent overgrowth or regression determines the development of variations of the celiac axis and the superior mesenteric artery.

Koops et al [25] in their series revealed frequency of 4.6% of nonclassified presentations; meanwhile, Ugurel et al [26] showed frequency of 3% of these forms in their paper. It is believed that the existence of rare variants shows that the embryological development of the branches of the aorta can be influenced by many factors and is a complex process.

## Conclusion

Knowledge of the vascular anatomy of the upper abdomen is significant for the daily practice for surgeons specializing in the hepatobiliary and pancreatic area, and also for general surgeons and radiologists, mainly those involved in interventional radiology. Since anatomical variants of the celiac axis and hepatic arteries are common and various, an accurate description of vascularization is required before procedures to avoid iatrogenic vascular changes [2,25–30].

Radiologists play a fundamental role in their identification; with advances in the imaging techniques employed in angiography, computed tomography, and magnetic resonance, in both data acquisition but also in image postprocessing on workstations, it is possible to obtain information that facilitates the planning of a procedure which can ultimately contribute to reducing the associated rates of morbidity and mortality [31–34].

Furthermore, our case demonstrates that it is feasible to perform successfully interventional endovascular treatment also in presence of vascular anatomical variants of the celiac axis with an accurate pretreatment evaluation of vascular anatomy.

## REFERENCES

- Brasil IRC, de Araujo IF, Lima AALA, Melo ELA, Esmeraldo RM. Computed tomography angiography study of variations of the celiac trunk and hepatic artery in 100 patients. *Radiol Bras* 2018;51(1):32–6.
- Chen H, Yano R, Emura S, Shoumura S. Anatomic variation of the celiac trunk with special reference to hepatic artery patterns. *Ann Anat* 2009;191:399–407.
- Sureka B, Mittal MK, Mittal A, Sinha M, Bhambri NK, Thukral BB. Variations of celiac axis, common hepatic artery and its branches in 600 patients. *Indian J Radiol Imaging* 2013;23:223–33.
- Michels NA. Newer anatomy of the liver and its variant blood supply and collateral circulation. *Am J Surg* 1966;112:337–47.
- Hiatt JR, Gabbay J, Busuttill RW. Surgical anatomy of the hepatic arteries in 1000 cases. *Ann Surg* 1994;220:50–2.
- Lipshutz B. A composite study of the coeliac axis artery. *Ann Surg* 1917;65(2):159–69.
- Eaton PB. The coeliac axis. *Anat Rec* 1917;13(6):369–74.
- Santos PVD, Barbosa ABM, Targino VA, Silva NA, Silva YCM, Barbosa F, et al. Anatomical variations of the celiac trunk: a systematic review. *Arq Bras Cir Dig* 2018;31(4):e1403.
- da Fonseca-neto OCL, de Souza Lima HC, Rabelo P, de Melo PSV, Amorim AG, Lacerda CM. Anatomic variations of hepatic artery: a study in 479 liver transplantations. *Arq Bras Cir Dig* 2017;30(1):35–7 Original Article.
- White RD, Weir-McCall JR, Sullivan CM, Mustafa SAR, Yeap PM, Budak MJ, et al. The celiac axis revisited: anatomic variants, pathologic features, and implication for modern endovascular management. *Radiographics* 2015;35:879–98.
- Song SY, Chung JW, Yin YH, Jae HJ, Kim HC, Jeon UB, et al. Celiac axis and common hepatic artery variations in 5002 patients: systematic analysis with spiral CT and DSA. *Radiology* 2010;255:278–88.
- Reis FRS, Cardia PP, D'Ippolito G. Computed tomography angiography in patients with active gastrointestinal bleeding. *Radiol Bras* 2015;48:381–90.
- Erbay N, Raptopoulos V, Pomfret EA, Kamel IR, Kruskal JB. Living donor liver transplantation in adults: vascular variants important in surgical planning for donors and recipients. *Am J Roentgenol* 2003;181:109–14.
- Schmidt S, Demartines N, Soler L, Schnyder P, Denys A. Portal vein normal anatomy and variants: implication for liver surgery and portal vein embolization. *Semin Intervent Radiol* 2008;25:86–91.
- Soares RV, Coelho JCU, Matias JEF, Zeni Neto C, de Freitas ACT, de Godoy JL. Anatomia da artéria hepática em doadores e receptores de transplante hepático intervivos. *Rev Col Bras Cir* 2006;33:63–7.
- Natsis K, Piagkou M, Lazaridis N, Koimtzis G, Apostolidis S. The coexistence of both replaced proper hepatic and gastroduodenal arteries due to the common hepatic artery absence. *Surg Radiol Anat* 2017;39(11):1293–6.
- Kimura S, Okazaki M, Higashihara H, Nozaki Y, Haruno M, Urakawa H, et al. Analysis of the origin of the right inferior phrenic artery in 178 patients with hepatocellular carcinoma treated by chemoembolization via the right inferior phrenic artery. *Acta Radiol* 2007;48:728–33.
- Basile A, Tsetis D, Montineri A, Puleo S, Massa Saluzzo C, Runza G, et al. MDCT anatomic assessment of right inferior phrenic artery origin related to potential supply to hepatocellular carcinoma and its embolization. *J Vasc Interv Radiol* 2008;31:349–58.
- Loukas M, Hullett J, Wagner T. Clinical anatomy of the inferior phrenic artery. *Clin Anat* 2005;18:357–65.

- [20] Aslaner R, Pekcevik Y, Sahin H, Toka O. Variations in the origin of inferior phrenic arteries and their relationship to celiac axis variations on CT angiography. *Korean J Radiol* 2017;18:336–44.
- [21] Gürses İA, Gayretli Ö, Kale A, Öztürk A, Usta A, Şahinoğlu K. Inferior phrenic arteries and their branches, their anatomy and possible clinical importance: an experimental cadaver study. *Balkan J Med* 2015;32:189–95.
- [22] Kim HC, Chung JW, Lee W, Jae HJ, Park JH. Recognizing extrahepatic collateral vessels that supply hepatocellular carcinoma to avoid complications of transcatheter arterial chemoembolization. *Radiographics* 2005;25: S25–S39.
- [23] Sebben GA, Rocha SL, Sebben MA, Parussolo Filho PR, Habu Gonçalves BH. Variações da artéria hepática: estudo anatômico em cadáveres. *Rev Col Bras Cir* 2012;40(3): 221–226.
- [24] Tandler J. Über die Varietäten der Arteria coeliaca und deren Entwicklung. *AnatHefte* 1904;25:473–500.
- [25] Koops A, Wojciechowski B, Broering DC, Adam G, Krupski-Berdien G. Anatomic variations of the hepatic arteries in 604 selective celiac and superior mesenteric angiographies. *Surg Radiol Anat* 2004;26:239–44.
- [26] Ugurel MS, Battal B, Bozlar U, Nural MS, Tasar M, Ors F, et al. Anatomical variations of hepatic arterial system, celiac trunk and renal arteries: an analysis with multidetector CT angiography. *Br J Radiol* 2010;83:661–7.
- [27] Olewnik A, Wysiadecki G, Polguy M, Jankowski M, Topol M. Types of coeliac trunk branching including accessory hepatic arteries: a new point of view based on cadaveric study. *Folia Morphol* 2017 <https://doi.org/>. doi:10.5603/FM.a2017.0053.
- [28] Olewnik Ł, Wysiadecki G, Polguy M, Topol M. A rare anastomosis between the common hepatic artery and the superior mesenteric artery: a case report. *Surg Radiol Anat*. 2017 <https://doi.org/>. doi:10.1007/s00276-017-1859-2.
- [29] Polguy M, Gabryniak T, Topol M. The right accessory hepatic artery; a case report and review of the literature. *Surg Radiol Anat* 2010;32:175–9 <https://doi.org/>. doi:10.1007/s00276-009-0536-5.
- [30] Wang L, Xu J, Sun D, Zhang Z. Aberrant hepatic arteries running through pancreatic parenchyma encountered during pancreatoduodenectomy: Two rare case reports and strategies for surgical treatment. *Medicine* 2016;95:e3867. doi:10.1097/MD.0000000000003867.
- [31] de Melo-Leite AF, Mota Jr A, Chagas-Neto FA, Teixeira SR, Junior JE, Muglia VF. Acquired portosystemic collaterals: anatomy and imaging. *Radiol Bras* 2016;49:251.
- [32] Winston CB, Lee NA, Jarnagin WR, Teitcher J, DeMatteo RP, Fong Y, et al. CT angiography for delineation of celiac and superior mesenteric artery variants in patients undergoing hepatobiliary and pancreatic surgery. *Am J Roentgenol* 2007;188:W13–19.
- [33] Iezzi R, Cotroneo AR, Giancristofaro D, Santoro M, Storto ML. Multidetector-row CT angiographic imaging of the celiac trunk: anatomy and normal variants. *Surg Radiol Anat* 2008;30:303–10.
- [34] Saylisoy S, Atasoy Ç, Ersöz S, Karayalçın K, Akyaret S. Multislice CT angiography in the evaluation of hepatic vascular anatomy in potential right lobe donors. *Diagn Interv Radiol* 2005;11:51–9.