Evaluation of the morphology and angles of celiac trunk

Azad Hekimoglu, Onur Ergun

Diskapi Yildirim Beyazit Training and Research Hospital, Department of Radiology, Ankara, Turkey

SUMMARY

The objective of this study is to investigate the morphology, direction, and the origin angle of the celiac trunk. The abdominal CT images of the included 304 patients (165 males, 139 females) were retrospectively evaluated in the axial and sagittal planes following the formation of the multiplanar images. The mean age of the patients was 51 years (17-91 years). Calibration of the celiac trunk and the length between the origin of the trunk and the first branching were measured. The angle between the abdominal aorta and the celiac trunk at the level of the origin at the sagittal plane and the direction of the distal part of the trunk at the axial plane were also evaluated.

The mean length of the celiac trunk was 28.11 mm (11.1-44.6 mm) and the mean diameter was 8.05 mm (5.9-10.5 mm). There was a statistically significant difference between males and females for the length and diameter of the celiac trunk. The mean origin angle of the celiac trunk was 121.20° at the sagittal plane. There was no statistically significant difference between males and females for the origin angle of the celiac trunk. Regarding the axial images, celiac trunk had a straight direction in 187 patients (61.5%), a rightward direction in 111 patients (36.5%) and a leftward direction in 6 patients (1.9%). We believe that the knowledge about the morphology, origin angle, and direction of the celiac trunk can be a guide for the interventional radiological procedures and decrease the risk of possible complications.

Key words: Celiac trunk – Morphological findings – Multidetector computed tomography

INTRODUCTION

The celiac trunk, which is the first and one of the most important branches of the aorta, originates at the level of diaphragm's aortic hiatus and upper edge of the first lumbar vertebra. Its three branches (left gastric artery, splenic artery and common hepatic artery) are responsible for the perfusion of the liver, gall bladder, pancreas, spleen, stomach, distal esophagus and proximal duodenum (White et al., 2015).

As the celiac trunk is the most important structure supplying the upper gastrointestinal system, knowledge about its morphology and variations is critical for the management of the surgical and interventional radiological procedures in the upper abdomen. There are several studies on the morphology and variations of the celiac trunk and they showed that variations of the celiac trunk are not rare (Iezzi et al., 2008; Marco-Clement et al., 2016; Ozbülbül, 2011). The majority of these

Corresponding author:
Azad Hekimoglu, M.D. Dışkapı Yıldırım Beyazıt Eğitim ve Ararştırma Hastanesi, Radyoloji Bölümü, Dışkapı, 06110, Ankara, Turkey.
Phone: 00 90 312 5962619 / Mobile: 00 90 506 7559485. E-mail: azadhekimoglu@gmail.com

Submitted: November 21, 2020. **Accepted:** February 13, 2021

studies had been focused on the branching of the celiac trunk and on the classification related to the branching (Iezzi et al., 2008; Marco-Clement et al., 2016; Panagouli et al., 2013).

In our study, our objective was to investigate the corpus of the celiac trunk: in other words, the part between the origin of the trunk and the bifurcation instead of the branching of the trunk. The length, diameter of the celiac trunk and the rate of stenosis were also examined. In addition, we measured the direction of the celiac trunk at the axial plane and the angle of the origin from the aorta at the sagittal plane.

MATERIALS AND METHODS

The CT images of 320 patients, who had undergone contrast-enhanced CT angiography due to any reason in our hospital, were investigated in a retrospective study design. In 4 of the evaluated patients, the common hepatic artery and gastrosplenic trunk originated separately from the aorta. In 2 patients, the left gastric artery, common hepatic artery and splenic artery originated individually. In 8 patients, there was a gastrosplenic trunk and the common hepatic artery originated from the superior mesenteric artery (SMA). In one patient, the celiac trunk and the superior mesenteric artery formed together the celiacomesenteric trunk, and finally another patient had the history of a previous surgery related to the vascular structures of the upper abdomen. Depending on the abovementioned findings, these 16 patients were excluded from the study. The mean age of the included 304 patients was 51 years (17-91 years) and 165 of them were males (Table 1).

The abdominal CT angiography examination was performed with a 128-slice multi-detector CT scanner (GE, Optima CT 660). The images were created with the following parameters: 120kV, 60-100mA, and 0.625mm slice thickness. Arterial CT angiography images were obtained by placing region-of-interest (ROI) in the descending aorta, and by administering 80-100 ml of contrast intravenously at 300 psi and 4 ml / sec. The thin-slice imaging data obtained at the axial plane in all patients were obtained from PACS and evaluated retrospectively. Multiplanar reformatted (MPR) and maximum intensity projection (MIP) images were created. As the celiac trunk is easily visible at the sagittal plane, we preferred the axial and sagittal planes for the evaluation. All CT images were evaluated by two radiologists and the reports were prepared after the consensus between them.

First, calibration of the celiac trunk and the length between the origin of the trunk and the first branching were measured. The angle between the abdominal aorta and the celiac trunk at the level of the origin at the sagittal plane and the direction of the distal part of the trunk at the axial plane were also evaluated. A straight truncal direction within the abdominal aorta margins were considered as *straight*, as *rightward* if this direction exceeded the imaginary line drawn from the right margin of abdominal aorta towards the anterior, and as *leftward* if the direction exceeded the imaginary line drawn from the left margin of abdominal aorta towards the anterior (Fig. 1). Finally, we checked

Table 1. Demographical and radiological characteristics.

	Female	Male	Total
Patient	139 (45.7%)	165 (54.3%)	304
Age	53.16	50.16	(p=0.126)
No stenosis	121 (40%)	147 (48.2%)	268 (88.2%)
Mild stenosis	14 (4.6%)	11 (3.6%)	25 (8.2%)
Severe stenosis	4 (1.3%)	7 (2.3%)	11 (3.6%)
Straight forward direction	82 (27%)	105 (34.5%)	187 (61.5%)
Rightward direction	54 (17.8%)	57 (18.7%)	111 (36.5%)
Leftward direction	3 (0.99%)	3 (0.99%)	6 (1.98%)

the presence and grade of stenosis in the origin of the celiac trunk. Stenosis was evaluated in two grades as mild (<50%) and severe (>50%) (Fig. 2).

The data of our study were analyzed with the SPSS v21 software package and normally-distributed parameters were assessed with the T-test. The Mann-Whitney U test was used for the angle of the celiac trunk.

RESULTS

The mean length of the celiac trunk (segment between the origin and the first branching) in the included 304 individuals was 28.11 mm (11.1-44.6 mm), and the mean diameter was 8.05 mm (5.9-10.5 mm). The mean length of the celiac trunk was 27.13 mm and mm in females and males respectively, and the difference was statistically significant.

The mean diameter of the celiac trunk was 7.83 mm and 8.24 mm in females and males respectively, and the difference was also statistically significant (Table 2).

Stenosis was observed in the celiac trunk in a total of 36 patients (11.8%). Twenty- five patients (8.2%) were categorized as mild (<50%), while the remaining 11 patients as severe (>50%). Poststenotic dilatation in the celiac trunk was observed in 4 of the patients with severe stenosis. Eighteen patients with stenosis were female (14 mild, 4 severe). Similarly, 18 male patients had stenosis (11 mild, 7 severe) (Table 1).

The origin angle between the celiac trunk and the abdominal aorta was between 90° and 150° at the sagittal plane in the participating 304 individuals (mean value=121.20°) (Fig. 3). The origin angle of the celiac trunk was 124.32° and 118.58° in females and males respectively, and the difference was not statistically significant (p=0.05) (Table 2).

Regarding the direction of the celiac trunk in the axial images, the trunk had a straight course in 187 patients (61.5%), while it had a rightward and leftward direction in 111 (36.5%) and 6 patients (1.9%) respectively (Table 1).

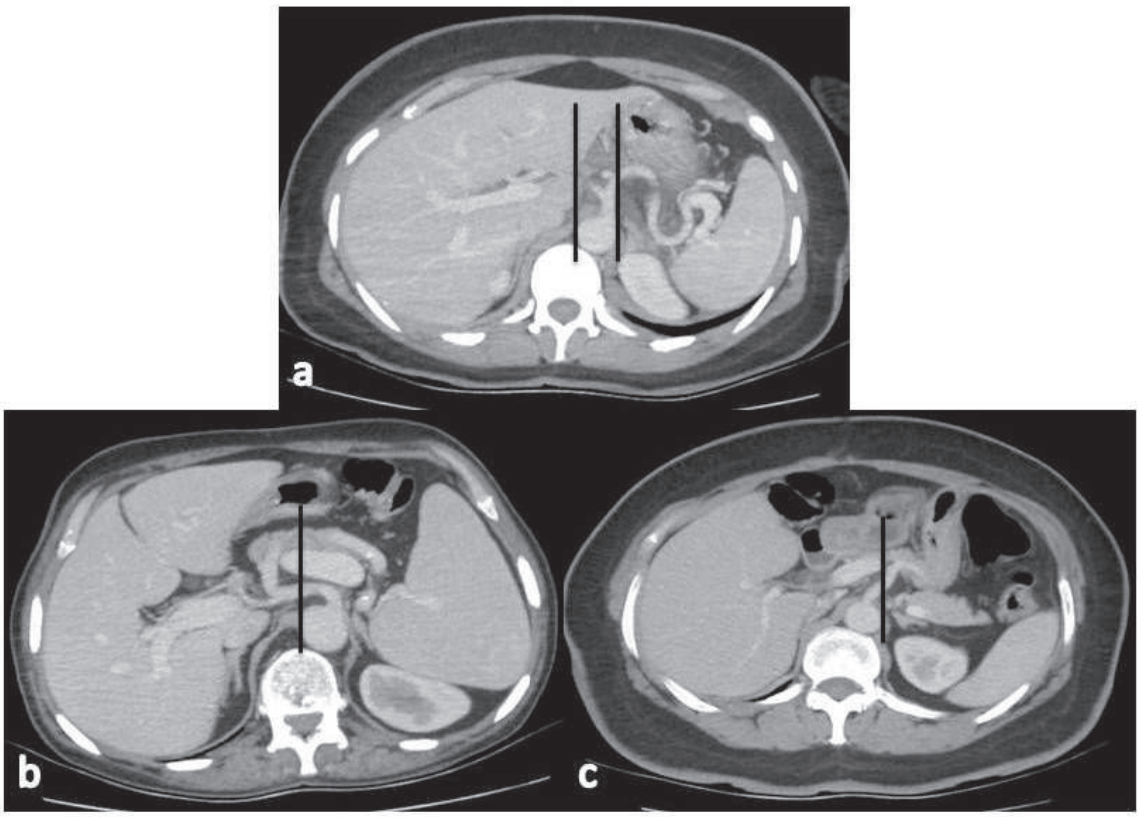

Fig. 1.- Axial contrast-enhanced abdominal CT image **a.** Direction of the celiac trunk is straight forward within the imaginary lines at the margins of abdominal aorta. **b.** Rightward direction of the celiac trunk. **c.** Leftward direction of the celiac trunk.

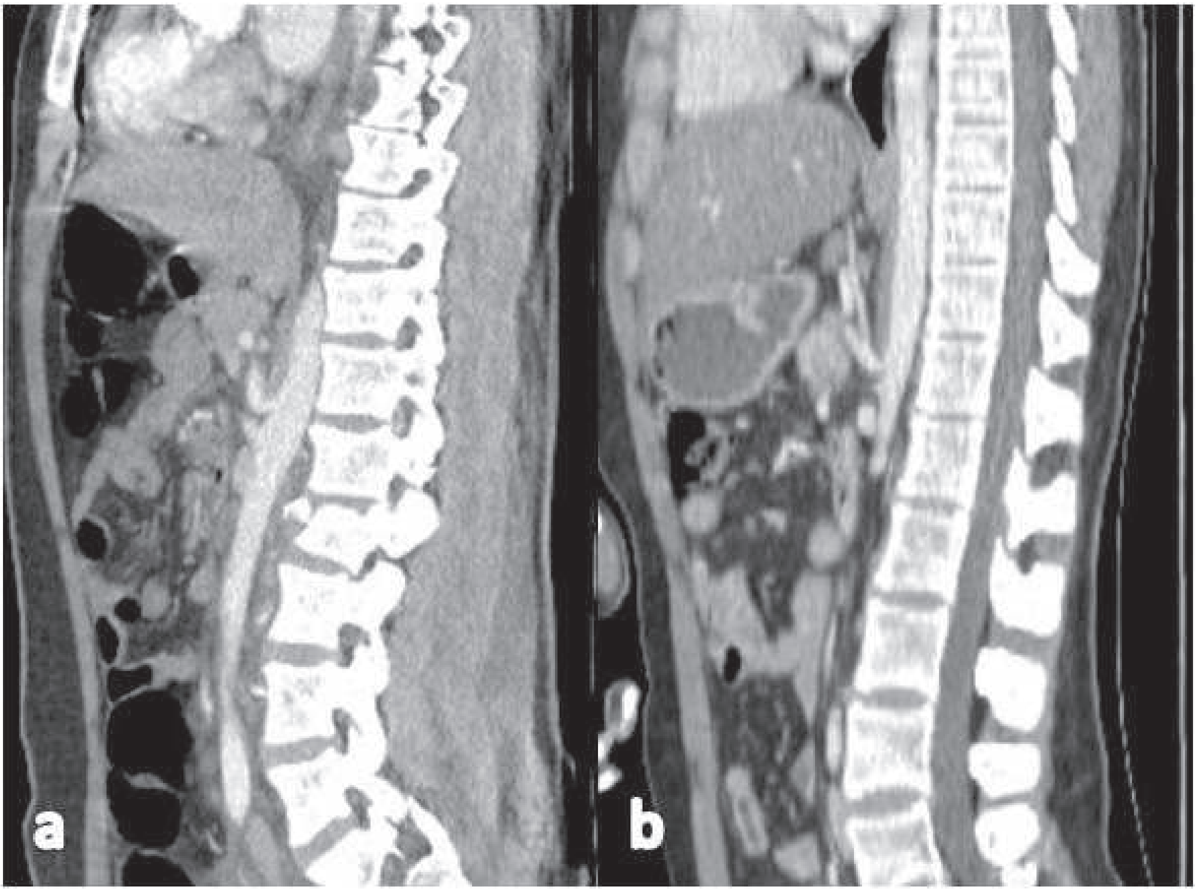

Fig. 2.- Sagittal contrast-enhanced abdominal CT images. **a.** Mild stenosis at the origin of the celiac trunk (<%50); **b.** Severe stenosis (>%50).

Table 2. Length, diameter and angle differences of the celiac trunk between females and males with p values.

	Female	Male	p
Length	27.13	28.93	<0.05
Diameter	7.83	8.24	<0.05
Origin angle	124.32˚	118.58˚	=0.05

DISCUSSION

The abnormal embryonic development of the ventral splanchnic arteries may lead to different vascular variations. Therefore, knowledge about the morphology of the celiac trunk is necessary for the planning of the upper abdominal surgeries and angiographic interventional procedures like transarterial chemoembolization for the liver tumors. The identification of the vascular variations is important not only for both anatomic and embryological knowledge but also for the prevention of the complications during the surgery and invasive radiological procedures. Parallel to the developments in the CT technology, multi-detector computed tomography (MDCT) became a valuable tool for the imaging of the celiac trunk and branches. MDCT angiography, which enables the definition of the anatomic variants apart from the normal anatomy, is a suitable and minimally invasive method for the evaluation of the celiac structure. It enables the avoidance of the complications related to the conventional angiography (Cavdar et al., 1997; Koops et al., 2004; Winston et al., 2007; Sone et al., 2008; Sahani et al., 2002).

In our study, the segment between the origin of the celiac trunk and the first branching was evaluated and the length and diameter of the celiac trunk were primarily measured. The mean length of the celiac trunk was reported 23 mm in a previous study performed with MDCT (Araujo Neto et al., 2015) and 26 mm in a study performed on cadavers (Panagouli et al., 2011). The mean length of the celiac trunk was 28.11 mm in our study. Furthermore, the mean diameter of the celiac trunk was reported 8 mm in an MDCT study (Panagouli et al., 2011) and 7.9 mm in another study performed on cadavers (Silveira et al., 2009). Our result was 8.05 mm, which was compatible with the previous studies. In our study, we determined significant differences between males and females for the length and diameter of the celiac trunk. The dimension of these parameters was significantly higher in males compared to females.

Although the distal part of the celiac trunk is free and its position may minimally change according to the localization of the intraabdominal organs, breathing condition and lying position of the patient, we believe that the origin of the celiac trunk will be not much affected from this condition (Fig. 4). Measurements showed that the origin angle between the celiac trunk and aorta was between 90° and 150° with a mean value of 121.2°. Although it was not statistically significant, we noticed that the angle of the celiac trunk was wider in females compared to males and directed towards inferior. In addition, we determined that the celiac trunk had straight anterior direction in 61.5% of patients at the axial planes. We observed that it had a rightward direction in 36.5% and a leftward direction in as less as 1.9% of patients. We concluded that the celiac trunk usually had a direction towards inferior and anterior and to a lesser direction rightwards, which can be a guide for the angiographic interventional procedures.

The median arcuate ligament syndrome (MALS), which is also known as the celiac artery compression syndrome or Dunbar syndrome, is a clinical condition caused by the compression of the celiac trunk by the median arcuate ligament. MALS was first recognized in the 1960s and reported to occur usually in slim women between the ages of 20 and 40 (Harjola, 1963; Dunbar et al., 1965; Horton et al., 2005). However, it was demonstrated with angiographic examinations that the celiac body compression may be encountered in normal population with changing rates (13-50%) (Szilagyi et al., 1972; Bron and Redman, 1969). It was stated that

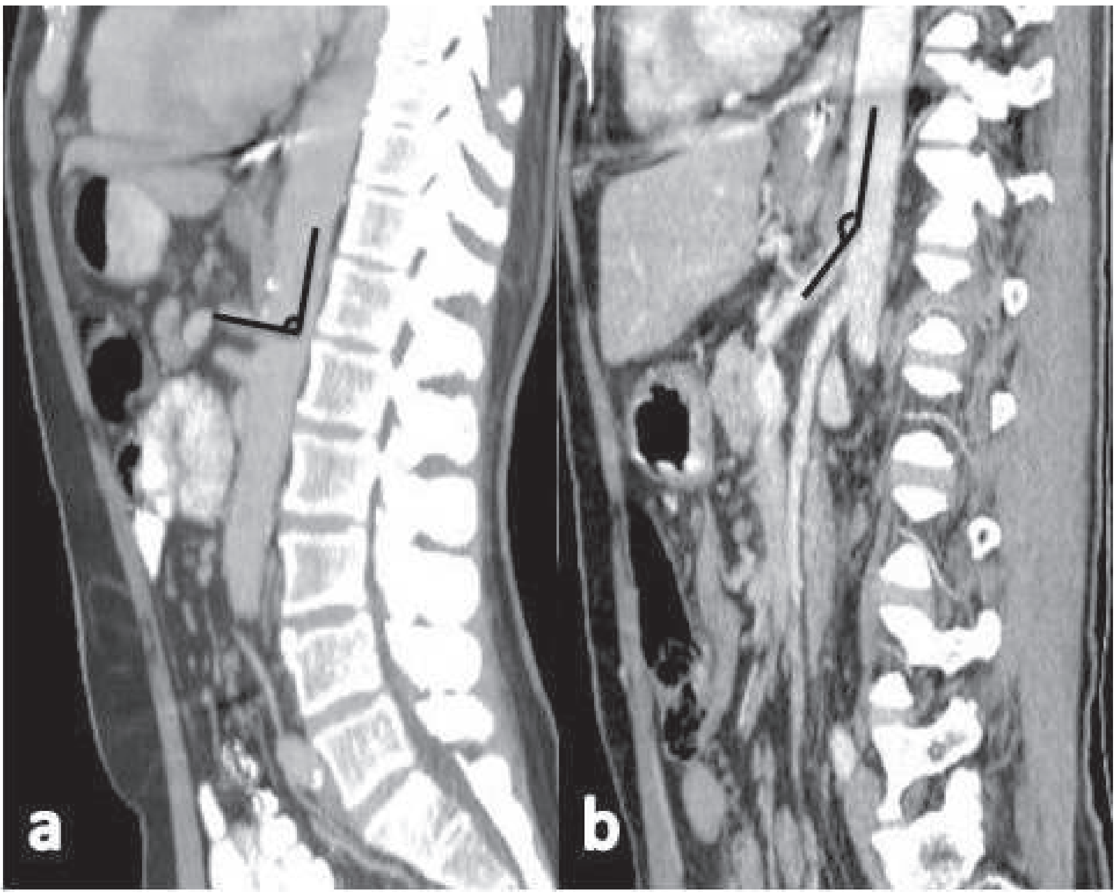

Fig. 3.- Sagittal contrast-enhanced abdominal CT image. Angle between the celiac trunk and abdominal aorta ranges between **a.** 90° and **b.** 150°.

the absence of MALS symptoms in cases with stenosis in the celiac trunk may be associated with the retrograde filling through SMA or other branches (Van Petersen et al., 2014). In our study, we observed stenosis in 11.8% of the cases at the celiac trunk origin, and all of them were attributed to compression of the median arcuate ligament.

The findings of the celiac artery stenosis caused by the median arcuate ligament in the CT scans were defined with the stenosis detected in the axial images and with the hook or "J" shape appearance in the sagittal reconstructions (Horton et al., 2005; Lee et al., 2018). However, in a study conducted by Petnys et al. (2018), the authors stated that the hook or "J" appearance should not be interpreted as a result of the external compression. They emphasized that the compression of the celiac axis by the median arcuate ligament occurred in 3.42% of the normal population but did not manifest any symptoms, a hook or "J" appearance was mostly not observed in this subgroup in the standard inspiratory phase CT imaging (Petnys et al., 2018). In our study, it was observed that this appearance changed in CT images taken at different dates in several patients. We think that the hook or "J" appearance in the distal of the celiac body may change depending on the respiratory condition of the patient, such as inspiration or expiration. (Fig. 4).

CONCLUSION

We conclude that the knowledge of the origin angles and the possible direction of the distal segment of the celiac trunk, as well as the vessel diameter, presence and degree of stenosis, provides useful information when planning endovascular treatments. This information may shorten the duration of the interventional procedures by suitable equipment selection, as well as decrease iatrogenic injuries.

REFERENCES

ARAUJO NETO SA, FRANCA HA, DE MELLO JUNIOR CF, SILVA NETO EJ, NEGROMONTE GR, DUARTE CM, CAVALCANTI NETO BF, DE FONSECA FARIAS RD (2015) Anatomical variations of the celiac trunk and hepatic arterial system: an analysis using multidetector computed tomography angiography. *Radiol Bras,* 48(6): 358-362.

BRON KM, REDMAN HC (1969) Splanchnic artery stenosis and occlusion: incidence, arteriographic and clinical manifestations. *Radiology,* 92: 323-328.

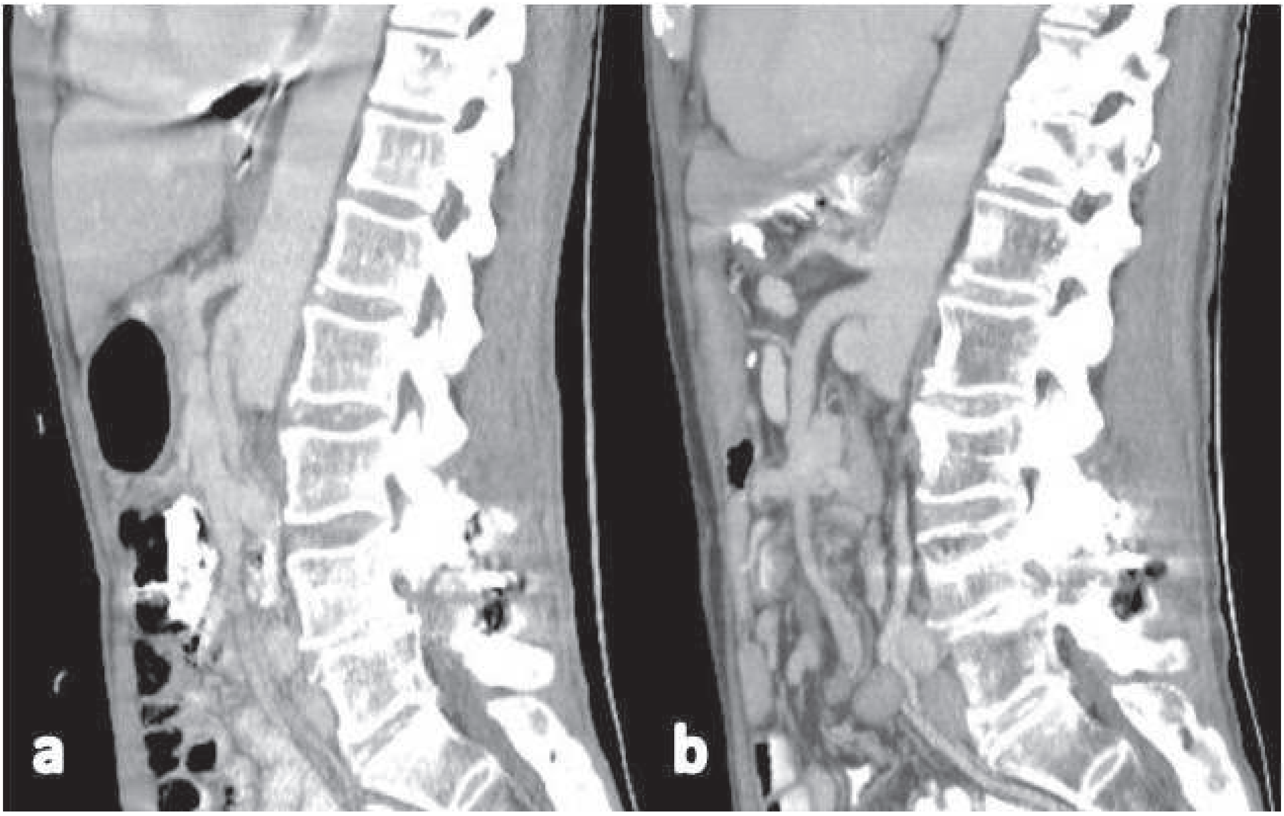

Fig. 4.- a, b. Sagittal contrast-enhanced abdominal CT images of a 61-year-old male patient taken on different dates. The distal part of the celiac trunk is displaced according to the position of the patient and intraabdominal organs while the angle of the origin is preserved.

CAVDAR S, SEHIRLI U, PEKIN B (1997) Celiacomesenteric trunk. *Clin Anat,* 10(4): 231-234.

DUNBAR JD, MOLNAR W, BEMAN FF, MARABLE SA (1965) Compression of the celiac trunk and abdominal angina. *Am J Roentgenol Radium Ther Nucl Med,* 95: 731-744.

HARJOLA PT (1963) A rare obstruction of the coeliac artery. Report of a case. *Ann Chir Gynaecol Fenn,* 52: 547-550.

HORTON KM, TALAMINI MA, FISHMAN EK (2005) Median arcuate ligament syndrome: Evaluation with CT angiography. *Radiographics,* 25: 1177-1182.

IEZZI R, COTRONEO AR, GIANCRISTOFARO D, SANTORO M, STORTO ML (2008) Multidetector-row CT angiographic imaging of the celiac trunk: anatomy andnormal variants. *Surg Radiol Anat,* 30: 303-310.

KOOPS A, WOJCIECHOWSKI B, BROERING DC, ADAM G, KRUPSKI-BERDIEN G (2004) Anatomic variations of the hepatic arteries in 604 selective celiac and superior mesenteric angiographies. *Surg Radiol Anat,* 26: 239-244.

LEE KH, YU ML, CHEUNG M (2018) The hooked proximal celiac artery. *Abdom Radiol,* 43(3): 753-754.

MARCO-CLEMENT I, MARTINEZ-BARCO A, AHUMADA N, SIMON C, VALDERRAMA JM, SANUDO J, ARRAZOLA J (2016) Anatomical variations of the celiac trunk: cadaveric and radiological study. *Surg Radiol Anat,* 38(4): 501-510.

OZBÜLBÜL NI (2011) CT angiography of the celiac trunk: anatomy, variants and pathologic findings. *Diagn Interv Radiol,* 17(2): 150-157.

PANAGOULI E, LOLIS E, VENIERATOS D (2011) A morphometric study concerning the branching points of the main arteries in humans: relationships and correlations. *Ann Anat,* 193: 86-99.

PANAGOULI E, VENIERATOS D, LOLIS E, SKANDALAKIS P (2013) Variations in the anatomy of the celiac trunk: A systematic review and clinical implications. *Ann Anat,* 195(6): 501-511.

PETNYS A, PUECH-LEAO P, ZERATI AE, RITTI-DIAS RM, NAHAS WC, NETO ED, DE LUCCIA N (2018) Prevalence of signs of celiac axis compression by the median arcuate ligament on computed tomography angiography in asymptomatic patients. *J Vasc Surg,* 68(6): 1782-1787.

SAHANI D, SAINI S, PENA C, NICHOLS S, PRASAD SR, HAHN PF, HALPERN EF, TANABE KK, MUELLER PR (2002) Using multidetector CT for preoperative vascular evaluation of liver neoplasms: technique and results. *AJR Am J Roentgenol,* 179: 53-59.

SILVEIRA LA, SILVEIRA FBC, FAZAN VPS (2009) Arterial diameter of the celiac trunk and its branches. Anatomical study. *Acta Cir Bras,* 24: 43-47.

SONE M, KATO K, HIROSE A, NAKASATO T, TOMABECHI M, EHARA S, HANARI T (2008) Impact of multislice CT angiography on planning of radiological catheter placement for hepatic arterial infusion chemotherapy. *Cardiovasc Intervent Radiol,* 31(1): 91-97.

SZILAGYI DE, RYAN RL, ELLIOTT JP, SMITH JP (1972) The celiac artery compression syndrome: does it exist? *Surgery,* 72: 849-863.

VAN PETERSEN AS, KOLKMAN JJ, MEERWALDT R, HUISMAN AB, VAN DER PALEN J, ZEEBREGTS CJ, GEELKERKEN RH (2014) Mesenteric stenosis, collaterals, and compensatory blood flow. *J Vasc Surg,* 60: 111-119.

WHITE RD, WEIR-MCCALL JR, SULLIVAN CM, MUSTAFA SA, YEAP PM, BUDAK MJ, SUDARSHAN TA, ZEALLEY IA (2015) The celiac axis revisited: anatomic variants, pathologic features, and implications for modern endovascular management. *Radiographics,* 35(3): 879-898.

WINSTON CB, LEE NA, JARNAGIN WR, TEITCHER J, DEMATTEO RP, FONG Y, BLUMGART LH (2007) CT angiography for delineation of celiac and superior mesenteric artery variants in patients undergoing hepatobiliary and pancreatic surgery. *AJR Am J Roentgenol,* 189: W13-19.