Arch. Biol. Sci., Belgrade, 66 (1), 233-240, 2014 DOI:10.2298/ABS1401233O

MDCT ANGIOGRAPHY OF ANATOMICAL VARIATIONS OF THE CELIAC TRUNK AND SUPERIOR MESENTERIC ARTERY

NEDA OGNJANOVIĆ[1], D. JEREMIĆ[1], IVANA ŽIVANOVIĆ-MAČUŽIĆ[1], MAJA SAZDANOVIĆ[2], P. SAZDANOVIĆ[1], IRENA TANASKOVIĆ[2], J. JOVANOVIĆ [3], R. POPOVIĆ[4], R. VOJINOVIĆ[3], B. MILOŠEVIĆ[3], M. MILOSAVLJEVIĆ[3], D. STOJADINOVIĆ[1], J. TOŠEVSKI[1] and MAJA VULOVIĆ[1]

[1] *Department of Anatomy and Forensic Medicine, Faculty of Medical Sciences, University of Kragujevac,* 34000 Kragujevac, Serbia
[2] *Department of Histology, Faculty of Medical Sciences, University of Kragujevac,* 34000 Kragujevac, Serbia
[3] *Clinical Center Kragujevac,* 34000 Kragujevac, Serbia
[4] *Clinical Center Ostrog,* 11000 Belgrade, Serbia

Abstract - The aim of this study was to detect and describe the existence and incidence of anatomical variations of the celiac trunk and superior mesenteric artery. The study was conducted on 150 persons, who underwent abdominal Multi-Detector Computer Tomography (MDCT) angiography, from April 2010 until November 2012. CT images were obtained with a 64-row MDCT scanner in order to analyze the vascular anatomy and anatomical variations of the celiac trunk and superior mesenteric artery. In our study, we found that 78% of patients have a classic anatomy of the celiac trunk and superior mesenteric artery. The most frequent variation was the origin of the common hepatic artery from the superior mesenteric artery (10%). The next variation, according to frequency, was the origin of the left gastric artery direct from the abdominal aorta (4%). The arc of Buhler as an anastomosis between the celiac trunk and superior mesenteric artery, was detected in 3% of cases, as was the presence of a common trunk of the celiac trunk and superior mesenteric artery (in 3% of cases). Separate origin of the splenic artery and the common hepatic artery was present in 2% of patients. The MDCT scanner gives us an insight into normal anatomy and variations of the abdominal blood vessels, which is very important in the planning of surgical interventions, especially transplantation, as well as in the prevention of complications due to ischemia.

Key words: Angiography, variation, celiac trunk, superior mesenteric artery

INTRODUCTION

The celiac trunk and the superior mesenteric artery are accepted as the most important ventral visceral branches of the abdominal aorta with regard to their vascularization field (Cicekcibasi et al., 2005). The celiac trunk, as a first ventral visceral branch of abdominal aorta, divides into three branches: the left gastric artery, the common hepatic artery and the splenic artery (Van Damme and Bonte, 1990; Oran et al., 2001; Cicekcibasi et al., 2005; Chen et al., 2009). This trifurcation of the celiac trunk has been considered as the normal vascular anatomy for many years (Van Damme and Bonte, 1990; Oran et al., 2001).

The superior mesenteric artery supplies the pancreas and intestine from the lower part of the duodenum through 2/3 of transverse colon.

Vascular aberrations and anatomical variations of the celiac trunk and the superior mesenteric artery are not infrequent and have been described in many earlier studies. These vascular variations are due to unusual embryological development of the ventral splanchnic branches of aorta (Cavdar, 1997; Oran et al., 2001; Chitra 2009). Some of the described variants of the celiac trunk are: 1) the presence of only two of three branches of the celiac trunk, when the third is the branch of superior mesenteric artery or direct branch of aorta (Van Damme and Bonte, 1985; Shoumuro et al., 1991; Harada et al., 1997; Kahraman et al., 2001; Saeed et al., 2003; Babić et al., 2008); 2) all three of the classical branches of the celiac trunk are direct branches of aorta (Van Damme and Bonte, 1985; Basar et al., 1995; Yamaka et al., 1995), and 3) the presence of a celiacomesenteric trunk – a fusion of the celiac trunk and the superior mesenteric artery (Cavdar et al., 1997; Detroux et al., 1998; Agarwal et al., 2000). Other variations are related to diameter, length or location of these abdominal vessels (Yalcin et al., 2004).

These variations resulting in variable vascular anatomy of the abdominal viscera are very important to every radiologist or surgeon in planning and conducting surgical or interventional procedures. The first description of variable hepatic arteries was published in 1756 by Haller. The vascular anatomy of the liver was examined in many studies regarding its importance for liver surgery and the therapy of unresectable advanced liver malignancies. Adachi (1928) examined the CT of 252 subjects and classified six types with 28 forms of variations. Michels (1955) proposed a recognized classification of the variations of hepatic arteries, and this classification was modified by Hiatt in 1994 (Koops, 2004).

The aim of this study was to evaluate MDCT-detected variations of the celiac trunk and superior mesenteric artery, and to compare the results with previous reports in the literature.

MATERIALS AND METHODS

This study was conducted on 150 persons who underwent abdominal MDCT angiography in the period from April 2010 until November 2012. MDCT angiography was performed at the Clinical Center in Kragujevac and private clinic "Ostrog" in Belgrade.

CT images were obtained with a 64-row MDCT scanner (Siemens AG, Medical Solutions Computed Tomography Siemensstr. 1, D-91301 Forchheim, Germany and Toshiba Aquillion 64) with a symmetrical matrix of 64 detector rows, each with a minimum slice thickness of 0.625 mm at a collimation of 0.625. Contrast administration is fundamental to the success of the examination: to inject the contrast material, we used a dual-head injector (Ulrich, GMBH %Co, Buchrunnenweg, Ulm, Germany) which allows the injection of a compact bolus of iodinated contrast material followed by a saline flush (0.9% NaCl). A patient weighing 80 Kg will require an injection of approximately 80 ml of contrast medium followed by 40 ml of saline solution (Ultravist 370, Bayer HealthCare). The injection rate, identical for contrast bolus and saline solution, should be high, as arterial enhancement is directly dependent on flow rate: in our study, a flow rate of 4.5-5.0 ml/s was used. Scan delay was established with the automatic bolus tracking technique. A region of interest was placed at the level of the thoracoabdominal aorta, and the scan was initiated when density in the region reached 150 HU.

Image analysis was performed on a dedicated Siemens console equipped with Syngo software. We used multiplanar reconstructions (MPRs) in the three spatial planes and three-dimensional reconstructions using maximum intensity projection (MIP) and volume rendering (VR).

RESULTS

We found that 78% of patients presented a classic anatomy of the celiac trunk and superior mesenteric artery. The celiac trunk arises from the ventral side of the abdominal aorta, at the level of the 12th thoracic vertebra and then divides into three branches,

Fig. 1. Origin of the common hepatic artery from the superior mesenteric artery.

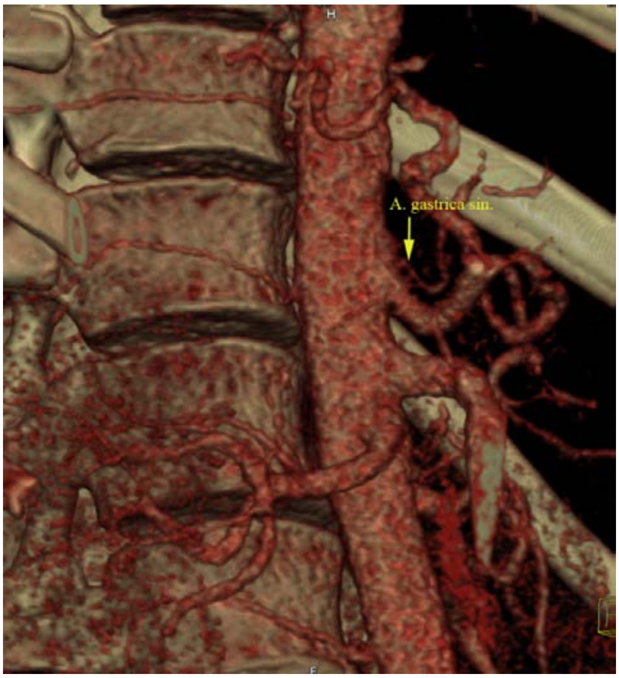

Fig. 2. Origin of the left gastric artery from the abdominal aorta.

the left gastric artery, the common hepatic artery and splenic artery. The superior mesenteric artery also has its origin on the ventral side of the abdominal aorta, lower than the origin of the celiac trunk.

Using this imaging technique, we found the existence of variations of these abdominal blood vessels in 22% of patients.

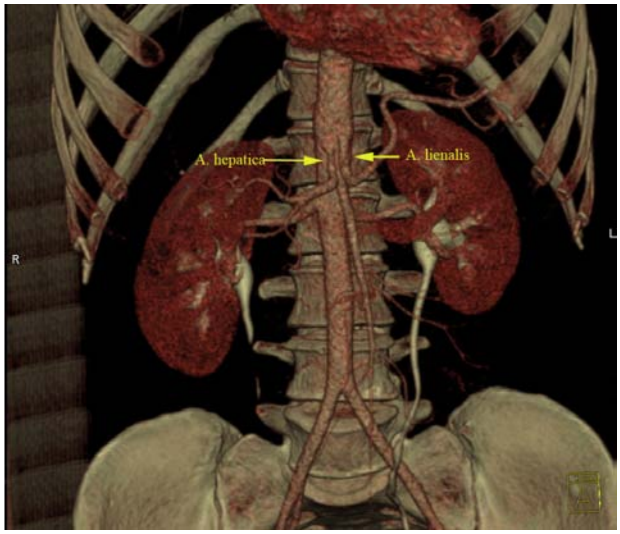

Fig. 3. Separate origins of the splenic artery and the common hepatic artery.

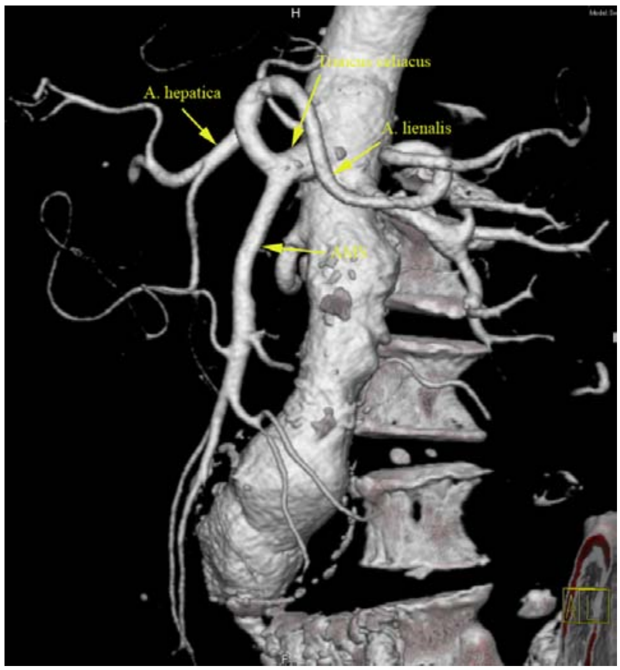

Fig. 4. The presence of a common trunk of the coeliac trunk and the superior mesenteric artery.

The most frequent variation was the origin of the common hepatic artery from the superior mesenteric artery (10%) (Fig. 1). The next variation, according to frequency, was the origin of the left gastric artery direct from the abdominal aorta (4%)

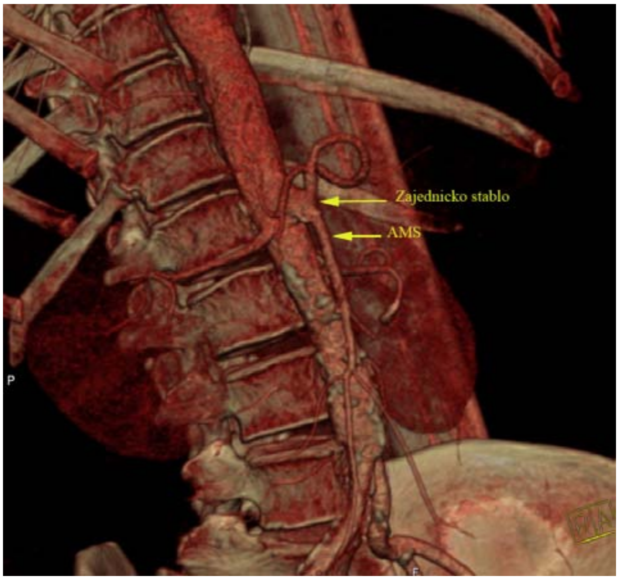

Fig. 5. The presence of a common trunk of the coeliac trunk and the superior mesenteric artery

Table 1 Michel's classification of the hepatic arteries

Type	Description
I	Normal anatomy
II	Left hepatic artery from left gastric artery
III	Right hepatic artery from superior mesenteric artery
IV	Left hepatic artery from left gastric artery and right hepatic artery from superior mesenteric artery
V	Acc. left hepatic artery from left gastric artery
VI	Acc. right hepatic artery from superior mesenteric artery
VII	Acc. left hepatic artery from left gastric artery and acc. right hepatic artery from superior mesenteric artery
VIII	Acc. left hepatic artery from left gastric artery and right hepatic artery from superior mesenteric artery
IX	Common hepatic artery from superior mesenteric artery
X	Common hepatic artery from left gastric artery

(Fig. 2). Separate origin of the splenic artery and the common hepatic artery was present in 2% of patients (Fig. 3). The presence of a common trunk of the celiac trunk and superior mesenteric artery is rarely present and this variation in our research was detected in 3% of patients (Figs. 4 and 5). The arc of Buhler as anastomosis between the celiac trunk and superior mesenteric artery was detected in 3% of cases (Fig. 6).

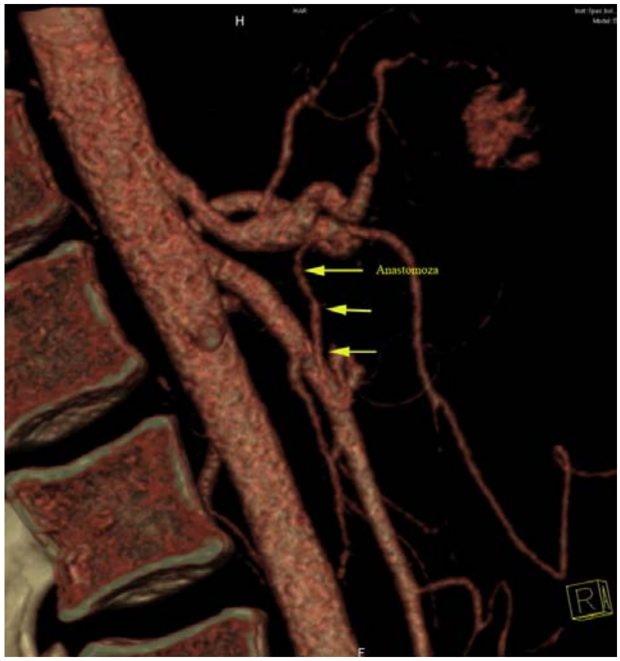

Fig. 6. The anastomosis between the coeliac trunk and the superior mesenteric artery.

DISCUSSION

Vascular anatomical variations of the celiac trunk and the superior mesenteric artery were described by Tandler in 1904, as the result of disorders during embryogenesis. During human embryogenesis, four roots of the omphalomesenteric artery, as the anterior branches of the abdominal aorta, are connected by the ventral longitudinal anastomosis (Längsanastomose). The central two of these four roots disappear during embryogenesis and the ventral anastomosis connects the first and the fourth roots. The splenic, left gastric and common hepatic artery arises from this longitudinal anastomosis. The superior mesenteric artery will come from the fourth root of omphalomesenteric artery. Retention or disappearance of any of these arteries results in arterial variation of the celiac trunk or superior mesenteric artery.

Based on hypothesis of Tandler (1904) and Morita (1935), variations of the celiac trunk are classified into 15 forms. There are no data about four of them to date. Adachi (1928) classified these anatomical variations of the celiac trunk into 6 types with 28 forms. Van Damme and Bonte (1985) and Bergman et al. (1989), after angiographic examinations, found a classic trifurcation of the celiac trunk in 86% of respondents, bifurcation in 12% and the absence of the celiac trunk in 2% of patients. Hazirolan et al. (2009), using MDCT scanners, found the trifurcation of the celiac trunk in 70% of patients, while in the study of Ferrari et al. (2007) this percentage was lower (56.7%). The results of our study have revealed the presence of classical trifurcation of the celiac trunk in 78% of patients, bifurcation in 14% and the absence of trunk in 2%, which corresponds to the results of previous studies.

Hepatic artery variations are described using Michels' (1955) and Hiatt's (1994) classification. Our results showed the existence of a ninth type of variation according to Michels' classification (Table 1), which was that the common hepatic artery arises from the superior mesenteric artery and this was found in 10% of patients. This corresponds to the fifth type of variation according to Hiatt's classification. Iezzi et al. (2008) revealed the presence of these variations in 3.6% patients. In cadaveric studies of Michels (1955) this variation was found in 4.5% of cadavers. The greater percentage of this variation in our study may be explained by the smaller number of respondents.

The left gastric artery is a direct branch of the celiac trunk. The origin of this artery from the aortic arch was described by Ferrari et al. (2007), and the percentage of this variation in their study was 1.7%, while the percentage of the same variation was 10% in the study of Piquand (1910). Hazirolan et al. (2009) showed an incidence of 3%, while the incidence of this variation in our study was 4%.

A separate origin of the splenic artery and the common hepatic artery, without the presence of the celiac trunk, is a rare variation and the incidence in our study was 2%. Winston et al. (2005) found that in 2% of cases the common hepatic artery arises directly from the aortic arch, and Ferrari et al. (2007) found this variation in 1.7% of cases.

The existence of a common celiacomesenteric trunk is a rare variation and according to available literature, it has been found in less than 2% of cases (Hazirolan et al. 2009; Yi et al., 2007; Yilmaz et al., 2013). In our study, the percentage of this variation was 3%.

Buhler's arc is the anastomosis between the superior mesenteric artery and the celiac trunk. This vascular anastomosis is present in less than 4% of individuals according to Dubel (Dubel, 2007), and 1.7% according to Ferrari et al. (2007). The types of the arterial anastomosis between the superior mesenteric artery and the celiac trunk described in the literature are as follows: 1) anastomosis between the gastroduodenal artery (the branch of the common hepatic artery, as the branch of the celiac trunk) and the inferior pancreaticoduodenal arteries (the branches of the superior mesenteric artery); 2) anastomosis between the dorsal pancreatic artery (the branch of the splenic artery, as the branch of the celiac trunk), and the anterior and posterior pancreaticoduodenal arcades (the branches of the superior mesenteric artery are parts of these arcades); 3) ventral arterial anastomosis between the superior mesenteric artery and the celiac trunk described by Buhler in 1904 (McNulty et al., 2001). The arc of Buhler was present in 3% respondents of our study, what is in agreement with the results of earlier studies.

According to the results of this study, 78% of respondents had a classic anatomy of the celiac trunk and superior mesenteric artery, but in 22% of respondents we found the existence of variations of these abdominal blood vessels. MDCT scanner gave us an insight into normal anatomy and variations of the abdominal blood vessels, which is very important for the planning of surgical interventions, especially transplantation, as well as for the prevention of complications due to ischemia.

REFERENCES

Adachi, B. (1928). Anatomie der Japaner I. das arteriensystem der Japaner. Band II. Kaiserlis-Japanischen Universitat yu Kyoto. *Maruzen Publishing Co., Kyoto*, 20-71

Agarwal, A.K., Youssef, M.K., Doyle, G.J. and *C.P.Wood* (2000). Coeliacomesenteric trunk stenosis a rare variation causing mesenteric ischaemia. *Eur. J. Vasc. Endovasc. Surg.* **20**, 405-406.

Babic, Z., Jasovic, A., Popovic, R. and *V. Babic* (2008). Anatomical variations of celiac trunk. *Abstract book, Second Congress of Serbian Anatomical Society*. 38-39.

Basar, R., Onderoglu, S., Cumhur, T., Yuksel, M. and *T. Olcer* (1995). Agenesis of the coeliac trunk: an angiographic case. *Kaibogaku Zasshi* **70**, 180-182.

Bergman, R.A., Afifi, A.K. and R. Miyauchi(1989). Http: /www.vh.org/adult/provider/anatomy/ Anatomic Variants/Cardiovascular/Text/Arteries/Coeliac Trunk.

Cavdar, S,, Sehirli, U. and *B. Pekin* (1997). Coeliacomesenteric trunk. *Clin. Anat.* **10**, 231-234.

Chen, H., Yano, R., Emura, S. and *S. Shoumura* (2009). Anatomic variation of the celiac trunk with special reference to hepatic artery patterns. *Annals of anatomy* **191**, 399-407.

Chitra, R. (2009). Clinical relevance of a rare variation in the origin of gastroduodenal artery. *International Journal of Anatomical Variations* **2**, 69-70.

Cicekibasi, A.E., Uysal, I. I., Seker, M., Tuncer, I., Büyükmumcu, M. and *A. Salbacak* (2005). A rare variation of the coeliac trunk. *Annals of anatomy* **187**, 387-491.

Detroux, M., Anidjar, S. and *R. Nottin* (1998). Aneurysm of a common celiacomesenteric trunk. *Ann. Vasc. Surg.* **12**, 78-82.

Dubel, G.J., Ahn, S.H. and *M.A. Saeed* (2007). Interventional management of arc of Buhler aneurysm. *Semin Intervent Radiol.* **24**, 76-81

Ferrari, R., De Cecco, C.N., Iafrate, F., Paolantonio, P., Rengo, M. and *A. Laghi* (2007). Anatomical variations of the coeliac trunk and the mesenteric arteries evaluated with 64-row CT angiography. *Abdominal radiology*. **112**, 988-998

Harada, H., Yamaki, K., Doi, Y., Hirata, T., Saga, T., Nishida, T., Nishimura, H. and *M. Yoshizuka* (1997). An anomalous case of the gastro-hepatic and splenomesenteric trunks independently arising from the abdominal aorta. *Kurume Med. J.* **44**, 237-240.

Hazirolan, T., Metin, Y., Karaosmanoglu, A.D., Canyigit, M., Turkbey, B., Oguz, B.S. and *M. Ariyurek* (2009). Mesenteric arterial variations detected at MDCT angiography of abdominal aorta. *AJR Am J Roentgenol*. **192**, 1097-1102

Hiatt, J.R., Gabbay, J. and *R.W. Busuttil* (1994).Surgical anatomy of the hepatic arteries in 1000 cases. *Annals of surgery*. **220**, 50-52

Iezzi, R., Cotroneo, A.R., Giancristofaro, D., Santoro, M. and *M.L. Storto* (2008). Multidetector-row CT angiographic imaging of the celiac trunk: anatomy and normal variants. *Surg Radiol Anat*. **30**, 303-310

Kahraman, G., Marur, T., Tanyeli, E. and *M. Yıldırım* (2001). Hepatomesenteric trunk. *Surg. Radiol. Anat.* **23**, 433-435.

Koops, A., Wojciechowski, B., Broering, D.C., Adam, G. and *G. Krupski-Berdien* (2004). Anatomic variations of the hepatic arteries in 604 selective celiac and superior mesenteric angiographies. *Surg. Radiol. Anat.* **26**, 239-244.

McNulty, J.G., Hickey, N., Khosa, F., O'Brien, P. and *J.P. O'Callaghan* (2001). Surgical and radiological significance of variants of Bühler's anastomotic artery: a report of three cases. *Surg Radiol Anat*. **23(4)**, 277-280

Michels, N.A. (1955). Blood supply and anatomy of the upper abdominal organs with a descriptive atlas. *JB Lippincot Co*., Philadelphia, Montreal, 3-137

Morita, M., (1935). Reports and conception of three anomalous cases on the area of the celiac and superior mesenteric arteries. Igaku Kenkyu (*Acta Med.*) **9**, 159-172

Oran, I., Yesildag, A. and *A. Memis* (2001). Aortic origin of right hepatic artery and superior mesenteric origin of splenic artery two rare variations demonstrated angiographically. *Surg. Radiol. Anat.* **23**, 349-352.

Piquand, G.(1910). Recherches suri amatomie du tronc coeliaque et des ses branches. *Bibliogr. Anat.* **19,** 159-201

Saeed, M., Murshid, K.R., Rufai, A.A., Elsayed, S.E. and *M.S. Sadiq* (2003). Coexistence of multiple anomalies in the coeliac mesenteric arterial system. *Clin. Anat.* **16**, 30-36.

Shoumuro, S., Emura, S., Utsumi, M., Chen, H., Hayakawa, D., Yamahira, T. and *H. Isono* (1991). Anatomical study on the branches of the coeliac trunk (IV). Comparison of the findings with Adachi's classification. *Kaibogaku Zasshi* **66**, 452-461.

Tandler, J. (1904). Zur entwickelunggeschicte des menschliden darmarterien. *Anat. Hefte.* **23**, 189-209, 475-499.

Van Damme, J.P. and *J. Bonte* (1990). Vascular anatomy in abdominal surgery. Georg Thieme Verlang, Stuttgart, 4-42.

Van Damme, J.P. and *J. Bonte* (1985). The branches of the coeliac trunk. *Acta. Anat.* **122**, 110-114.

Winston, C.B., Lee, N.A., Teitcher, J., Dematteo, R.P., Fong, Y. and *L.H. Blumgart* (2007). CT angiography for delineation of celiac and superior mesenteric artery variants in patients undergoing hepatobiliary and pancreatic surgery. *AJR Am J Roentgenol*.**188**, W13-W19

Yalcin, B., Kocabiyik, N., Yazar, F., Ozan, H. and *Ö. Özdogmus* (2004). Variations of the branches of the celiac trunk. *Gülhane Tip Dergisi* **46 (2)**, 163-165.

Yamaka, K., Tanaka, N., Matsushima, T., Miyazaki, K. and *M. Yoshizuka* (1995). A rare case of absence of the coeliac trunk: the left gastric, the splenic, the common hepatic and the superior mesenteric arteries arising independently from the abdominal aorta. *Anat. Anz.* **177**, 97-100.

Yi, S.Q., Terayama, H., Naito, M., Hayashi, S., Moriyama, H., Tsuchida, A. and *M. Itoh* (2007). A common celiacomesenteric trunk and a brief review of the literature. *Annals of anatomy*. **189**, 482-488

Yilmaz, M.T., Tezer M., Cicecibasi, A.E., Aydin, A.D. and *A. Salbacak* (2013). A case report of coeliacomesenteric trunk. *Biomedical Research.* **24**, 150-152