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Compression of the Celiac Artery by the Median Arcuate Ligament: Multidetector Computed Tomography Findings and Characteristics

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Abstract

Purpose: The prevalence of the celiac artery stenosis caused by median arcuate ligament (MAL) compression and its multidetector computed tomography (MDCT) characteristics were evaluated in patients who underwent abdominal MDCT procedures, retrospectively.

Methods: Totally 1121 patients who had abdominal MDCT with arterial phase or MDCT angiography of the abdominal aorta for various indications were analyzed for celiac artery compression by the MAL.

Results: Fifty (ie, 4.6%) patients showed typical MDCT features of MAL compression. Focal narrowing of the proximal celiac artery, a characteristic hooked appearance of the narrowed segment without calcification and atherosclerotic changes were diagnostic. Poststenotic dilatation was detected in 22 (44%) patients with MAL compression. The ratio of the stenosis of the celiac artery was between 35%-50% in 15 patients and 51%-80% in 35 patients. The gastroduodenal artery diameter of these patients was not significantly different from the asymptomatic control group.

Conclusion: MALS is an uncommon entity but it should be kept in mind in the presence of unexplained gastrointestinal symptoms. MDCT is a minimally invasive and plays a dominant role in the diagnosis of MAL compression especially with reformatted and 3-D reconstructed images.

Résumé

Objet : Nous avons évalué, de façon rétrospective, le taux de prévalence de la sténose du tronc cœliaque attribuable à une compression par le ligament arqué médian et les caractéristiques observées par tomodensitométrie multibarrettes (TDM multibarrettes) chez des patients ayant subi des techniques d'imagerie abdominale par TDM multibarrettes.

Méthodes : Au total, nous avons analysé le dossier de 1 121 patients ayant subi une TDM multibarrettes abdominale avec acquisition à la phase artérielle ou une angiographie par TDM multibarrettes de l'aorte abdominale pour divers motifs afin de déceler une compression du tronc cœliaque par le ligament arqué médian.

Résultats : Des caractéristiques évoquant une compression par le ligament arqué médian ont été observées par TDM multibarrettes chez 50 patients (soit 4,6 % des patients). Le rétrécissement focal de la partie proximale du tronc cœliaque, l'aspect recourbé caractéristique de ce tronçon et l'absence de calcification et de modifications athéroscléreuses ont permis d'établir le diagnostic. Une dilatation post-sténotique a été décelée chez 22 des 50 patients (44 %) qui présentaient une compression par le ligament arqué médian. Le degré de sténose du tronc cœliaque était de 35 à 50 % chez 15 patients, et de 51 à 80 % chez 35 patients. Chez ces patients, le diamètre de l'artère gastroduodénale ne différait pas sur le plan statistique de celui du groupe témoin asymptomatique.

Conclusion : Le syndrome du ligament arqué médian n'est pas courant, mais il doit être pris en considération en présence de symptômes gastro-intestinaux inexplicables. La TDM multibarrettes est une technique peu effractive et de premier plan pour établir un diagnostic de compression du tronc cœliaque par le ligament arqué médian, notamment avec des techniques de reformatage et de reconstruction tridimensionnelle des images.

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Key Words: Celiac artery; Median arcuate ligament; Median arcuate ligament syndrome; Aorta; Abdominal; Multidetector computed tomography

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The median arcuate ligament (MAL) is a fibrous arch that unites the diaphragmatic crura on either side of the aortic hiatus at the T12–L1 level. It normally passes cranial to the origin of the celiac artery [1]. A low insertion of the MAL or a high origin of the celiac artery may cause extrinsic compression of the proximal celiac artery by the MAL [2,3]. The celiac artery origin was at or above the median arcuate ligament in up to 33% [1] and in 16%, the median arcuate ligament covers the celiac artery and may compress it.

MAL syndrome (MALS) that is known as Dunbar's syndrome or celiac artery compression syndrome (CACS), is caused by external compression of the celiac artery by the MAL, and characterized by postprandial abdominal pain, nausea, vomiting, and weight loss [4]. Most patients with celiac artery compression have no symptoms [5–7]. In a small group of these patients, the celiac artery compression is severe enough to be hemodynamically significant and cause symptoms. Diagnosis is based on the presence of symptoms, typical imaging findings, and exclusion of other causes.

The development of multidetector computed tomography (MDCT) in the past few years has allowed a shorter examination time and thinner sections, while giving the possibility of sagittal reconstructed and 3-dimensional (3-D) reformatted images in abdominal examinations. With the increasing use of the MDCT, incidentally detected celiac compression is rising [5].

The aim of the present study was to evaluate the prevalence of the celiac artery stenosis caused by MAL compression in the patients who had MDCT examinations for various indications and to describe the findings and the stenosis with the clinical findings according to the MDCT findings, retrospectively. To our knowledge, there are no published studies of the prevalence of MAL compression in the general population.

Material and Methods

From September 2012 to January 2014 totally 1121 patients (522 female, 599 male; mean age 52.2 years; age range 18–93 years) who underwent abdominal MDCT with arterial phase or MDCT angiography of the abdominal aorta for various indications in our department were analysed retrospectively. The local institutional review board approved this retrospective study. No limitation used for the indications.

All examinations were performed by using a 256-slice MDCT scanner (Brilliance iCT, Phillips Healthcare, Best, the Netherlands) during full inspiration. The protocols and the timing of the abdominal MDCT arterial phase and MDCT abdominal angiography were identical in our institution that is recommended by the vendor. The scan parameters were: 80–120 Kvp tube voltage, 150–300 mAs tube current, 0.4–0.6 pitch, gantry rotation time 0.4–0.5, 1.5 mm slice thickness and 0.75 reconstruction interval, detector collimation 128×0.625 , field-of-view 30–35 cm. A volume of 50–100 ml (350 mg/mL) of nonionic contrast medium based upon patients' weight was injected through an antecubital vein at a

speed of 4.0–5.0 mL/s with an automatic power injector followed by a saline flush.

All patients had MDCT source images in our hospital's picture archiving and communication system (PACS). After recalling the source images to the workstation, 2 radiologists with more than 10 years of experience re-examined all the patients with the axial, sagittal reformatted and 3-D reconstructed images on the workstation. When a luminal narrowing of the celiac artery on the axial images, a hooked appearance on sagittal reformatted and 3-D reconstructed images were detected as described in the literature [5], MAL compression was considered with consensus of the 2 radiologists. We classified the patients in 3 groups according to their clinical symptoms based on the information given by the clinician; asymptomatic, nonepigastric pain, epigastric pain, or nausea or vomiting. Then the patients with MAL compression were evaluated in detail by clinical symptoms.

The percent of luminal narrowing of the celiac artery was detected and classified as described in the literature [8]. We have got the ratio of the narrowest diameter of the stenotic segment to the distal normal lumen's diameter. The patients with MAL compression were evaluated for poststenotic dilatation that was decided by consensus of the 2 radiologists. Because the gastroduodenal artery is the 1 of the major collateral between the superior mesenteric artery (SMA) and the celiac artery, its diameter was measured and compared with the 50 asymptomatic patients who were found to have neither stenosis nor occlusion of the celiac axis. The mean age of the control group was 52.64 (age range 24–84 years, SD 14.3; 30 female, 20 male). The diameter of the gastroduodenal artery was measured at 2 cm distance to the origin in all of the patients. For the statistical analysis of the quantitative imaging parameters and patient demographics, 1-way analysis of variance was used. A $P < .05$ indicated statistical significance.

Results

Totally 1121 patients who had abdominal MDCT with arterial phase or MDCT angiography of the abdominal aorta for various indications were analysed with the axial, sagittal reformatted and 3-D reconstructed images on the workstation, retrospectively. Fifty patients (ie, 4.46% of all patients) with a mean age of 51.4 years (age range 22–85 years, SD 15.87; 31 female, 19 male) showed typical imaging findings of MAL compression without calcification and atherosclerotic changes. Focal narrowing of the proximal celiac artery (Figure 1), a characteristic hooked appearance of the narrowed segment (Figures 2 and 3) without calcification and atherosclerotic changes were diagnostic. We detected the downward angulation of the celiac artery with no stenosis in 79 (7%) patients and noted for further evaluation in discussion.

Among these patients, 21 were asymptomatic, 22 had nonepigastric pain, and 7 (6 female, 1 male) had epigastric pain with nausea or vomiting. Postprandial characteristic of the epigastric pain is detected in 5 patients, but in 2 patients



Figure 1. Axial maximum intensity projection images of different patients demonstrate the characteristic narrowing of celiac artery (arrows) secondary to median arcuate ligament compression, (A) high-grade stenosis in short segment without poststenotic dilatation, (B) high-grade stenosis in short segment with poststenotic dilatation (arrowhead), and (C) high-grade stenosis in long segment with poststenotic dilatation (arrowhead).

pain was not related with eating. The ratio of the stenosis of the celiac artery was between 35%-50% in 15 patients and 51%-80% in 35 patients. In the symptomatic 7 patients the stenosis ratio was between 48%-70%. Poststenotic dilatation was detected in 22 (44%) patients with MAL compression (Figures 1-3). The poststenotic dilatation was present in 4 (57%) of the symptomatic patients who had epigastric pain with nausea or vomiting. The gastroduodenal artery diameter of these patients was not significantly different from the asymptomatic control group (3.36 ± 0.66 mm and 3.46 ± 0.59 mm, $P > 0.5$, respectively).

Discussion

The diaphragmatic crura arise from the anterior surface of the first to fourth lumbar vertebrae on the right and the first 2 or 3 lumbar vertebrae on the left. The crural fibers pass superiorly and surround the openings of the aorta then insert on the central. Low-lying ligament or high origin of the celiac

artery may cause the compression of the proximal celiac artery by the MAL.

The incidence of the MAL compression is found 1.76%-4% [9,10]. In our study, we detected 50 patients (4.46%) with celiac compression due to MAL. Park et al [9] evaluated 400 patients for celiac compression and found the incidence of the MAL compression as 4% in asymptomatic individuals, which is consistent with our result. In studies published by Ilica et al [11] and Gümüő et al [10] the ratio of the celiac artery compression were found 1.76% and 2.8%, respectively. In our study the female:male ratio was 31:19 (ie, 4:2.5) while in the symptomatic patients the ratio was 6:1 (ie, 4:0.7). These findings were consistent with the literature [2,5]. On the other hand, in the mean age of our group was 51.4 years and range between 22-85 years, in contrast to these studies (5), which mentioned that the compression was seen in young patients (20-40 years).

The symptoms caused by the MAL compression were first described by Harjola [12] in 1963 and then by Dunbar et al

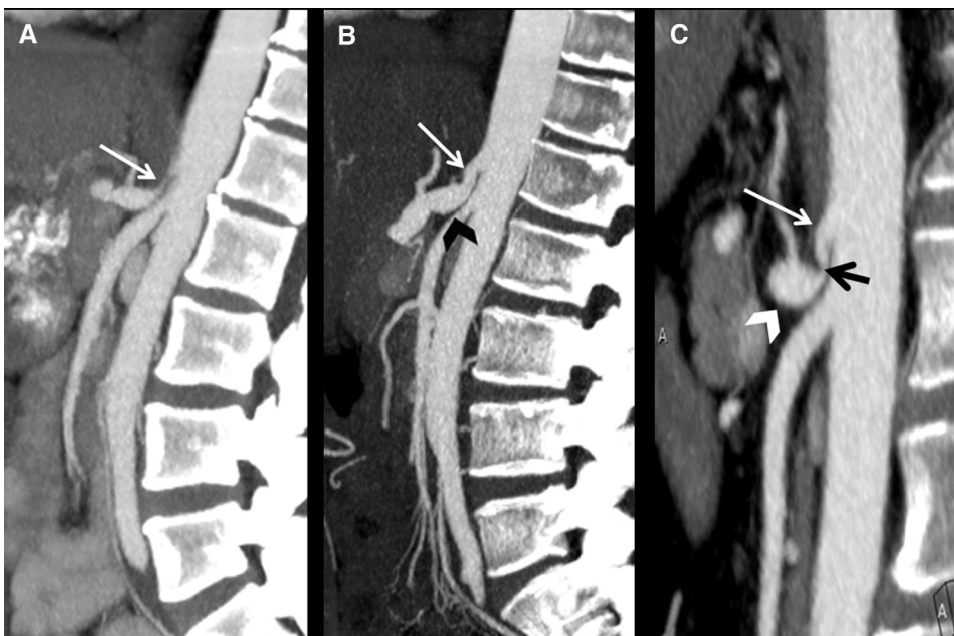


Figure 2. Sagittal reformatted maximum intensity projection images of different patients (A-C) demonstrate median arcuate ligament (arrows) compressing the proximal celiac artery, poststenotic dilatation (arrowheads), and (C) classical hooked appearance (black arrow) of the proximal celiac artery due to median arcuate ligament compression.

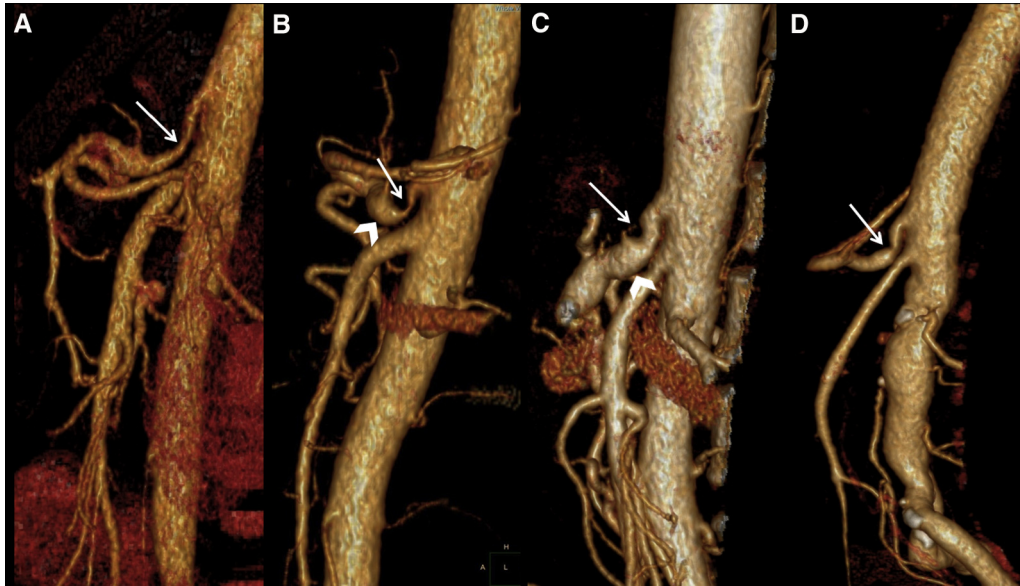


Figure 3. Sagittal 3-D volume rendering images of different patients (A-D) demonstrate focal narrowing of the proximal celiac axis caused median arcuate ligament (arrows) and poststenotic dilatation (arrowheads). This figure is available in colour online at <http://carjonline.org/>.

[13] in 1965. When narrowing of the proximal celiac trunk by the MAL compression results in clinical symptoms of epigastric pain, nausea vomiting and weight loss, MALS is considered. The relationship between the celiac stenosis and symptoms has not been completely understood. There are some theories. Symptoms are thought to arise from the compression of the celiac trunk, resulting in a decrease in blood flow and mesenteric ischemia [14]. Usually these patients become symptomatic, if the arterial blood flow is reduced by 60%-75% [15]. An alternative theory is that collateral blood supply through the SMA to the celiac artery might cause a “steal syndrome” [14]. Most celiac artery compressions present with no symptoms due to the rich collaterals between the SMA and the celiac artery. Severe stenosis, higher than 50% percent was detected in 70% of our patients and, the majority of the patients (86%) were asymptomatic. We detected poststenotic dilatation in 22 (44%) patients. We did not find any evidence of aneurysm formation in the pancreaticoduodenal arcade. In the symptomatic 7 patients the stenosis was between 48%-70% and in only 4 had poststenotic dilatation. Although the small number of symptomatic patient was the limitation of our study, we did not find any strong relationship between the percentage of the stenosis and the symptoms.

The relative position of the celiac axis and MAL varies with respiration, the celiac indentation typically is less apparent during inspiration and compression of the celiac axis typically increases during expiration [5,6]. Lee et al [6] showed that narrowing of the proximal celiac artery more than 60% was present in 16 patients at end expiration and in 12 patients at full inspiration in 97 patients without any symptoms of mesenteric ischemia who had underwent abdominal magnetic resonance angiography. During expiration, the aorta and its branches move cranially in relation to the MAL, which results in the MAL moving over the celiac

artery to cause maximal compression. Severe compression occurs in approximately 1% of patients and persists during inspiration [16,17]. Cross-sectional abdominal imaging and CT angiography are usually performed during a breath hold at full inspiration. Enterline et al [18] performed a CT angiography of the abdomen in both inspiration and expiration with a low-dose technique during a single injection of contrast. We had detected the downward angulation of the celiac artery with no stenosis in 79 (7%) of the 1121 patients. The angulation of the celiac artery without compression and stenosis during the inspiration might be a sign of the compression during expiration. On the other hand, in the symptomatic 7 patients the stenosis was between 48%-70%, the stenosis percentage might be more pronounced during expiration in these group of the patient that could be related with the symptoms. The dynamic changes in celiac artery diameter with respiration and the angle between the celiac artery and the aorta might be the investigation subjects. These are the limitations of our study. The angle between the celiac artery and the aorta and its clinical significance might be evaluated in future studies.

The development of MDCT in the past few years has allowed a shorter examination time and thinner sections. MDCT provides an excellent 3-D overview of the vascular anatomy in these patients. The characteristic finding of proximal celiac narrowing may not be seen well on routine axial images. For analysing the origin of the celiac trunk and excluding the other causes of occlusion or narrowing of celiac artery, sagittal multiplanar reformatted (MPR) reformatted and 3-D maximum intensity projection (MIP) reconstructed images are very useful. This narrowing is best visualized on sagittal MPR reformatted and 3D-MIP reconstructed images. The characteristic hooked appearance and acute downward angulation of the proximal segment of the celiac axis on the sagittal images without calcification and intimal thickening

can be used to distinguish MAL compression from atherosclerotic stenosis. The MAL compression to the celiac truncus can be diagnosed accurately by conventional angiography but direct visualization of the MAL and differential diagnosis cannot be made. The MDCT allows detailed visualization of the vascular anatomy with multiplanar reformatted, MIP, and volume rendering techniques. The MAL itself and its relation to the celiac artery can be shown accurately and noninvasively with MDCT.

The causes of celiac artery stenosis can be classified as extrinsic stenosis by the MAL, intrinsic stenosis by arteriosclerosis, and various causes including congenital and neoplastic [9,19]. The MAL is the most common cause of celiac artery stenosis in Eastern countries [9]. In conclusion, MALS is an uncommon entity but it should be kept in mind in the presence of unexplained gastrointestinal symptoms. MDCT is a minimally invasive and plays a dominant role in the diagnosis of MAL compression especially with reformatted and 3D images.

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