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RESEARCH ARTICLE

Evaluation of Abdominopelvic Vascular Compression Syndromes using Computed Tomography

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ABSTRACT

Introduction: Various abdominopelvic vascular compression syndromes can cause a wide spectrum of symptoms which can be diagnosed incidentally in asymptomatic patients or in patients in which imaging was done for other indications. The purpose of this study is to evaluate the typical imaging findings of superior mesenteric artery syndrome, median arcuate ligament syndrome, nutcracker syndrome, and May-Thurner syndrome using computed tomography and correlating with clinical symptoms.

Methods: This observational, cross-sectional study was performed on patients who were referred for computed tomography of the abdomen and pelvis for various indications. Different measurements, ratios, and common symptoms for superior mesenteric artery syndrome, median arcuate ligament syndrome, nutcracker syndrome, and May-Thurner syndrome are discussed separately under each heading.

Result: A total of 35 patients were included in this study with 10 patients each with superior mesenteric artery syndrome, median arcuate ligament syndrome, and nutcracker syndrome with five patients of May-Thurner syndrome. Out of 35, 24(68.5%) were female and 11(31.5%) were male. SMAS: The mean age of individuals was 32.7 ± 17.5 years with a mean aortomesenteric angle of 18.3° and aortomesenteric distance of 6.2 mm. MALS: The mean age of patients was 34.3± 15.8 years and the mean thickness of the median arcuate ligament was 5.4 mm. NCS: The mean age of patients was 37 ± 22 years and the mean compression ratio was 3.9. MTS: Mean age was 45± 14.2 years with mean diameter of LCIV 2.4 mm.

Conclusion: Abdominopelvic compression syndromes are rare and often underdiagnosed because of a lack of awareness among clinicians and radiologists. Contrast-enhanced triple-phase computed tomography is performed to maximize the visibility of involved vessels in different planes and allow the identification of typical imaging features and possible complications.

Keywords: Vascular compression syndromes; Computed tomography; Symptoms.

Introduction

Many vascular structures in the abdomen and pelvis may be compressed by adjacent structures or they themselves may compress adjacent hollow viscus and result in a variety of clinical symptoms. Mostly in our practice, these subtle findings can be easily missed or go undiagnosed in a vague clinical setting. Sometimes these compression syndromes are seen incidentally however in symptomatic patients it may manifest with a variety of nonspecific abdominal symptoms, ranging from vague abdominal pain, nausea and vomiting, loss of weight to acute abdominal hemorrhage, arterial ischemia and venous stasis and thrombosis, making the clinical diagnosis challenging. [1] Some common abdominopelvic vascular compressions include superior mesenteric artery syndrome, median arcuate ligament syndrome (celiac artery compression syndrome), nutcracker syndrome (renal vein entrapment syndrome), and May-Thurner syndrome (left common iliac vein [LCIV] compression syndrome). Diagnosis of vascular compression syndromes is based on a comparison of clinical and imaging findings. [2] Multiple invasive and non-invasive investigations can be done to detect these conditions with Ultrasonography (USG), computed tomography (CT), and Magnetic resonance imaging (MRI) being the common noninvasive techniques. Owing to its high contrast, spatial and temporal resolution, remarkable accuracy, widespread accessibility, and speed; contrast-enhanced computed tomography (CECT) is the recommended modality of choice for many of these syndromes providing accurate detection of vascular structures and their relationship with adjacent organs. [3] Also, multiplanar reformations (MPR), maximum intensity projections (MIP), and 3D (three-dimensional) volume rendering can be performed for better delineation of the vessels.

This study aims to evaluate the typical imaging findings and major clinical symptoms of superior mesenteric artery (SMA) syndrome, median arcuate ligament syndrome (MALS), nutcracker syndrome (NCS), and May-Thurner syndrome (MTS) and thus aid the surgeon in deciding if the patients require surgical intervention.

Superior Mesenteric Artery Syndrome: First described by Wilkie in 1927 [4] it refers to compression of the third portion of the duodenum between the abdominal aorta and the superior mesenteric artery itself, resulting in duodenal obstruction. The duodenum typically passes through the aortomesenteric plane with a protective layer of mesenteric adipose tissue, which serves as a natural fatty cushion to prevent external compression. Depletion of this fatty cushion and a decrease in aortomesenteric angle are the primary causes of SMA syndrome.

Median arcuate ligament syndrome: First described by Harjola [5], also known as celiac artery compression syndrome or Dunbar syndrome refers to external compression of the celiac artery root by the median arcuate ligament. The median arcuate ligament is a fibrous arch that connects the right and left diaphragmatic crura on either side of the aortic hiatus. A higher origin of the celiac artery or the lower insertion of the median arcuate ligament may result in this syndrome.

Nutcracker Syndrome: First described by El-Sadr and Mina in 1950 [6] it refers to symptomatic compression of the left renal vein (LRV) by the aorta and superior mesenteric artery (SMA). It is often referred to as "anterior nutcracker syndrome." Less commonly, a circumaortic or completely retroaortic LRV may be compressed between the aorta and vertebral body, which is termed "posterior nutcracker syndrome" [7]

May-Thurner Syndrome: First jointly described by May and Thurner in 1957 [8] it refers to symptomatic compression of the left common iliac vein between the overlying right common iliac artery and the lumbar vertebrae usually the fifth. The inferior vena cava is situated on the right side of the spine, while the left common iliac vein intersects at an acute angle, crossing the midline at the point where the lumbar vertebrae exhibit their most noticeable natural curvature. MTS can result in persistent venous stasis, which can lead to thrombosis in the left iliac and femoral veins.

Methodology

This observational, cross-sectional study was performed in patients sent for CECT abdomen and pelvis in our department from November 2021 to September 2023 excluding the patients in which surgical treatment or endovascular stent placement was done and patients refusing to give consent. The study consisted of 35 patients. Institutional review committee approval was obtained. This study aims to evaluate the common clinical symptoms seen in these syndromes, patient demographics, and characteristic imaging findings for each condition.

All patients were evaluated by GE (General Electronics) Revolution Evo 128 slice CT scan (120KV/ 200mA / 34.2x24.5cm FOV / collimation 0.6). For contrast studies, non-ionic contrast (IOHEXOL) was given via pressure injector, and sections were taken in hepatic arterial phase (HAP) at 22-27 seconds, portal venous phase (PVP) at 40-60 seconds, and delayed phase (DP) at 5-8 minutes

in craniocaudal direction from superior to the inferior margin of the liver. 5mm slice thickness images were reformatted and reconstructed in the various sections in the workstation and multiplanar reformations (MPR), maximum intensity projections (MIP), and 3D volume rendering were performed.

Different measurement techniques and accepted values for each of the syndromes are discussed below in detail.

Superior mesenteric artery syndrome: Reformatted sagittal CT images were used which allows to measure the aortomesenteric angle and distance on the arterial phase accurately. [9, 10] The cut-off value considered for the diagnosis of SMA syndrome was an aortomesenteric angle (AMA) less than 6-22° and an aortomesenteric distance (AMD) shorter than 2-8 mm. [11]

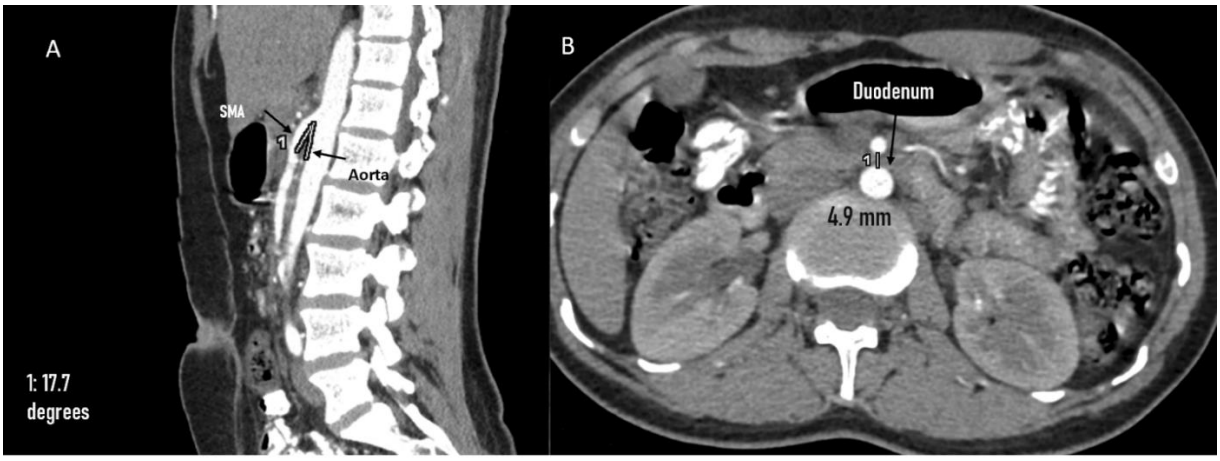

***Figure 1**: Measuring aortomesenteric angle and aortomesenteric distance in SMA syndrome. (A) Sagittal CT image on arterial phase shows measurement of aortomesenteric angle (17.7°). (B) Axial CT image on arterial phase demonstrates compression of the third part of duodenum between aorta and SMA and measurement of the aortomesenteric distance (4.9 mm), the values diagnostic for superior mesenteric artery syndrome.*

For Median arcuate ligament syndrome: Sagittal and coronal sections were used for optimal visualization of the celiac trunk. Images were taken in deep expiration in the early arterial phase to increase the proximal celiac trunk compression by the median arcuate ligament, followed by the portal venous phase in deep inspiration. [12] Asymmetry and thickness of median arcuate ligament were assessed. Thickness more than 4 mm was considered abnormal. [1] Focal narrowing of the superior aspect of the celiac axis can be seen giving a 'hooked appearance'.

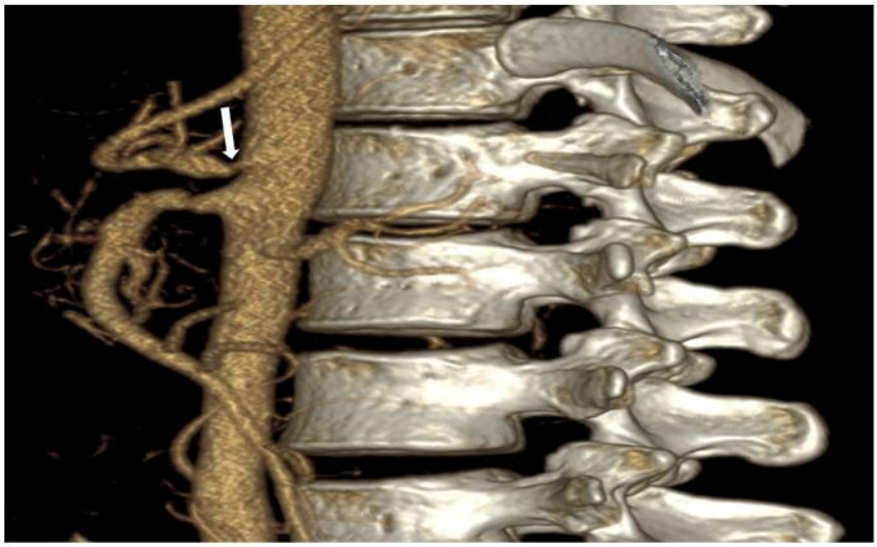

***Figure 2:** 3D reconstructed computed tomography angiography of the celiac artery compression syndrome demonstrates the characteristic 'hooked' narrowing of the proximal celiac artery (arrow) with post-stenotic dilatation.*

For Nutcracker syndrome: Images were viewed in axial and sagittal planes in both arterial and venous phases. 'Beak Sign' seen in CT is an abrupt narrowing of LRV at the aortomesenteric portion between the aorta and SMA with distal dilatation of LRV. [13] Ratio of dilated distal LRV to stenosed LRV was calculated. The diagnosis of anterior NCS may be made when AMA is less than 35° and aortomesenteric distance less than 8 mm. [14]

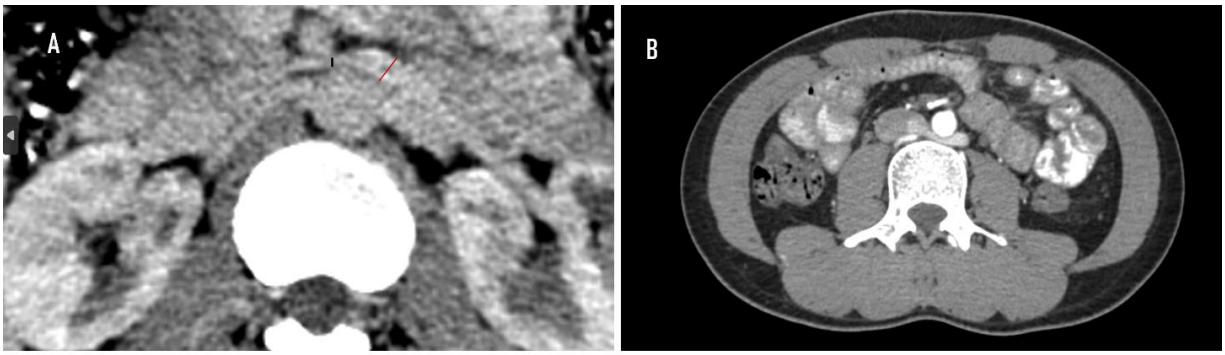

***Figure 3**: Measuring left renal vein diameter in nutcracker syndrome. (A) Axial CT image on portal venous phase shows measurement of pre compressed (red line) and compressed segment (black line) of left renal vein. (B) Axial CT image on arterial phase demonstrates retro-aortic left renal vein which is being compressed between aorta and vertebral body.*

For May Thurner Syndrome: There are no known radiological signs that are diagnostic of May-Thurner syndrome (MTS). Contrast-enhanced CT images in venous and delayed phases are often sufficient to visualize the iliac vein compression and associated deep vein thrombosis and venous collaterals. Further, CT helps in excluding other causes of iliac vein compression such as pelvic mass or lymph nodes.

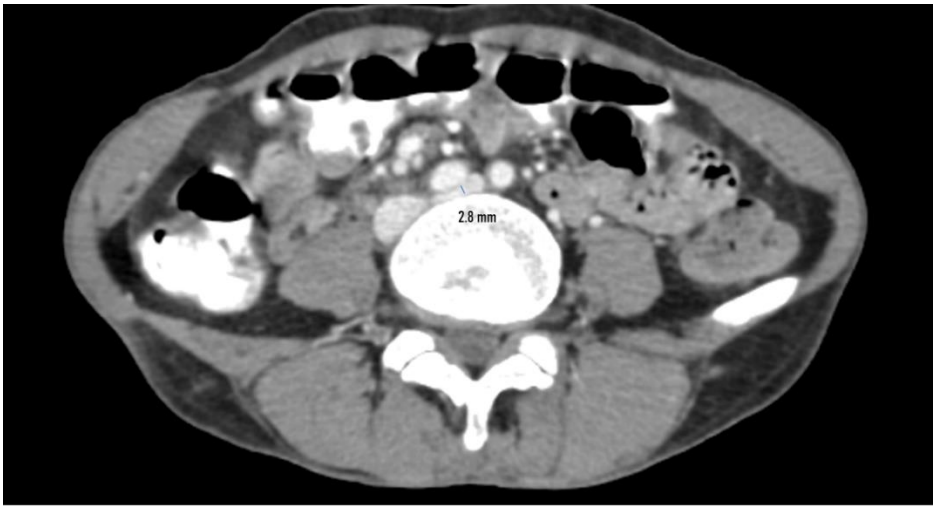

***Figure 4:** Axial CT image on portal venous phase demonstrates compression of left common iliac vein by overlying right common iliac artery. Diameter of LCIV is 2.8 mm.*

For accurate measurements, all the images were magnified. The statistical analysis was done using a statistical package for the social sciences (SPSS) version 26. Mean, standard deviation, minimum, and maximum diameters and ratios were calculated.

Results

A total 35 number of patients were included in this study with 10 patients each of SMA syndrome, MALS, and NCS and 5 patients with MTS. Statistical findings, patient demographics, and common symptoms are discussed separately for each of the syndromes. Sex distribution for each syndrome is illustrated in Figure 4.

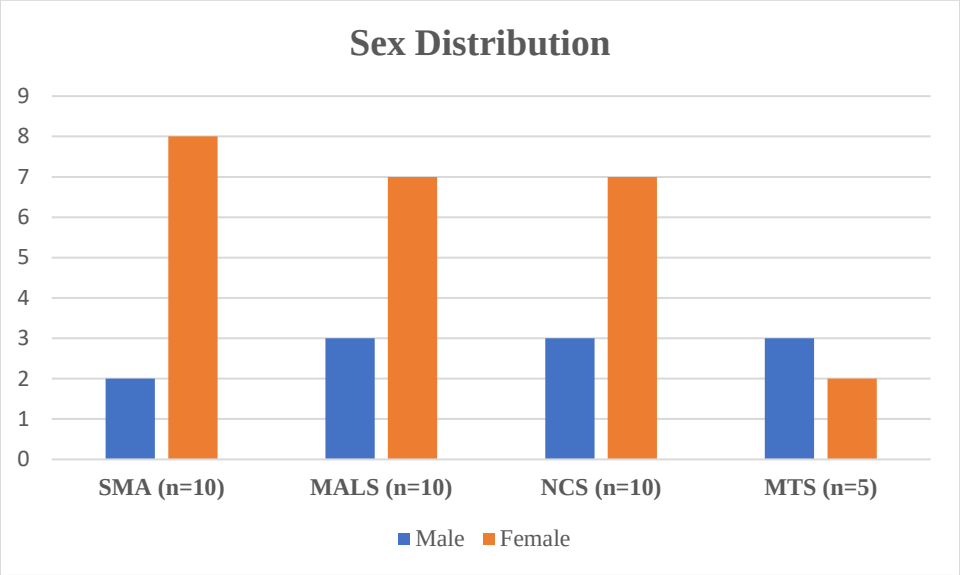

Figure 4: *Bar Graph showing sex distribution for each syndrome separately.*

Superior mesenteric artery syndrome: Out of 10, 8 were female and 2 were male. The age of individuals ranged from 13 to 65 years with a mean age of 32.7 ± 17.5 years. The mean aortomesenteric angle was 18.3 degrees and the aortomesenteric distance was 6.2 mm. Common clinical symptoms included post-prandial pain (70%), nausea (60%), vomiting, and weight loss (40%).

Median arcuate ligament syndrome: 7 female patients and 3 males with ages ranging from 21 to 68 years were included with a mean age of 34.3± 15.8 years. The mean thickness of the median arcuate ligament was 5.4 mm. Almost all the patients presented with post-prandial abdominal pain (100%). Other symptoms comprised of nausea/ vomiting (60%) and less commonly weight loss (10%).

Nutcracker syndrome: Out of 10, the majority were females (70%). The mean age was years 37 ± 22 years with ages ranging from 17 to 82 years. The mean compression ratio was 3.9. A total of 8 patients had anterior NCS and 2 had posterior NCS with at least 4 associated SMA syndrome. In all of the patients, AMA was <35 degrees. 7 patients complained of diffuse abdominal pain while 3 had left flank pain. Hematuria was observed in 4 patients and proteinuria in 2.

May-Thurner syndrome: 3 male and 2 female patients were evaluated with a mean age of 45± 14.2 years (ages ranging from 29 to 67 years). The mean diameter of LCIV was 2.48mm. Common symptoms included dull aching pain and swelling of the left leg (80%). Two patients had associated deep venous thrombosis (DVT).

Discussion

Vascular compression syndromes are medical conditions arising from the confinement of one or multiple blood vessels between rigid or partially rigid surfaces within a limited anatomical area. They are usually infrequent (<1 % of the general population affected) and asymptomatic, however, if present, they can give rise to numerous complications that have the potential to be life-threatening, if not treated. The precise occurrence rate of these syndromes remains uncertain, but it can be approximated by considering the prevalence of underlying anatomical variations that predispose individuals to them. Although these abdominopelvic vascular compression syndromes have been described in various literature for almost a century, it is not well understood and may often go unnoticed in our regular practice or in the background of some other illness. Furthermore, the lack of standard diagnostic criteria in these compression syndromes often makes the diagnosis challenging. A fundamental comprehension of these syndromes and an awareness of their clinical and radiological characteristics are crucial. Triple-phase contrast-enhanced computed tomography (CECT) is the preferred minimally invasive method for assessing these conditions due to its capability to create image reconstructions in various planes and generate three-dimensional renderings. This advanced imaging technique allows healthcare professionals to thoroughly and accurately examine these syndromes, enabling them to make informed diagnoses and treatment decisions based on the collected data. Alternatively, magnetic resonance imaging (MRI) is usually preferred in children, young patients, and pre-menopausal to avoid radiation exposure. Ultrasonography (US) is largely operator and patient-dependent, although doppler US can

provide information on the flow velocity and vessel caliber.[15]

Superior mesenteric artery syndrome: Thinning out of the retroperitoneal fat pad between SMA and aorta, consequently upon weight loss or in thin patients, narrows the aortomesenteric angle and distance, thereby compressing the duodenum and thus producing the clinical manifestations of the syndrome. The prevalence of SMA syndrome is around 0.0024–0.03% and it may coexist with anterior NCS due to the common pathogenesis. [16] Many authors have agreed that when the AMA decreases to 6-22 degrees and AMD decreases from 2-8 mm compression of the duodenum can occur [3,9,17]. Our study showed a mean AMA of 18.3 degrees and a mean AMA of 6.23mm which is in line with their studies. Sense of fullness, postprandial epigastric pain, belching, and vomiting are characteristic features with pain and vomiting being the most prevalent symptoms in our study.

Median arcuate ligament syndrome: Major clinical symptoms of MALS include a triad of postprandial pain, nausea/ vomiting, and weight loss. [18] In our study postprandial pain was seen in all of the patients followed by nausea/ vomiting. Previous studies show this disease is usually encountered in young female population[18, 19]. The mean age of patients in our study was 34.3 ± 15.8 years with 70% female predominance. Apart from the classic 'hooked appearance' of the celiac trunk, our study showed asymmetry of MAL with a mean thickness of 5.4mm. Eliahou R et. Al [1] and Narwani P et al [20] in their study stated a thickness of more than 4mm be considered abnormal.

Nutcracker syndrome: Park SH et al [13] and He Y et al [14] in their study found that in NCS the ratio of dilated distal portion and compressed segment to be approximately 4:1. Another study done by Hangge PT et al [21] found pre-compression to compression ratio of the LRV over 2.25 demonstrated 91% specificity and sensitivity and thus compression ratio of the LRV over 2.25 should raise suspicion for NCS in the context of clinical symptoms. The mean ratio in our study was 3.9:1 which is similar to their studies. [13, 14] Also, in our study, patients with a higher compression ratio (>4.2) were associated with hematuria and a greater degree of abdominal pain.

May-Thurner syndrome: Recognition of the use of CT scan to diagnose this disease has recently been established. In a study done by Chung et al [22] 37 out of 44 patients with left-sided deep vein thrombosis (DVT) had significant compression of LCIV or inferior vena cava (IVC). In our study, 2 patients with DVT were associated with compression of LCIV. Although there are not enough studies that determine the actual cutoff diameter of compressed LCIV, one study done by Oguzkurt L et al [23] found the mean diameter to be less than 3.5mm. In our study the mean diameter was 2.4mm, however, the cut-off diameter could not be concluded due to small number of patients.

Conclusion

Abdominopelvic vascular compression syndromes discussed in this study are relatively uncommon and can cause a wide spectrum of atypical symptoms which on imaging can be underdiagnosed because of a lack of awareness in a vague clinical setting. These findings may be discovered in young, apparently asymptomatic patients who have undergone imaging for unrelated indications. Frequently, patients in whom the source of these symptoms is not found are sent for psychiatric evaluation for pain management. Thus, it is important to have knowledge of classic imaging findings and related clinical symptoms of these syndromes for accurate diagnosis. Different modalities can be used to assess the anatomy and compression of the vessels, however, contrast-enhanced triple-phase CECT is performed in order to maximize the visibility of involved vessels in different planes and allow the identification of typical imaging features and possible complications.

Limitations

This study has a number of limitations. Due to a small number of patients and a single institute-based study, it is not possible to conclude the exact values and ratio of the vessels. Although surgical intervention is the definitive choice of management in these diseases, in a low-income country having limited resources and a lack of clinical experience in doctors; it is seldom performed. However, we believe this study provides an overview to what a radiologist needs to know when diagnosing these conditions.

Conflict Of Interest

None

Sources Of Funding

None

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