Unveiling the Significance of Body Mass Index in Diagnosis of Superior Mesenteric Artery Syndrome: A Hidden Link

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ABSTRACT
Background & Aims: The superior mesenteric artery syndrome (SMAS) is an uncommon syndrome characterized by the compression of the third part of the duodenum between the superior mesenteric artery (SMA) and abdominal aorta with resultant proximal duodenal dilatation. The radiological diagnosis of the SMAS is based on reduced angle and distance between the SMA and aorta in presence of proximal duodenal dilatation. A reduction in these is closely associated with depletion of the mesenteric fat between the vessels. Our primary aim is to establish the relationship, if any, of body mass index (BMI) with the angle and distance between the SMA and abdominal aorta in general population. **Materials and Methods:** This study was carried out in 200 patients who had undergone contrast enhanced computed tomography for various other complaints. Various parameters such as aortomesenteric distance (AMD) and aortomesenteric angle (AMA) along with the body mass indices were calculated. Pearson correlation coefficients were calculated to establish the relationship between BMI, AMD and AMA. **Results:** Pearson's correlation coefficient for BMI and AMD was 0.868, indicating strong positive correlation and 0.577 for BMI and AMA, indicating moderate positive correlation. Furthermore, AMD and AMA also showed positive correlation with Pearson's correlation coefficient of 0.568. **Conclusion:** There is significant positive correlation of BMI with AMD and AMA in general population suggesting people with low BMI are at an increased risk of developing SMAS.
Keywords: Aortomesenteric angle, Aortomesenteric Distance, Body mass index, Superior mesenteric Artery Syndrome. Computed Tomography

INTRODUCTION
Superior mesenteric artery syndrome (SMAS), also known as Wilkie's syndrome was first discovered by Rokitansky in 1861[1]. It is an uncommon vascular compression disorder characterized by the compression of the third part of the duodenum between the aorta and superior mesenteric artery (SMA) due to very acute angulation and reduced distance between the vessels. Also known as chronic duodenal ileus, megaduodenum, arteriomesenteric duodenal obstruction, aortomesenteric artery compression and chronic duodenal pseudo obstruction, it has a general prevalence rate of 0.1–0.3 % and is more commonly seen in females and young adults[2]. The diagnosis of the SMAS is made on the basis of reduced distance and angle between the superior mesenteric artery (SMA) and abdominal aorta in arterial phase on CT scan in the presence of proximal duodenal dilatation[3]. According to previous studies, several factors lead to reduced aortomesenteric angle (AMA) and aortomesenteric distance (AMD) including reduced body weight, prior history of some abdominal surgery, prolonged immobility, lordosis or body

casts[4]. Computed tomography serves as an accurate method in diagnosing and evaluating the relevant anatomy as compared to fluoroscopy and ultrasound. In this study, we aimed to assess the relationship, if any, of the angle and distance between the SMA and abdominal aorta with body mass index (BMI) in general adult population and to establish significance of BMI in diagnosis of SMAS.

MATERIALS AND METHODS

This was a single centre study undertaken in patients who were referred to CT scan department of LG hospital for various other complaints from November 2022 to March 2023. Patients with scoliosis, previous abdominal surgery, significant abdominal fluid, mass lesion and tortuous abdominal aorta that might disrupt the normal anatomy were not included in this study. Patients who were previously diagnosed with SMA syndrome were also excluded. The study comprised of 200 subjects of the age range 18 to 90 years. CT scan was done on 16 - slice Philips MX-16 multidetector scanner with routine protocol comprising of non-enhanced plain phase followed by contrast (80–100 ml Omnipaque) enhanced arterial and venous phases. The values for the study were obtained in the arterial phase using multiplanar reformatted axial and sagittal images. AMD was measured on axial images as the maximum distance between the anterior wall of the aorta and the posterior wall of the SMA at the level where the left renal vein and duodenum intersect. AMA was measured on sagittal images at a point 1 cm from the posterior wall of the SMA and 1 cm from the anterior wall of the aorta, at the level SMA origin. If the AMA angle did not lie in the true sagittal plane, oblique plane was used for an accurate measure between the aorta and SMA. Mean values of distance and angle measurements were calculated with 95 % confidence intervals BMI was calculated for each patient as BMI = weight/(height)^2. Pearson correlation coefficients were calculated between distance, angle, and BMI and also between AMD and AMA.

RESULTS

Of the 200 patients who underwent CT scan, 93(46.7%) were male and 107 (53.3%) were female, with the average age of 44 years , minimum being 18 years and maximum being 90 years. The mean BMI was 24.72 kg/m^2.

Table 1: Distribution of AMA with various BMI categories

BMI group	AMD (mm)					Total
	>0-10	>10-20	>20-30	>30-40	>40	
Underweight (<18.5)	33	13	3	0	0	49
Healthy weight (18.5-24.9)	8	34	11	1	0	54
Overweight (25.0-29.9)	0	12	23	7	0	42
Obese (>30)	0	0	23	24	8	55

The mean values for the AMD and AMA were 19.78 ± 10.02 mm and 45.08° ± 12.01° respectively. The lowest AMD, 4mm was found in underweight patient with BMI 15kg/m^2, whereas the AMD, 41mm was found in obese patient with BMI 36 kg/m^2. Further, the lowest AMA, 25° was found in underweight patient with BMI 15 kg/m^2, whereas the highest AMA, 78° was found in patient with BMI 33 kg/m^2

Table 2: Distribution of AMA with various BMI categories

BMI Group	AMA (degrees)						Total
	0-20	20-40	40-60	60-80	80-100	>100-120	
Underweight (<18.5)	0	35	13	1	0	0	49
Healthy Weight (18.5-24.9)	0	27	25	2	0	0	54
Overweight (25.0-29.9)	0	19	22	1	0	0	42
Obese (>30)	0	1	36	18	0	0	55

Pearson's correlation coefficient (r) is a measure of the strength of the association between the two variables and ranges from -1 to +1. +1 indicates a perfect positive correlation and -1 indicates a perfect negative correlation.

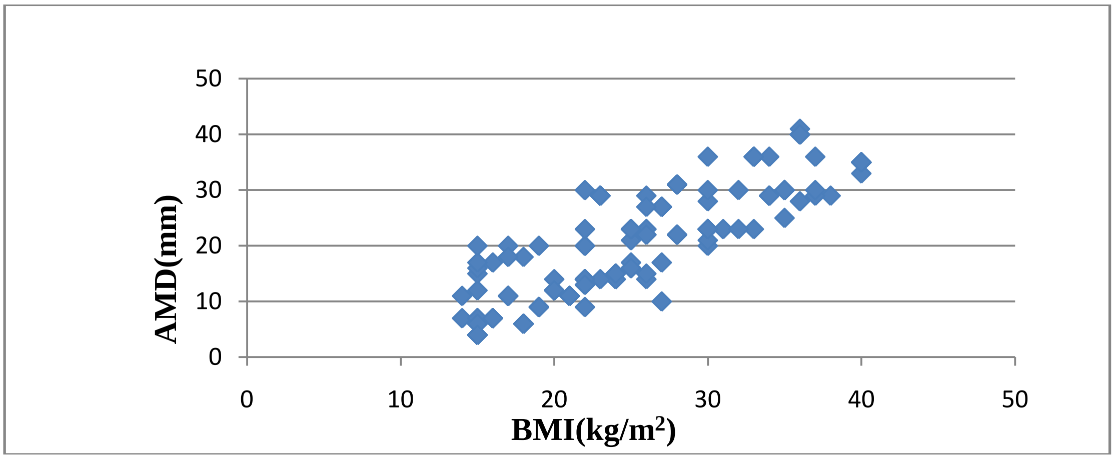

Figure 1: Scatter Diagram Depicting Positive Correlation of BMI with AMD

As shown in figure 1, BMI and AMD showed statistically significant strong positive correlation with Pearson's correlation coefficient (r) of 0.868 at $p < 0.001$.

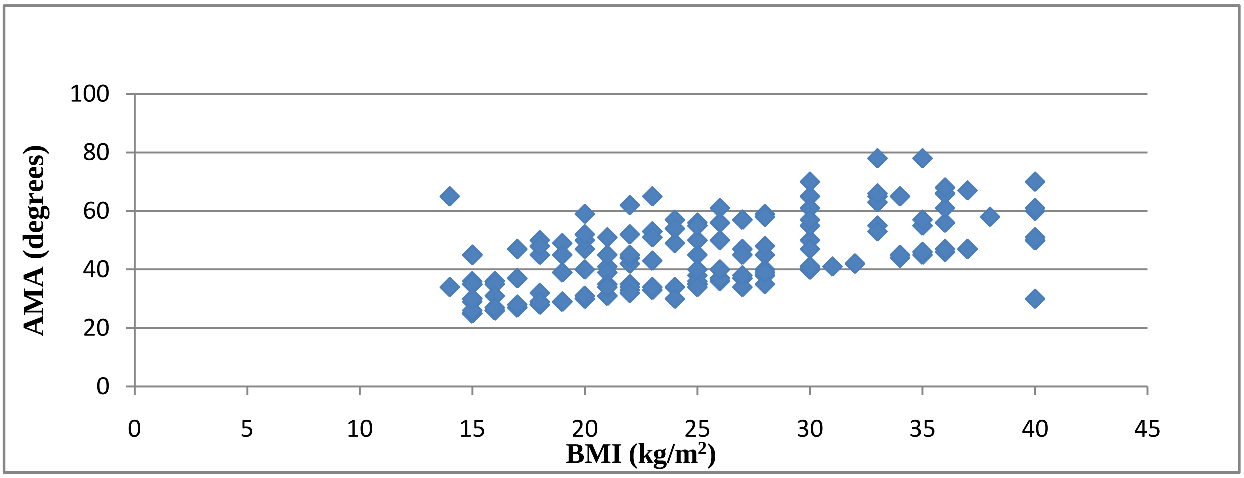

Figure 2: Scatter Diagram Depicting Positive Correlation of BMI with AMA

As shown in figure 2, BMI and AMA showed statistically significant moderate positive correlation with Pearson's correlation coefficient (r) of 0.577 at $p < 0.001$.
Furthermore AMD and AMA also showed statistically significant moderate positive correlation with Pearson's correlation coefficient of 0.568 at $p < 0.001$.
This indicates that there is potential for high BMI values to go with high AMD and AMA values and vice versa.

Figure 3(a) and 3(b): CECT axial and sagittal images at the level of SMA origin depicting reduced AMD and AMA respectively, in a case with low BMI who presented with recurrent epigastric pain and vomiting.

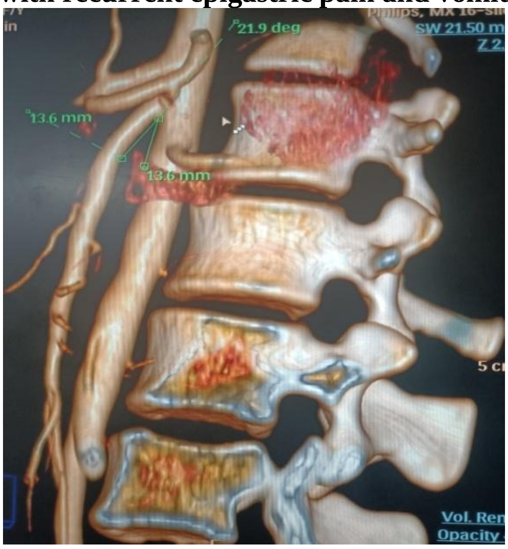

Figure 4: 3D reconstruction in the same patient demonstrated the vascular anatomy with high accuracy.

DISCUSSION

The SMA is the second major branch of abdominal aorta that arises from its anterior aspect at the L1 vertebral body level, approximately 1cm inferior to the origin of celiac trunk and superior to the origin of renal arteries. It descends inferiorly and along the posterior aspect of the abdominal wall at an acute angle into the mesentery. The aorta runs posteriorly and parallel to the SMA. The caudal part of SMA generally forms an angle of 45° with the aorta; normal angle ranging from 25° to 60°[5]. The normal AMD is measured as duodenum passes between aorta and SMA at the level of intersection of left renal vein with third part of duodenum. The normal AMD is typically between 10-28mm.[5]

The duodenum is generally surrounded by mesenteric adipose tissue as it passes through the aortomesenteric plane that prevents its extrinsic compression. Hence, any condition causing depletion of this adipose tissue leads to acute narrowing of the AMA (<22°) along with reduction of AMD and results in compression of the third part of the duodenum leading to SMA syndrome. This fat depletion is generally seen with acute catabolic states or chronic debilitating diseases that cause significant weight loss namely, anorexia nervosa, immunodeficiency diseases like AIDS, tuberculosis and burns, malabsorption syndromes, major surgery, and malignancy.[6] It is also seen in patients with low body mass index as seen in this study. Anatomical variations such as increased lumbar lordosis[4], short ligament of Treitz, high fixated duodenum by ligament of Treitz, low origin of SMA, anomalous SMA directly crossing over aorta and corrective scoliosis surgeries may also precipitate the syndrome[7]. It is more commonly seen in females and young adults. Decreased AMA and AMD not only compresses the duodenum, but at times compresses the left renal vein, resulting in Nutcracker Syndrome[8]

A patient with SMAS may either present acutely with abdominal distension and signs of duodenal obstruction or have chronic symptoms such as recurrent postprandial epigastric pain which worsens in supine position, early satiety, nausea, vomiting, and anorexia and weight loss.[9]

Imaging findings include non-specific air or fluid filled dilatation of stomach and proximal duodenal loops on plain abdominal x-ray. On fluoroscopy, which was earlier the modality of choice for diagnosing SMAS, dilated first and second parts of duodenum (with or without gastric distension) with an abrupt termination at the third part of duodenum is seen[8]. Distal bowel loops appears collapsed. Other findings include vertical compression of the duodenal folds at the third part of duodenum, antiperistaltic flow of the contrast material proximal to the obstruction resulting in to and fro rocking flow of barium and a relief of obstruction when the patient is turned to left lateral decubitus or prone position[8]. Ultrasonography can be used to measure SMA angle and distance from the aorta, however it is of little value in obese patients. CT and MRI are both used to accurately measure the SMA angle and distance and demonstrate vascular compression of the third part of duodenum and is now the mainstay in diagnosing SMAS. CT criteria for the diagnosis of SMA syndrome include an AMA of less than 22° and an AMD of less than 8–10 mm in presence of proximal duodenal dilatation[10].

In an acute condition, the primary management is conservative and includes relief of compression by postural change into prone knee–elbow position, decompression by nasogastric tube as well as providing enteral feeding and weight gain. Surgery is indicated only if conservative treatments fails or in patients with severe symptoms. Traditionally open duodenojejunostomy was the surgery of choice with success rate of 79% -80%. However a review of nine articles found laproscopic duodenojejunostomy more effective with a success rate of 100%[8].

Several studies conducted previously have pointed out the association of low BMI with low AMA and AMD values[11]. A study conducted by Desai et al showed a strong positive correlation between BMI and AMA and moderate positive correlation between BMI and AMD, with coefficients of 0.95 and 0.76 respectively [1], which is in concordance to our study. It also showed positive correlation between AMA and AMD[1]. Similar results were seen in a study conducted by Ozkurt et al that found strong positive correlation between BMI and AMD with coefficients of 0.86 and mild positive correlation between BMI and AMA with coefficient of 0.29[12].

The main drawback of the study was a small sample size, which limits us from standardising the results.

CONCLUSION

This study proves that a decreased BMI would lead to decrease in AMD and AMA and vice versa and may serve as a precursor to SMAS. Awareness of the syndrome and its hidden link to BMI prevents us from missing it on cursory review of radiologic examination in patients with vague symptoms. Moreover it ensures proper diagnosis and initiation of early and accurate treatment.

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