Measurement of the Distance and Angle Between the Aorta and Superior Mesenteric Artery on CT Scan: Values in Indian Population in Different BMI Categories

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Abstract The primary intention of the study was to “prove” that the reduced angle and distance between the superior mesenteric artery (SMA) and aorta significantly correlates with reduced body mass index (BMI). This in turn indicates the strong etiological role of this factor for causation of SMA syndrome. (Most literature till date still mentions sudden depletion of fat pad between the vessels as a “proposed predisposing factor”). The superior mesenteric artery syndrome is characterized by the compression of the third segment of the duodenum by the mesentery at superior mesenteric artery level and a resulting duodenal ($\pm$ gastric) dilatation. The disease is closely related with the depletion of the fat pad between the vessels narrowing the angle and reducing the distance between the vessels. A prospective study of 100 patients (58 males and 42 females) in the age range 15–85 years (mean age 50 years) who had undergone CT scan for various other complaints. CT scan had been performed with routine protocol comprising plain phase followed by arterial and venous phase by measuring the angle between the aorta and superior mesenteric artery, and also BMI was calculated. Mean values for distance and angle were obtained with standard deviation and 95 % confidence intervals. Pearson coefficients were also calculated and results tabulated. A strong positive correlation exists between BMI and the angle between the aorta and SMA. With increment in BMI,

the angle also increases so less chance of developing superior mesenteric artery syndrome.

Keywords Superior mesenteric artery–aorta angle · Distance · Body mass index

Introduction

Superior mesenteric artery syndrome is characterized by compression of the third portion of the duodenum between the aorta and superior mesenteric artery (SMA) (<http://www.learningradiology.com>). This syndrome is variably known as arterial mesenteric duodenal compression, cast syndrome, or Willkie’s syndrome [1]. It has prevalence of 0.1–0.3 % [1]. Its pathophysiology consists of narrowing of angle between the SMA and aorta and reduced aortomesenteric distance.

Ultrasound and barium studies are helpful in diagnosing it, but CT scan is a more accurate consistent and sensitive method for evaluating the relationship between the aorta, SMA, and duodenum [2].

In this study, we had measured the values of distance and angle between the aorta and SMA in normal population and compared it with different body mass index (BMI) groups. After analysis for correlation between the variables, we may be able to screen out patients at risk of suffering from the syndrome.

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Materials and Methods

A single center prospective observational study was undertaken in 100 patients who visited CT scan department for various other complaints. Patients with previous abdominal surgery were not included in this study. The study comprised 58 males

Fig. 1 The sagittal section with origin of the SMA from the aorta. The angle between the vessels is measured at the origin whereas the perpendicular distance is measured at three levels at the site of duodenal crossing

and 42 females with mean age of 50 years (age range from 15 to 85 years). CT scan was done on Siemens multidetector scanner with routine protocol comprising of plain phase followed by contrast administration (80–100 ml Omnipaque) taking arterial and venous phases. The values for the study were obtained in the arterial phase using reformatted images: maximum intensity projection and multiplanar reconstruction with selected axial and sagittal images. The angle between the

Fig. 2 The distance between the vessels on axial image

SMA and aorta was measured at the origin (Fig. 1). The perpendicular distance between the SMA and aorta was measured at the site where the duodenum crosses at three different levels: D1, D2, D3 (Figs. 1 and 2). D1 is the superior border, D3 is the lower border, and D2 is the midpoint of the duodenal loop which is crossing at that site. BMI was calculated for each patient as $BMI = \text{weight}/(\text{height})^2$. The cases were divided into four groups (both gender) according to the BMI categories

- (a) Group A = <18.5
- (b) Group B = 18.5–24.99
- (c) Group C = 25–29.99
- (d) Group D = 30–34.99

Mean values of distance and angle measurements were calculated with standard deviations and 95 % confidence intervals. Pearson correlation coefficients were calculated between distance, angle, and BMI.

Statistical Analysis and Results

The frequency of patients (49 %) in BMI group “B” exceeded than other groups with no gender bias. Table 1 describes the distribution of the number of patients in each BMI group according to the different categories of angle (in degrees) between the vessels (i.e., 0–20, 20–40, and soon).

It was observed that the maximum number of patients of BMI group A had angles between 0° and 20°, group B between 20° and 40°, group C between 40° and 60°, and group D between 40° and 60°.

Tables 2, 3, and 4 describe the distribution of patients of different BMI groups into various categories for distance (in millimeter).

Table 1 BMI group versus angle

BMI Group	>0–20	>20–40	>40–60	>60–80	>80–100	>100–120
A	9	6	4	2	2	1
B	3	24	7	10	4	1
C	0	4	8	4	1	1
D	0	3	3	0	2	0
E	0	0	1	0	0	0

It is observed that as regard to D1, the maximum number of patients of BMI group A had distances between 0 and 10, groups B–C–D between 10 and 20. Similar tabulated calculations were also performed for D2 and D3.

Mean and Standard Deviations

The values of mean and standard deviation were calculated from the obtained data. It was observed that the mean value of the angle between the vessels increases progressively with increasing BMI. The values of standard deviation are seen to reduce in the same order.

Also, in case of distance in all three groups (D1, D2, D3), values are seen to be progressively increasing for BMI groups A, B, and C but not in group D. The possible reason may be the small sample size of patients in this group.

Pearson's correlation coefficient (r) is a number between -1 and 1 . In general, the correlation expresses the degree and strength of the correlation between the variables. If one variable increases when the second one increases, then there is a positive correlation (<http://www.medcalc.org/manual/correlation.php>). In this case, the correlation coefficient will be closer to 1 . If one variable decreases when the other variable increases, then there is a negative correlation and the correlation coefficient will be closer to -1 .

In the present study as per Table 5, we observe that (r) between BMI and angle is 0.95 , i.e., very close to 1 indicative of strong positive correlation between the variables.

We also see that the value of (r) between BMI and distance is 0.76 , 0.72 , and 0.70 for D1, D2, and D3, respectively, suggestive of positive correlation the strongest being with D1.

Table 2 BMI group versus distance: BMI versus D1

BMI group	>0–10	>10–20	>20–30	>30–40
A	18	6	0	0
B	14	27	7	1
C	2	9	6	1
D	1	4	3	0
E	0	1	0	0
Total	35	47	16	2

Table 3 BMI group versus distance: BMI versus D2

BMI group	>0–10	>10–20	>20–30	>30–40
A	17	6	1	0
B	16	22	9	2
C	1	10	6	1
D	2	4	1	1
E	0	1	0	0
Total	36	43	17	4

This is in concordance with the findings of the study performed by Ozkurt et al. [3] who concluded that the aortomesenteric angle and distance significantly correlate with BMI in normal population. Additionally, we also observe strong positive correlation between angle and distance.

Discussion

On the basis of this study we can discuss two clinical scenarios.

A patient presenting with symptoms suggestive of SMA syndrome The symptoms of this disease (epigastric pain, nausea, vomiting, postprandial discomfort) are nonspecific and can occur in variety of gastrointestinal diseases. However, recurrence of these would definitely warrant a CT scan examination irrespective of above/below threshold BMI because it is the diagnostic modality of choice for SMA syndrome and it is vital to rule out other diseases which may present with similar symptoms.

Patients undergoing CT scan for other diseases The patients included in the present study presented with varied complaints unrelated to SMA syndrome. Among these, with the help of this study by measuring the variables, we were able to screen out patients with predisposition for SMA syndrome. For example, in patients with below threshold BMI (sudden rapid weight loss due to debilitating illness or anorexia nervosa), the clinicians can be guided to improve/manage patients nutrition such that their BMI reaches to at least above threshold level and hence reduces the risk of developing this syndrome.

Table 4 BMI group versus distance: BMI versus D3

BMI group	>0–10	>10–20	>20–30	>30–40	>40–50
A	17	7	0	0	0
B	17	24	7	1	0
C	1	12	4	0	1
D	3	2	3	0	0
E	0	0	1	0	0
Total	38	45	15	1	1

Table 5 Pearson's correlation coefficient

P	Angle	D1	D2	D3
BMI	0.95	0.76	0.72	0.70
Angle	1	0.91	0.89	0.89

SMA syndrome (also known as Wilkie's syndrome) [4] is commonly due to reduced aortomesenteric angle and distance between the vessels causing compression of the third part of the duodenum [5]. Other causes include duodenal malrotation due to peritoneal adhesions causing duodenal compression, anomalous low origin of SMA, and high insertion of the duodenum by the ligament of Treitz [6–8].

SMA usually forms an angle of 45° with the aorta, normal angle ranging from 25° to 60° [9]. Any condition resulting in loss of mesenteric fat pad forming more acute angle (<22°) causes compression of the third part of the duodenum resulting in SMA syndrome [10]. Females, older children, and adolescents are most commonly affected (<http://www.learningradiology.com>). The condition most commonly affects underweight individuals with a history of rapid weight loss [11]. Proposed etiological factors being constitutional factors like thin body build exaggerated lumbar lordosis; depletion of the mesenteric fat by rapid severe weight loss due to catabolic states such as cancer, surgery, trauma, burns, or psychiatric problems; or due to dietary disorders like anorexia nervosa or malabsorption. Chief complaints of the patients with SMA syndrome are epigastric pain, nausea, eructation, voluminous vomiting, and postprandial discomfort. Imaging findings in the form of barium findings are dilation of the first and second part of the duodenum with an abrupt narrowing at the third portion, delayed gastroduodenal emptying and ant peristaltic waves proximal to the obstruction which may be relieved by a change in position, especially left lateral decubitus position [12]. USG of the abdomen may be helpful in measuring the angle of the superior mesenteric artery and the aortomesenteric distance but is difficult in obese patients and those with gaseous abdomen [13].

CT scan can provide diagnostic information in the form of aortomesenteric artery distance and duodenal distension; also it is helpful to assess intra-abdominal and retroperitoneal fat. CT criteria for the diagnosis of SMA syndrome include an aortomesenteric angle of less than 22° and an aortomesenteric distance of less than 8–10 mm [14].

Reversing or removing the precipitating factor is usually successful in a patient with acute SMA syndrome. However, management of this condition includes relief of compression by postural change into prone knee–elbow position, weight gain, and surgery. Duodenojejunostomy is indicated only when conservative treatment is not successful (<http://www.learningradiology.com>).

Conclusion

There is a strong positive correlation obtained between BMI and angle between the SMA and aorta; thus, the higher the BMI, the wider is the angle and hence reduced chances of developing SMA syndrome through statistical analysis based on this study.

Similarly, BMI and distance (especially D1) exhibit moderate positive correlation indicating that the higher the value of BMI, the more is the distance between the vessels and hence again decreased chances of compression of the duodenum.

Hence, by this study, we not only strengthen the role of a predisposing factor for SMA syndrome but we are also able to screen out patients with increased risk of suffering from this syndrome on the basis of the obtained value of the variables.

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