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Normal values of angle and distance between the superior mesenteric artery and aorta in Iraqi population: A single centre study

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Aortomesenteric angle, aortomesenteric distance, computed tomography, normal range, superior mesenteric syndrome

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Abstract

Introduction: The diagnosis of the superior mesenteric syndrome depends on measuring the distance and angle between the superior mesenteric artery (SMA) and aorta on CT scan in the presence of duodenal compression. Studies examining the normal range of these measurements are scarce and none of them was conducted on the Iraqi population. The aim of this study was to assess the values of aorto-SMA angle (AMA) and aorto-SMA distance (AMD) in asymptomatic patients to define the normal range in the Iraqi population and to compare it with the normal published range and different demographical values and body mass index (BMI). **Methods:** A total of 333 patients referred to arterial phase CT examinations for reasons unrelated to gastrointestinal tract were recruited. On axial and reformatted sagittal–oblique images, the angle and the distance between SMA and aorta were measured at the location where the duodenum crosses. **Results:** Both AMA and AMD had a wider range 10–147° and 4–44 mm, respectively, compared to the literature reported range. There was a significant reduction in AMA and AMD values in underweight participants (AMA, $P < 0.001$; and AMD, $P = 0.014$) and in female patients (AMA and AMD, $P < 0.0001$) and those who were younger than 20 (AMA, $P = 0.014$; and AMD, $P = 0.001$). A moderate correlation ($r = 0.507$, $P < 0.0001$) was found between AMA and AMD values. The correlation of BMI with AMD values was moderate ($r = 0.46$), and with AMA was weak ($r = 0.23$) ($P < 0.0001$). **Conclusion:** Very low values of AMA and AMD can occur in normal asymptomatic patients without compressing the duodenum, which warrants further follow-up studies. Evaluating normal values of AMA and AMD in the Iraqi population can help in providing a reference for CT-based diagnosis of SMA syndrome.

Introduction

The superior mesenteric artery (SMA) is a landmark in the abdominal cavity. It originates from the aorta at approximately L1, about 1.5–3 cm inferior to the celiac trunk, slightly to the right of the duodenojejunal junction and close to the left mid-clavicular–umbilical line.[1] SMA gives 6 major branches that supply the mid-gut. During its course, SMA passes behind the neck of the pancreas and splenic vein, crossing anterior to the left renal vein, then emerges anterior to the uncinate process of the pancreas. Before entering the mesentery, it crosses anterior to the third part of the duodenum.[2]

Narrowing of the angle between the SMA and aorta and reduced aortomesenteric distance SMA due to retroperitoneal fat loss may associate with extrinsic compression of the duodenum. This results in a proximal dilation and often gastrointestinal symptoms referred to as SMA syndrome and also known as Wilkie syndrome, arteriomesenteric duodenal compression, and cast syndrome.[3]

SMA syndrome is first described in 1861 by Bohemian pathologist called Baron Carl von Rokitansky who first gave it the name 'SMA syndrome'.[4] It is a rare condition with a prevalence not exceeding 0.3% usually suspected when bilious emesis and epigastric discomfort relieved by vomiting occur.[5] The rarity of the SMA syndrome and non-specific clinical presentation made the diagnosis of this syndrome substantially dependent on imaging techniques. Although barium meal has conventionally been used, computed tomography (CT) provides a more objective and sensitive method for evaluating the relationship among the aorta, SMA, and duodenum.[6]

In literature, a growing number of studies pointed to the significance of aorto-SMA angle (AMA) and aorto-SMA distance (AMD) in the aetiology and diagnosis of SMA syndrome. Several factors were reported to affect the angle between the SMA and aorta and aortomesenteric distance including weight,[7] lordosis,[4] body casts, lengthy bed rest,[8] or prior abdominal surgery.[4] Arterial phase CT allows visualisation of the vascular compression of the duodenum and accurate measurement of the aortomesenteric angle and distance.[9,10] It is generally reported that the normal value of AMA ranges between 28 and 65° and AMD ranged between 10 and 34 mm[1]; nonetheless, studies that examined the normal range of these measurements are less than a handful and none of them were conducted on the Iraqi population. In this study, we aimed to assess the values of AMA and AMD in a group of asymptomatic patients to define the normal range in the Iraqi population and compare it with the normal published range and different demographical values and BMI.

Material and Methods

Study group

This is a cross-sectional observational study approved by Medical City Directorate and Oncology Teaching Hospital ethical committees. Informed verbal consents were given by all participants. A total of 333 patients referred to Oncology Teaching Hospital Radiology Department to perform arterial phase CT scan of the abdomen for various reasons, including characterisation of renal mass or clinical staging of tumours other than gastrointestinal tract (GIT) cancers, such as breast, lung, head, and neck in a period between April 2019 and February 2020, were prospectively recruited. The cohort included 234 females and 99 males with a mean age of 51 years.

Excluding criteria comprised any previous abdominal surgery, history of gastrointestinal symptoms such as abdominal pain and vomiting, history of GIT tumour, ascites, any abnormal retroperitoneal or intraperitoneal mass that may affect measurements under investigation such as enlarged LNs, tortuous abdominal aorta due to extensive atherosclerotic changes, lower spinal scoliosis, and studies done with venous phase only.

Patients' demographic parameters including the height (measured in metres) and the weight (measured in kilograms) were taken before undergoing the procedure and BMI for each patient was calculated following the equation:

> *BMI categories were divided according to the WHO description[11] to underweight group (<18), normal weight (18–25), overweight (26–29), and obese ≥30.*

Technique and measurement

CT scan for each patient was done on Siemens 64 slice multidetector scanner (Somatom definition AS 64, Siemens). For each patient, a tube voltage of 120 kVp and automated exposure control tube current ranging between 100 and 350 mA were used depending on the patients' weight. The routine protocol included non-contrast image followed by contrast administration of iopromide (Ultravist 370) injected in a total volume of 80–100 mL by an automated injector at a rate of 2.5–3 mL/s taking images in both arterial and venous phases. According to our standard abdominal CT protocol, 5 mm sections were acquired with increments of 5 mm, while the patients were placed in the supine position. Subsequent reconstructed axial images of 1.25 mm slice thickness were obtained using a medium-smooth convolution kernel (B20 f). All the image data were sent electronically to a workstation (Syngo.via-Siemens) for interpretation. The values for this study were obtained in the arterial phase in axial, sagittal, or oblique-sagittal reformatted images (depending on the course of the SMA). The AMA of each case was measured in the reformatted sagittal or sagittal-oblique view by manual tracing along the posterior wall of the SMA root and along the anterior wall of the aorta at the SMA origin with the angle measurement obtained at the point where these two lines meet.

The distance between the SMA and the aorta (posterior wall to anterior wall) was measured in the axial images at the level where the third part of the duodenum crossed in between (specifically at the midpoint between the superior and inferior margin of the crossing duodenal loop).

Statistical analyses

All statistical analyses were carried out using Statistical Package for Social Sciences (IBM SPSS) software version 25. Continuous variables were expressed as mean+SD or median and inter-quartile range according to data distribution.

Sample normality was tested using a Shapiro–Wilk test ($P < 0.05$)[12] and visual inspection of their histograms and normal Q-Q plots and box blots showed that both AMA and AMD were not normally distributed for BMI groups. For age groups, only AMA measurements were normally distributed Shapiro–Wilk test ($P > 0.05$).

Comparisons between groups were conducted using unpaired Student's T-test and ANOVA for normally distributed data, while Mann–Whitney and Kruskal–Wallis tests were applied for data that were not normally distributed. Bonferroni test was used for post hoc analysis. Bivariate correlation using Pearson test was applied to examine the association of different variables. *P* values of <0.05 were considered statistically significant.

Results

The cohort included 234 (70.3%) females and 99 (29.7%) males with a mean age of 51 years and range 15–80. The mean BMI of patients was 29 kg/m^2, ranged between 14 and 49 (kg/m^2), the majority of the patients (43.8%) were obese and overweight (27.6%), whereas normal-weight patients constituted 23.1% and only 5.4% were underweight. The BMI in female patients was significantly higher than that of males, $P = 0.002$.

AMA and AMD values have a wide range

As Figure 1A shows, the measurement of AMA expanded beyond the normal recorded literature values ranged between 10 and 147° with a mean of 67.3° (SD = 25.5, 95%CI = 64.5–70). Similarly, the measurements of AMD values spanned the normal values described in the literature ranged 4–44 mm with a mean of 15.2 mm (SD = 7.79, CI = 14.4–16%; Figure 1B).

AMA and AMD values affected by age and gender

Aorto-SMA angle ($P = 0.014$) and AMD ($P = 0.001$) were significantly lower in participants younger than 20 years compared to other age groups. Although the number of the cases in this age group was small ($n = 4$), all were below the normal previously reported value,[1] suggesting age as contributing factor (Table 1). We also found significant differences in the angle and distance measurements between females and males. The number of males in the cohort was smaller, yet their AMA ($P < 0.0001$) and AMD ($P < 0.001$) were significantly larger than females suggesting gender as another contributing factor.

Low AMA and AMD are frequent in underweight females

BMI is the factor that has been frequently reported to be associated with both AMA and AMD. In our cohort, underweight participants had significantly lower values of AMA (Fig. 2A, $P < 0.0001$) and AMD (Fig. 2B, $P = 0.0001$) compared to normal, overweight, and obese participants.

There was a significant moderate correlation between AMA and AMD measurements (Spearman's correlation = 0.51, $P < 0.0001$, Table 2). BMI showed a significant moderate correlation with AMD (Spearman's correlation = 0.46, $P < 0.0001$), but AMA correlation was weak yet significant ($r = 0.23$, $P < 0.0001$).

We further looked into a subgroup of our patients who had AMA and/or AMD values below the lower limit of normal values (AMA < 22° and/or AMD < 8 mm)[6] and their distribution in age, sex, and BMI groups as shown in Table 3.

Fifteen of 333 (4.5%) of the cohort had AMA < 22° and 52 (15.6%) had AMD < 8 mm (Fig. 3), whereas 13 (3.9%) had both AMA and AMD below threshold values. The majority of these patients were underweight or normal-weight females aged between 20 and 59 years, none of them were obese. AMA and AMD measurements in this subgroup did not show association with BMI.

Discussion

Studying the radiological normal range of SMA measurements has a considerable contribution to the diagnosis of a rare but important disease, precisely SMA syndrome. In this study, we have shown for the first time that, in an Iraqi cohort, SMA radiological measurements (both AMA and AMD) had a wider range than the literature reported range and were significantly affected by patients' BMI, age, and sex. More importantly, we showed for the first time that very low values of AMA and AMD can occur in normal asymptomatic patients without compressing the duodenum. Hence, establishing normal values of AMA and AMD in the Iraqi population can provide a reference for CT-based diagnosis of SMA syndrome.

Radiological imaging, arterial phase CT scan, in particular, has a substantial role in the diagnosis of SMA syndrome. The anatomical variation of the SMA root and

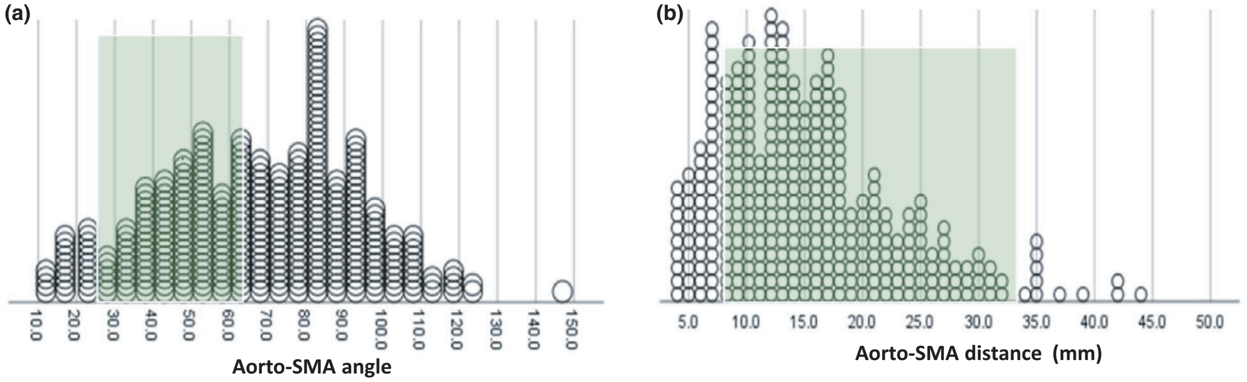

Figure 1. The distribution of aorta-superior mesenteric (SMA) angle and distance values in asymptomatic participants. (A) The distribution of AMA; (B) the distribution of AMD. The green shadow in both graphs refers to literature normal AMA range (28–65°) and AMD range (8.5–33 mm).[1]

Table 1. The differences in the values of aorta-SMA angle and distance in demographics categories.

	Number (%)	Aorto-SMA angle Mean (±SD)	*P*	Aorto-SMA distance (mm) Mean (±SD)	*P*
Total	333 (100)	67.1 (25.7)	-	15 (8)	-
Age					
<20	4 (1.1)	21.5 (7.4)	0.014	7.5 (2.8)	0.001
20–39	54 (16.5)	64.6 (30)		12.1 (6.6)	
40–59	170 (51.1)	68.6 (25.2)		15.4 (7.8)	
≥60	105 (31.5)	68.3 (22.1)		16.5 (8.4)	
Sex					
Female	234 (70.3)	63 (24.4)	<0.0001	13.9 (6.8)	<0.0001
Male	99 (29.7)	77.5 (25.2)		18.4 (9.1)	
BMI					
<18.5	18 (5.4)	39.9 (26.7)	<0.0001	8.8 (5.2)	<0.0001
18.5–24.9	77 (23.1)	60.7 (26.8)		11.0 (5.1)	
25–29.9	92 (27.6)	68.4 (23.8)		14.9 (6.7)	
≥30	146 (43.8)	73.5 (22.8)		18.5 (8.2)	

several acquired changes that affect the AMA and AMD measurements predispose to SMA syndrome. Nevertheless, in the literature, there is no reported normal values for AMA and AMD in different demographic categories in normal population apart from a couple of studies, which focused primarily on the association of these measurements with patients BMI.[13,14]

Multiphase CT scan was first proposed in the diagnosis of SMA syndrome in the late eighties. In a series of four cases, Applegate et al reported proximal duodenal dilatation along with reduced AMD ranging between 4 and 8.5 mm, whereas six asymptomatic normal participants' AMD values were 9–19 mm.[15] A later study reported a similar finding with a relatively larger sample size. In 2005, Ünal and colleagues confirmed in a case–control study with a decent sample size the utility of multiphase CT in the diagnosis of SMA syndrome.[6] They determined the normal value of AMD in 79 normal control as 8.2–33.3 mm, 1 of which has had duodenal dilatation due to organic cause. Several subsequent studies reported SMA syndrome diagnosed basically by arterial phase CT using AMD < 8 mm, AMA < 22°, and duodenal dilatation as the diagnostic criteria.[16–18] These studies have depicted that arterial phase CT study has a high diagnostic rate and provides similar measurements to conventional and CT angiographic measurements. Additionally, CT is considered superior to upper gastrointestinal barium study in that it has greater patient comfort and is relatively less invasive in comparison to conventional angiography.

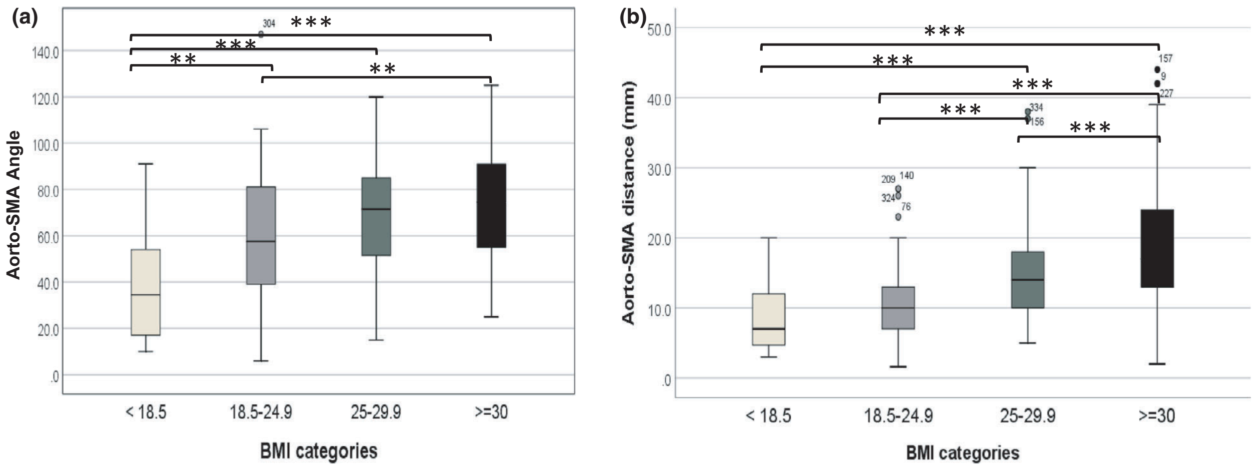

Figure 2. Aorta- superior mesenteric (SMA) angle (A) and distance (B) in BMI categories. *$P < 0.05$. **$P < 0.01$, ***$P < 0.0001$.

Table 2. Correlation among AMA, AMD, and BMI.

Correlation			
Spearman's rho	SMA- aorta angle	SMA- aorta distance (mm)	BMI
Aortomesenteric angle			
Correlation coefficient	1.000	0.507*	0.232*
Sig. (2-tailed)	-	0.000	0.000
N	333	333	333
Aortomesenteric distance (mm)			
Correlation coefficient	0.507*	1.000	0.456*
Sig. (2-tailed)	0.000	-	0.000
N	333	333	333
BMI			
Correlation coefficient	0.232*	0.456*	1.000
Sig. (2-tailed)	0.000	0.000	-
N	333	333	333

*Correlation is significant at the 0.01 level (2-tailed).

We have shown that, in our study group, the normal values of AMD (4–44 mm) and AMA (10–147°) are expanding around the literature reported values 8.5–33 mm and 28–65°, respectively.[19,20] This is because all the referenced studies had a small sample size not exceeding $n = 80$. More importantly, the referenced AMA measurement recurrently cited in the literature was referring to the one study conducted by Konen et al. which used CT angiography for only 10 normal control rather than multiphase CT.[20] The low incidence of the SMA syndrome can explain the small number of studies looking at the reference normal values.

We have shown that in the Iraqi population, AMA and AMD values were affected by participant age, sex, and BMI. Younger patient (<20 years) seems to have their values significantly lower than other age groups. Epidemiological studies reported that SMA syndrome in the younger age group (10–30 years) was up to 75% higher than the total incidence.[21] This high incidence may be related mainly to congenital variation in the anatomy of SMA root particularly in scoliosis,[22] yet in our cohort, none of the participants have had scoliosis or recent surgery. We have also shown significantly lower AMA and AMD values in women participants compared to men. This can probably explain the slight women predominance (64–66%) in SMA syndrome.[23] Furthermore, AMA and AMD were significantly lower in underweight patients. Several studies pointed to the correlation between low BMI and low AMA and AMD values which has been contributed to the depletion of the retroperitoneal and mesenteric fat in underweight people that support aortomesenteric angle and distance.[13,14] On the same line, high values of AMA and AMD observed in our study can be explained by the high proportion of obese participants. Generally, we have shown that AMA value is moderately associated with AMD, and only the latter is associated with BMI. Ozkurt and colleagues showed in a study done on asymptomatic Turkish participants, similar findings.[13] They reported a moderate association of AMD (but not AMA) with BMI in both women and men. In a smaller Indian study, Desai and colleagues reported a strong association between AMA and AMD, on the one hand, and between each value and BMI, on the other hand.[24] The issue with this study was that they recruited symptomatic patients and only excluded recent abdominal surgery and there was no

Table 2. Demographics of the study group when the value of aorta-SMA angle and distance is less than normal values

	No (%)	Aorta-SMA Angle < 22° Mean (±SD)	No (%)	Aorta-SMA Distance < 8 Mean (±SD)	No (%)	Angle <22° and Distance <8 Mean (±SD)
Total	15 (100)	17.7 (4.8)	52 (100)	6.7 (1.8)	13 (100)	17.2 (4.7)- 5.7 (1.6)
Age						
<20	3 (20)	18 (3)	2 (3.8)	5 (0)	2 (15.3)	16.5 (2.1)–5 (0)
20–39	5 (33.3)	16.8 (2.7)	15 (29.0)	5.7 (1.2)	5(38.4)	16.8 (2.6)–5 (1.6)
40–59	5 (33.3)	16.6 (2.9)	22 (42.3)	6.0 (1.2)	4 (30.7)	16 (3)–5.7 (1.5)
≥60	2 (13.4)	14.5 (6.4)	13 (25)	5.3 (1.2)	2 (15.3)	14.5 (6.4)–7 (0)
Sex						
Female	11 (73)	16.4 (2.5)	42 (80.1)	5 (1.4)	9 (69.3)	15.6 (1.9)–5.1 (1.4)
Male	4 (27)	17.3 (4.9)	10 (19.2)	6 (1.2)	4 (30.7)	17.3 (4.9)–6.5(1)
BMI						
<18.5	7 (47)	15.1 (2.9)	11(22.2)	5.2 (1.3)	7 (53.8)	15.1 (2.9)–5 (1.5)
18.5–24.9	5 (33)	18.2 (3)	21 (64.8)	5.8 (1.2)	3 (23.1)	17 (3.5)–6.3 (1.6)
25–29.9	3 (20)	17.7 (3.1)	12 (40.7)	5.7 (0.9)	3 (23.1)	17 (3)–6 (1)
≥30	0		8 (37.3)	6 (1.1)	0	

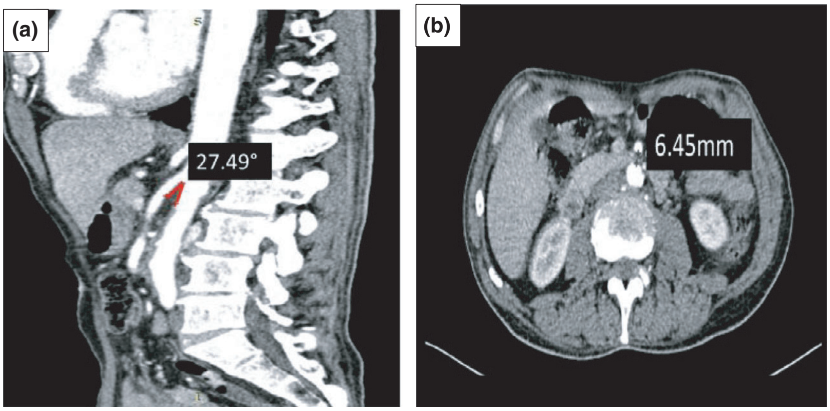

Figure 3. Sagittal and axial CT views showing (A) aorta- superior mesenteric angle (27°) and (B) aorta- superior mesenteric distance (6.45 mm).

comment on a duodenal and gastric status, therefore the study does not strongly reflect normal values.

The literature has proposed an AMD of 8 mm and AMA of 22° as cut-off values for diagnosing SMA syndrome in the presence of proximal duodenal/gastric dilatation and clinical suspicion.[1,6] Intriguingly in our study group, 52 participants had SMD less than 8 mm, and 15 participants had AMA less than 22° and 13 had both AMD and AMA less than the cut-off values in the absence of evident proximal duodenal/gastric dilatation. 69.3% of these participants were females and more than 50% were underweight, suggesting that the normal value of AMA and AMD in different demographic groups may differ. We acknowledge that our cohort included a higher number of females with a significant difference in the BMI between the genders; yet the rate of male patients when AMA or AMD individually reduced was higher or similar compared to rates of females, by contrast when both values were below the threshold the rate of females tends to be higher. The other possibility could be that these patients may be at higher risk for developing SMA syndrome at some point in their life and may need follow-up.

In conclusion, normal values of AMA and AMD and correlation with age, sex, and BMI are essential for accurate diagnosis of SMA syndrome; however, a third component is needed for a definite diagnosis which is proximal duodenal dilatation. Finding AMA <22° and AMD < 8 mm in the absence of duodenal dilatation warrants patient follow-up with a dietary intervention to avoid the development of SMA syndrome.

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Conflict of Interest

The authors declare no conflict of interest.

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