

# Morphometric evaluation of the vertebral origin level, aortomesenteric angle, and distance of the superior mesenteric artery using computed tomography angiography

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## ABSTRACT

**Aims:** The aim of this study was to evaluate the vertebral origin level of the superior mesenteric artery (SMA), the aortomesenteric angle (SMA-angle), and the aortomesenteric distance (SMA-distance) using computed tomography angiography (CTA) in adults and to investigate their relationship with age and gender.

**Methods:** This retrospective radiological anatomy study included abdominal CTA images of 1000 adults (500 females and 500 males) obtained between October 2021 and February 2024. The vertebral origin level of the SMA was determined relative to vertebral body subdivisions. The SMA-angle was measured in the sagittal plane and the SMA-distance in the axial plane at the level of the left renal vein. Statistical analyses were performed using SPSS software. Chi-square test, student's t-test, ANOVA, and Mann-Whitney U test were applied where appropriate. Correlations between variables were evaluated using Pearson correlation analysis ( $p < 0.05$ ).

**Results:** The SMA originated between T12 and L2, most commonly at the L1-middle level in both females (31.8%) and males (35.2%). Significant gender differences were observed at the L1-upper and L1-lower levels ( $p = 0.005$ ). The mean SMA-angle was  $58.69 \pm 23.36^\circ$  in females and  $64.20 \pm 23.08^\circ$  in males ( $p = 0.001$ ). The mean SMA-distance was  $12.54 \pm 5.97$  mm in females and  $15.32 \pm 7.16$  mm in males ( $p = 0.001$ ). A positive correlation was found between the SMA-angle and distance. Age-related analysis demonstrated significant differences in both SMA-angle and SMA-distance among age groups, with the highest values observed in individuals aged 68-77 years.

**Conclusion:** The SMA most commonly originates at the L1 vertebral level. The aortomesenteric angle and distance were significantly greater in males and showed a positive correlation. These findings may provide reference values for normal populations and aid radiological evaluation of vascular compression syndromes.

**Keywords:** Superior mesenteric artery, computed tomography angiography, aortomesenteric angle, aortomesenteric distance

## INTRODUCTION

The superior mesenteric artery (SMA) is a major visceral branch of the abdominal aorta. It supplies arterial blood to the pancreas, small intestine, and proximal colon. Typically, the SMA branches from the abdominal aorta distal to the celiac trunk, most often at the L1 level. However, the literature reports that the SMA can arise anywhere between T12 and L2.<sup>1,2</sup> Knowledge of these anatomical variations is important, especially during abdominal surgery, pancreatic resections, and endovascular procedures.

The aortomesenteric angle (SMA-angle) is the angle between the SMA and the aorta. The aortomesenteric distance (SMA-distance) is the space between these two vessels. Both are important morphometric parameters of abdominal vascular anatomy. The third portion of the duodenum and the left renal vein lie within the narrow aortomesenteric space

between them. Changes in these parameters may contribute to vascular compression syndromes.<sup>3</sup> Superior mesenteric artery syndrome (Wilkie syndrome) results from duodenal compression due to a narrow SMA-angle. Nutcracker syndrome occurs when the left renal vein is compressed. Both are clinically important conditions.<sup>4,5</sup>

Radiological studies in normal populations show that the SMA-angle ranges from  $28^\circ$  to  $65^\circ$ . The SMA-distance ranges from 10 to 34 mm.<sup>6</sup> Some studies report that an aortomesenteric distance of 8 mm or less and an angle of  $22^\circ$  or less may mark significant diagnostic thresholds for SMA syndrome.<sup>7</sup> Body-mass index and retroperitoneal fat affect these parameters. Increased fat tissue can widen the angle by increasing the distance between the SMA and the aorta.<sup>6,8</sup>

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In recent years, multidetector computed tomography (MDCT) and computed tomography angiography (CTA) have enabled high-accuracy evaluation of abdominal vascular anatomy. Thanks to these methods, morphometric features and anatomical variations of abdominal aortic branches can be reliably measured.<sup>9</sup>

While various studies in the literature address the SMA-angle and SMA-distance, large-sample studies evaluating the vertebral origin level of the SMA in conjunction with demographic variables and examining its relationship with SMA-angle and SMA-distance remain limited. Therefore, the aim of our study is to determine the vertebral level at which the SMA branches off from the abdominal aorta, and to measure the SMA-angle and SMA-distance in adult individuals using CT angiography images, and to evaluate the relationship of these parameters with age and gender. Furthermore, by revealing the correlation between these parameters, we aim to contribute to the literature with morphometric data from a normal population.

## METHODS

### Ethics

The study was conducted in a retrospective radiological anatomy format. Prior to starting the study, approval was obtained from the Sivas Cumhuriyet University Health Sciences Researches Ethics Committee (Date: 30.10.2025, Decision No: 2025-10/10). Since the study was conducted retrospectively, informed consent was not obtained. The study did not receive any funding. All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

### Study Design

Between October 2021 and February 2024, we retrospectively evaluated complete abdominal CTAs from patients aged 18 years or older. These patients visited our clinics for trauma or benign or malignant intra-abdominal pathologies. We included only those with an equal gender distribution. Inclusion criteria were a complete abdominal CTA in the cranio-caudal orientation. Exclusion criteria were age under 18, low-resolution images, or inability to perform complete visualization. We also excluded cases with pathological conditions compressing the abdominal aorta or its branches, a history of related surgery, or aortic aneurysmal changes.

### CTA Technique

This study used a 128-slice multidetector CT scanner (Revolution Evo; GE Healthcare, Milwaukee, WI, USA). We applied our institution's standard abdominal aorta CT angiography protocol to assess the abdominal aorta and its branches. All scans were done with patients in the supine position during full inspiration. We administered 80-120 ml of iodinated intravenous contrast material using an automated power injector to ensure optimal arterial enhancement. Scanning parameters included tube voltage (80-120 kV), rotation time (0.5 seconds), and pitch factor (1.48). The field of view (FOV) was 370 mm. Total scanning time was 4.3

seconds. Total tube current was 180 mAs. We reconstructed images at a slice thickness of 1 mm.

## Computed Tomography Angiography (CTA)

### Evaluations

CT image analysis was performed using the institutional picture archiving and communication system (Sectra PACS, Sectra AB, Linköping, Sweden). An experienced radiologist (NB >10 years of experience) and an anatomist (KÇ >10 years, of experience in cardiovascular anatomy) independently reviewed the images. We determined the vertebral level where the SMA originates from the abdominal aorta. Four planes were used for vertebral level assessment: upper, middle, lower, and intervertebral disc levels, each relative to the vertebral body. The upper level is between the peduncle and the disc. The middle level is at the peduncle. The lower level is between the lower edge of the peduncle and the intervertebral disc. The intervertebral disc level is between the upper and lower disc boundaries (Figure 1). We measured the SMA-angle as the angle between the SMA origin and the abdominal aorta in the sagittal plane (Figure 2). The SMA-distance is the distance between the abdominal aorta and the SMA. It was measured in the axial plane at the level of the renal vein (Figure 3).



**Figure 1.** Shows the method for determining the vertebral origin level of the superior mesenteric artery from the abdominal aorta in the sagittal plane. Four levels are determined by the vertebral body. Upper level above the peduncle, middle level at the peduncle, lower level below the peduncle, and the IVD

IVD: Intervertebral disc, AA: Abdominal aorta, SMA: Superior mesenteric artery, Sup: Superior, Inf: Inferior, Ant: Anterior, Post: Posterior



**Figure 2.** Shows SMA-angle measurement on sagittal plane computed tomography angiography

SMA-angle: Superior mesenteric artery angle, AA: Abdominal aorta, SMA: Superior mesenteric artery, a indicates SMA-angle, Sup: Superior, Inf: Inferior, Ant: Anterior, Post: Posterior



**Figure 3.** Shows SMA-distance measurement on axial plane computed tomography angiography

SMA-distance: Superior mesenteric artery distance, AA: Abdominal aorta, SMA: Superior mesenteric artery, LRV: Left renal vein, Ant: Anterior, Post: Posterior

### Statistical Analysis

Power analysis; using Minitab 17 and previous studies, the population standard deviation was estimated at 1.6, and the effect size (difference) at 0.6. According to the analysis, to achieve a power of  $1-\beta = 0.995673$  (99%) at the 5% significance level, the sample size was set at  $n=1000$  (500 females/500 males).

To assess measurement reproducibility, interobserver agreement was evaluated using a randomly selected subset of 100 CTA examinations. The SMA-angle and SMA-distance measurements obtained independently by the two observers were analyzed using the intraclass correlation coefficient (ICC) based on a two-way random-effects model with absolute agreement. Agreement for the vertebral origin level of the SMA was assessed using the weighted Cohen's kappa coefficient.

Statistical analyses were performed using the SPSS software package [version 23.0 for Windows (IBM Corp., Armonk, NY, USA)]. Categorical data were reported as numbers and percentages. Age was shown as mean  $\pm$  standard deviation. We applied the Chi-square test for categorical data. The normality of the counted data was checked using the Shapiro-Wilk test. Data with normal distribution were evaluated with student's t-test and ANOVA. For non-normal data, we used the Mann-Whitney U test. We applied the Post-Hoc Tukey HSD test. The Pearson correlation coefficient was used to assess relationships among gender, age, SMA vertebral level, SMA-angle, and SMA-distance. A p-value  $<0.05$  was considered statistically significant.

### RESULTS

The mean age was  $61.51 \pm 17.39$  years for females and  $58.70 \pm 16.99$  years for males. The age difference between genders was statistically significant ( $T=6.639$ ,  $p=0.01$ ) (Figure 4).

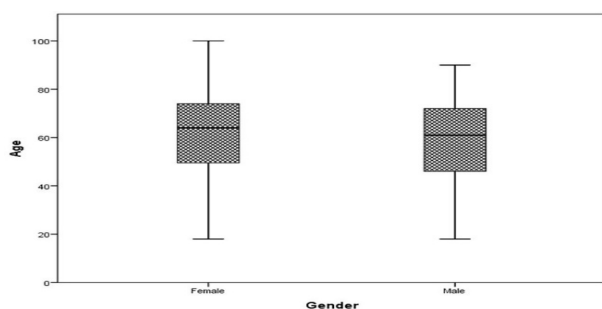


**Figure 4.** The whiskers box plot shows the minimum, maximum, and mean ages for each gender group

Interobserver agreement was excellent for both continuous measurements. The ICC was 0.96 (95% CI: 0.94-0.98) for SMA-angle and 0.95 (95% CI: 0.93-0.97) for SMA-distance. Agreement for the vertebral origin level of the SMA was also excellent, with a weighted Cohen's kappa coefficient of 0.93.

### Gender Group Comparisons of SMA Origin Vertebral Level

Gender group comparisons of the SMA origin vertebral level are shown in Table 1. The vertebral level from which SMA originates from AA was between T12 (upper) and L2 (lower). It was most frequently found at the L1-middle level in both females (31.8%) and males (35.2%). The levels where a statistically significant difference between genders was observed were L1-upper and L1-lower. It was determined that SMA originated from AA at the L1-upper level more often in females (16.6%) than in males (10.4%). It was determined that SMA originates from AA at the L1-lower level more frequently in males (20.8%) than in females (15.2%) ( $\chi^2=25.223$ ,  $p=0.005$ ).

**Table 1.** Superior mesenteric artery origin vertebral level distributions by gender

|                                                              |             | Gender |        |      |       |
|--------------------------------------------------------------|-------------|--------|--------|------|-------|
|                                                              |             |        | Female | Male | Total |
| SMA level                                                    | T12-upper   | n      | 1      | 1    | 2     |
|                                                              |             | %      | 0.2    | 0.2  | 0.2   |
|                                                              | T12-middle  | n      | 15     | 9    | 24    |
|                                                              |             | %      | 3      | 1.8  | 2.4   |
|                                                              | T12-lower   | n      | 17     | 12   | 29    |
|                                                              |             | %      | 3.4    | 2.4  | 2.9   |
|                                                              | T12-L1 disc | n      | 80     | 56   | 136   |
|                                                              |             | %      | 16.0   | 11.2 | 13.6  |
|                                                              | L1-upper    | n      | 83*    | 52*  | 135   |
|                                                              |             | %      | 16.6   | 10.4 | 13.5  |
|                                                              | L1-middle   | n      | 159    | 176  | 335   |
|                                                              |             | %      | 31.8   | 35.2 | 33.5  |
|                                                              | L1-lower    | n      | 76*    | 104* | 180   |
|                                                              |             | %      | 15.2   | 20.8 | 18    |
|                                                              | L1-L2 disc  | n      | 53     | 61   | 114   |
|                                                              |             | %      | 10.6   | 12.2 | 11.4  |
|                                                              | L2-upper    | n      | 12     | 21   | 33    |
|                                                              |             | %      | 2.4    | 4.2  | 3.3   |
|                                                              | L2-middle   | n      | 3      | 8    | 11    |
|                                                              |             | %      | 0.6    | 1.6  | 1.1   |
|                                                              | L2-lower    | n      | 1      | 0    | 1     |
|                                                              |             | %      | 0.2    | 0    | 0.1   |
| Total                                                        |             | n      | 500    | 500  | 1000  |
|                                                              |             | %      | 100    | 100  | 100   |
| Chi-square=25.223, p=0.005*, SMA: Superior mesenteric artery |             |        |        |      |       |

Chi-square=25.223,  $p=0.005^*$ , SMA: Superior mesenteric artery

### Comparison of SMA-angle and SMA-distance Measurements Between Gender Groups

The mean SMA-angle was  $58.69 \pm 23.36$  degrees in females and  $64.20 \pm 23.08$  degrees in males. The difference between gender groups was statistically significant ( $T=14.064$ ,  $p=0.001$ ).

The mean SMA-distance was  $12.54 \pm 5.97$  mm in females and  $15.32 \pm 7.16$  mm in males. The difference between gender groups was statistically significant ( $T=44.459$ ,  $p=0.001$ ) (Table 2).

|                                                                                     | SMA-angle (degrees) |        |        | SMA-distance (mm)   |       |       |
|-------------------------------------------------------------------------------------|---------------------|--------|--------|---------------------|-------|-------|
|                                                                                     | Female              | Male   | Total  | Female              | Male  | Total |
| n                                                                                   | 500                 | 500    | 1000   | 500                 | 500   | 1000  |
| Min                                                                                 | 11.20               | 5.50   | 5.50   | 1.67                | 1.91  | 1.67  |
| Max                                                                                 | 134.20              | 129.10 | 134.20 | 35.10               | 41.50 | 41.50 |
| Mean                                                                                | 58.69               | 64.20  | 61.44  | 12.54               | 15.32 | 13.93 |
| SD                                                                                  | 23.36               | 23.08  | 23.37  | 5.97                | 7.16  | 6.74  |
| Statistics results, t-test                                                          | T=14.064, p=0.001** |        |        | T=44.459, p=0.001** |       |       |
| SMA: Superior mesenteric artery, Min: Minimum, Max: Maximum, SD: Standard deviation |                     |        |        |                     |       |       |

Moderate correlations were found between SMA-angle and distance parameters in females (Pearson's  $R=0.666$ ), and strong correlations were found in males (Pearson's  $R=0.739$ ).

### Age Groups

Those included in the sample were evaluated in six subgroups according to age ranges; group I 18-37 years ( $n=116$ , 11.6%), group II 38-47 years ( $n=129$ , 12.9%), group III 48-57 years

( $n=159$ , 15.9%), group IV 58-67 years ( $n=209$ , 20.9%), group V 68-77 years ( $n=234$ , 23.4%), group VI >78 years ( $n=153$ , 15.3%) (Figure 5).

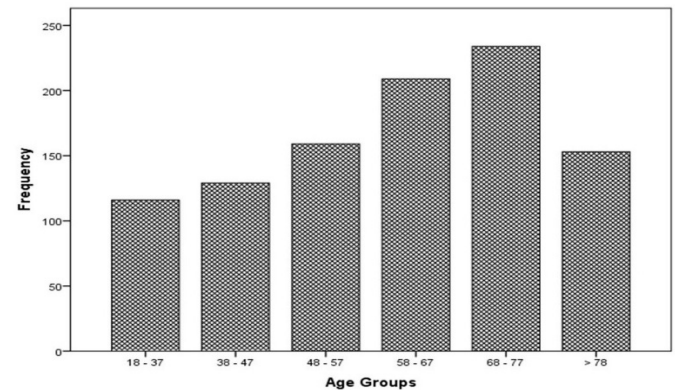


Figure 5. Shows age subgroups' frequencies

### Comparisons of SMA Origin Vertebral Levels Between Age Groups

Comparisons of the vertebral levels of SMA origin among age groups are shown in Table 3. According to this table, SMA origin was not observed at the T12-upper level in groups II, III, V, and VI. In group IV, SMA does not originate from the

Table 3. Superior mesenteric artery origin vertebral level distributions by age groups

|                                                              |             |     | Age groups |            |             |            |           |          | Total |
|--------------------------------------------------------------|-------------|-----|------------|------------|-------------|------------|-----------|----------|-------|
|                                                              |             |     | I (18-37)  | II (38-47) | III (48-57) | IV (58-67) | V (68-77) | VI (>78) |       |
| SMA level                                                    | T12-upper   | n   | 1          | 0          | 0           | 1          | 0         | 0        | 2     |
|                                                              |             | %   | 0.9        | 0          | 0           | 0          | 0         | 0        | 0.2   |
|                                                              | T12-middle  | n   | 4          | 2          | 4           | 0          | 7         | 7        | 24    |
|                                                              |             | %   | 3.4        | 1.6        | 2.5         | 0          | 3         | 4.6      | 2.4   |
|                                                              | T12-lower   | n   | 7          | 2          | 6           | 4          | 7         | 3        | 29    |
|                                                              |             | %   | 6          | 1.6        | 3.8         | 1.9        | 3         | 2        | 2.9   |
|                                                              | T12-L1 disc | n   | 16         | 24         | 25          | 30         | 23        | 18       | 136   |
|                                                              |             | %   | 13.8       | 18.6       | 15.7        | 14.4       | 9.8       | 11.8     | 13.6  |
|                                                              | L1-upper    | n   | 22         | 16         | 22          | 29         | 25        | 21       | 135   |
|                                                              |             | %   | 19.0       | 12.4       | 13.8        | 13.9       | 10.7      | 13.7     | 13.5  |
|                                                              | L1-middle   | n   | 40         | 53         | 59          | 68         | 67        | 48       | 335   |
|                                                              |             | %   | 34.5       | 41.1       | 37.1        | 32.5       | 28.6      | 31.4     | 33.5  |
|                                                              | L1-lower    | n   | 18         | 19         | 28          | 44         | 50        | 21       | 180   |
|                                                              |             | %   | 15.5       | 14.7       | 17.6        | 21.1       | 21.4      | 13.7     | 18    |
|                                                              | L1-L2 disc  | n   | 5          | 7          | 12          | 24         | 41        | 25       | 114   |
|                                                              |             | %   | 4.3        | 5.4        | 7.5         | 11.5       | 17.5      | 16.3     | 11.4  |
|                                                              | L2-upper    | n   | 2          | 4          | 2           | 6          | 12        | 7        | 33    |
|                                                              |             | %   | 1.7        | 3.1        | 1.3         | 2.9        | 5.1       | 4.6      | 3.3   |
|                                                              | L2-middle   | n   | 1          | 2          | 1           | 3          | 2         | 2        | 11    |
|                                                              |             | %   | 0.9        | 1.6        | 0.6         | 1.4        | 0.9       | 1.3      | 1.1   |
|                                                              | L2-lower    | n   | 0          | 0          | 0           | 0          | 0         | 1        | 1     |
|                                                              |             | %   | 0          | 0          | 0           | 0          | 0         | 0.7      | 0.1   |
| Total                                                        | n           | 116 | 129        | 159        | 209         | 234        | 153       | 1000     |       |
|                                                              | %           | 100 | 100        | 100        | 100         | 100        | 100       | 100      |       |
| Chi-square=75.210, p=0.012*, SMA: Superior mesenteric artery |             |     |            |            |             |            |           |          |       |

AA at the T12-middle level. At the L2-lower level, no SMA originating from it was found in groups I, II, III, IV, and V.

It was determined that the L1-L2 disc level was most frequent in group V and least frequent in group I. The L1-L2 disc level was determined to be the only parameter with a statistically significant difference among age groups ( $\chi^2=75.210$ ,  $p=0.012$ ) (Table 3).

### Comparison of SMA-angle and SMA-distance Measurements Between Age Groups

The mean values of SMA-angle and SMA-distance parameters across age groups are shown in Table 4. According to this table, group I has the lowest mean values for both SMA-angle and SMA-distance, while group V has the highest. While the difference in mean values between group I and group VI for the SMA-angle parameter was not statistically significant, the differences between group I and groups II, III, IV, and V were statistically significant ( $F=6.495$ ,  $p=0.001$ ).

Similarly, in the SMA-distance parameter, the differences in mean values between group I and groups II, III, IV, and V were statistically significant ( $F=7.255$ ,  $p=0.001$ ). In the SMA-distance parameter, the mean differences between group VI and group IV ( $p=0.025$ ) and between group V and group IV ( $p=0.024$ ) were also statistically significant (Table 4).

## DISCUSSION

The SMA is one of the major unpaired visceral branches of the abdominal aorta and provides the principal arterial supply to the midgut. Detailed knowledge of its vertebral origin and morphometric relationship with the abdominal aorta is important for abdominal surgery, interventional radiology, and the radiological evaluation of vascular compression syndromes. In the present study, the vertebral origin level of the SMA, together with the SMA-angle and SMA-distance, was evaluated in a large adult population using computed tomography angiography.

The vertebral origin of the SMA ranged from T12 to L2, with the most common origin at the middle portion of the L1 vertebral body. These findings are consistent with classical anatomical descriptions. Gray's Anatomy describes the SMA as arising from the anterior aspect of the abdominal aorta, typically just inferior to the celiac trunk and around the L1 vertebral level.<sup>1</sup> Bergman et al.<sup>2</sup> also emphasized that the origins of abdominal aortic branches may show considerable anatomical variability among individuals. The wide vertebral distribution observed in the present study supports this anatomical variability and provides detailed CTA-based data from a large cohort of adults.

Table 4. Superior mesenteric artery angle and distance measurement comparisons between age groups

|                                                                                                                                                                      | SMA-angle (degrees) |                   |                    |                   |                  |                 | SMA-distance (mm)  |                   |                    |                   |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|-------------------|--------------------|-------------------|------------------|-----------------|--------------------|-------------------|--------------------|-------------------|------------------|-----------------|
| Age groups                                                                                                                                                           | Group I<br>18-37    | Group II<br>38-47 | Group III<br>48-57 | Group IV<br>58-67 | Group V<br>68-77 | Group VI<br>>78 | Group I<br>18-37   | Group II<br>38-47 | Group III<br>48-57 | Group IV<br>58-67 | Group V<br>68-77 | Group VI<br>>78 |
| n                                                                                                                                                                    | 116                 | 129               | 159                | 209               | 234              | 153             | 116                | 129               | 159                | 209               | 234              | 153             |
| Min                                                                                                                                                                  | 5.5                 | 11.3              | 11.3               | 11.7              | 15.1             | 13.4            | 1.67               | 3.32              | 2.46               | 2.62              | 2.94             | 2.34            |
| Max                                                                                                                                                                  | 127.5               | 115.9             | 129.1              | 124.8             | 134.2            | 119.4           | 32.9               | 35.9              | 37.6               | 37.2              | 39.2             | 41.5            |
| Mean                                                                                                                                                                 | 51.25               | 63.25             | 63.18              | 64.05             | 63.97            | 58.41           | 11.12              | 14.62             | 14.52              | 14.75             | 14.71            | 12.57           |
| SD                                                                                                                                                                   | 28.01               | 24.37             | 24.22              | 20.51             | 21.92            | 21.46           | 6.81               | 6.52              | 6.79               | 6.39              | 6.81             | 6.5             |
| ANOVA                                                                                                                                                                | F=6.495, p=0.001**  |                   |                    |                   |                  |                 | F=7.255, p=0.001** |                   |                    |                   |                  |                 |
| Post Hoc, Tukey HSD                                                                                                                                                  |                     |                   |                    |                   |                  |                 |                    |                   |                    |                   |                  |                 |
| I-II                                                                                                                                                                 | p=0.001**           |                   |                    |                   |                  |                 | p=0.001**          |                   |                    |                   |                  |                 |
| I-III                                                                                                                                                                | p=0.001**           |                   |                    |                   |                  |                 | p=0.001**          |                   |                    |                   |                  |                 |
| I-IV                                                                                                                                                                 | p=0.001**           |                   |                    |                   |                  |                 | p=0.001**          |                   |                    |                   |                  |                 |
| I-V                                                                                                                                                                  | p=0.001**           |                   |                    |                   |                  |                 | p=0.001**          |                   |                    |                   |                  |                 |
| I-VI                                                                                                                                                                 | p=0.119             |                   |                    |                   |                  |                 | p=0.483            |                   |                    |                   |                  |                 |
| II-III                                                                                                                                                               | p=1                 |                   |                    |                   |                  |                 | p=1                |                   |                    |                   |                  |                 |
| II-IV                                                                                                                                                                | p=1                 |                   |                    |                   |                  |                 | p=1                |                   |                    |                   |                  |                 |
| II-V                                                                                                                                                                 | p=1                 |                   |                    |                   |                  |                 | p=1                |                   |                    |                   |                  |                 |
| II-VI                                                                                                                                                                | p=0.496             |                   |                    |                   |                  |                 | p=0.102            |                   |                    |                   |                  |                 |
| III-IV                                                                                                                                                               | p=0.999             |                   |                    |                   |                  |                 | p=0.999            |                   |                    |                   |                  |                 |
| III-V                                                                                                                                                                | p=0.999             |                   |                    |                   |                  |                 | p=1                |                   |                    |                   |                  |                 |
| III-VI                                                                                                                                                               | p=0.449             |                   |                    |                   |                  |                 | p=0.099            |                   |                    |                   |                  |                 |
| IV-V                                                                                                                                                                 | p=1                 |                   |                    |                   |                  |                 | p=1                |                   |                    |                   |                  |                 |
| IV-VI                                                                                                                                                                | p=0.196             |                   |                    |                   |                  |                 | p=0.025*           |                   |                    |                   |                  |                 |
| V-VI                                                                                                                                                                 | p=0.187             |                   |                    |                   |                  |                 | p=0.024*           |                   |                    |                   |                  |                 |
| SMA: Superior mesenteric artery, Min: Minimum, Max: Maximum, SD: Standard deviation, ANOVA: Analysis of variance, Tukey HSD: Tukey's honestly significant difference |                     |                   |                    |                   |                  |                 |                    |                   |                    |                   |                  |                 |

SMA: Superior mesenteric artery, Min: Minimum, Max: Maximum, SD: Standard deviation, ANOVA: Analysis of variance, Tukey HSD: Tukey's honestly significant difference

An important finding of the present study was the presence of gender-related differences in SMA morphology. Females demonstrated a higher prevalence of SMA origin at the L1-upper level, whereas males more frequently exhibited origins at the L1-lower level. In addition, both SMA-angle and SMA-distance were significantly greater in males. Ozkurt et al.<sup>6</sup> evaluated asymptomatic individuals using computed tomography and reported considerable variability in aortomesenteric measurements among healthy subjects. Similarly, Hadi et al.<sup>8</sup> demonstrated that normal aortomesenteric angle and distance values may vary considerably in asymptomatic individuals. These findings support the view that demographic and anatomical variation should be considered during radiological assessment.

One possible explanation for the gender-related differences observed in the present study is variation in body composition and retroperitoneal fat distribution. The aortomesenteric space is influenced by the amount of intervening fat tissue between the SMA and abdominal aorta. Previous studies and reviews have suggested that loss of this fat cushion narrows the aortomesenteric angle and distance, whereas preservation or increase of retroperitoneal fat may widen this space.<sup>4,11</sup> Although body mass index was not evaluated in the present study, this mechanism may partly explain the greater SMA-angle and SMA-distance values observed in males.

The mean SMA-angle and SMA-distance values observed in our cohort were generally compatible with previously reported normal ranges. Ozkurt et al.<sup>6</sup> reported normal aortomesenteric angle values ranging from 28° to 65° and distances from 10 to 34 mm on computed tomography in healthy individuals. Hadi et al.<sup>8</sup> also reported broad ranges of normal angle and distance values in asymptomatic subjects, reinforcing the importance of interpreting these parameters within the context of demographic and morphometric variability. Furthermore, Arthurs et al.<sup>10</sup> showed that normal SMA-angle values in children may differ from those in adults, highlighting the potential effect of age on aortomesenteric morphology.

A significant positive correlation was observed between SMA-angle and SMA-distance in both genders. This finding is anatomically expected because widening of the angle between the SMA and abdominal aorta increases the distance separating the two vessels. Similar associations have been reported in CT-based morphometric studies evaluating aortomesenteric anatomy.<sup>6,8</sup> Agrawal et al.<sup>9</sup> also emphasized the complementary role of multidetector CT measurements in evaluating the aortomesenteric region. Therefore, SMA-angle and SMA-distance should be interpreted together rather than as isolated parameters.

Age-related differences were observed in both the SMA-angle and SMA-distance. Although the youngest age group (18-37 years) demonstrated significantly lower values than most older groups, the relationship was not linear across all age categories. The highest mean SMA-angle and SMA-distance values were observed in individuals aged 68-77 years, whereas the oldest group (>78 years) showed a slight decline. These findings suggest that age-related changes in aortomesenteric morphology may not progress uniformly

throughout life. Alterations in body composition, nutritional status, and retroperitoneal fat distribution may partly explain these age-related differences. In addition, the higher frequency of SMA origin at the L1-L2 disc level among older individuals may reflect age-related vascular elongation, vertebral morphological changes, or anatomical remodeling. Although age-related changes in these parameters have not been extensively investigated in adults, alterations in body composition, nutritional status, and retroperitoneal fat distribution may contribute to enlargement of the aortomesenteric space over time.<sup>4,8,11</sup>

The clinical significance of aortomesenteric morphometry is particularly evident in superior mesenteric artery syndrome (SMAS). Narrowing of the aortomesenteric angle may compress the third portion of the duodenum, causing proximal intestinal obstruction. Unal et al.<sup>7</sup> reported that an aortomesenteric angle  $\leq 22^\circ$  and an aortomesenteric distance  $\leq 8$  mm may serve as useful diagnostic thresholds for SMAS. Neri et al.<sup>3</sup> showed that ultrasonographic evaluation of the aortomesenteric angle may contribute to the diagnosis of suspected SMAS. Similarly, Welsch et al.,<sup>4</sup> Agrawal et al.,<sup>9</sup> Mandarry et al.,<sup>12</sup> and Oka et al.<sup>13</sup> emphasized the role of radiological assessment in the diagnosis and management of SMAS.

In addition to duodenal compression, narrowing of the aortomesenteric space may also compress the left renal vein, resulting in nutcracker syndrome. Ahmed et al.<sup>5</sup> described renal nutcracker syndrome as compression of the left renal vein between the aorta and SMA and reviewed its diagnostic and therapeutic approaches. Kim et al.<sup>14</sup> demonstrated that Doppler ultrasonography of the left renal vein may be useful in diagnosing nutcracker syndrome. More recently, Ananthan et al.<sup>15</sup> emphasized that imaging-based assessment remains central to the diagnostic work-up and management of nutcracker syndrome. Therefore, normal reference data for SMA-angle and SMA-distance may be valuable not only for anatomical studies but also for evaluating vascular compression disorders.

## Limitations

This study has several limitations. First, because of its retrospective design, body-mass index (BMI) and other anthropometric measurements were not consistently available and therefore could not be analyzed. Second, the study population consisted of patients undergoing CTA for clinical indications at a single institution, which may limit the generalizability of the findings. Future multicenter prospective studies including anthropometric variables would further strengthen these findings.

Despite these limitations, the large sample size, equal gender distribution, and comprehensive evaluation of vertebral origin together with SMA-angle and distance provide robust reference data for radiological anatomy.

## CONCLUSION

As a result, the SMA most commonly originated from the L1 vertebral level, although considerable variation was observed between T12 and L2. Significant differences according to

gender and age were identified for both vertebral origin and aortomesenteric morphometric parameters. Furthermore, the positive correlation between SMA-angle and SMA-distance highlights their close anatomical relationship and supports their combined use during radiological assessment of abdominal vascular anatomy and vascular compression syndromes.

## ETHICAL DECLARATIONS

### Ethics Committee Approval

This study was approved by the Sivas Cumhuriyet University Health Sciences Researches Ethics Committee (Date: 30.10.2025, Decision No: 2025-10/10).

### Informed Consent

This retrospective study used pre-existing anonymized patient data. No additional intervention was performed, and there was no direct patient contact. The study was approved by the Ethics Committee, and the requirement for written informed consent was waived by the ethics committee.

### Peer Review Process

This manuscript was subject to external peer review.

### Conflict of Interest

The authors declare no conflicts of interest related to this study.

### Financial Disclosure

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### Author Contributions

Concept: KÇ, NB; Design: KÇ, NB; Control: KÇ; Resources: KÇ, NB; Materials: KÇ, NB; Data Collection and/or Processing: NB; Analysis and/or Interpretation: KÇ, NB; Literature Review: KÇ, NB; Writing the Article: KÇ; Critical Review: KÇ, NB.

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