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Superior mesenteric artery syndrome: CT and ultrasonography findings

Birsen Ünal, Aykut Aktaş, Gökhan Kemal, Yasemin Bilgili, Sefa Güliter, Çağatay Daphan, Kuzey Aydınuraz

PURPOSE

The purpose of the study was to describe computed tomography (CT) and ultrasonography findings in superior mesenteric artery syndrome (SMAS).

MATERIALS AND METHODS

The study was performed on 89 CT examinations. Ultrasonography was performed on 32 and barium study was performed on four of these subjects. Group A consisted of cases with one or more of the following complaints: postprandial epigastric pain, weight loss and vomiting. Group B consisted of the remaining cases. Cases who had all of the above-mentioned clinical findings and duodenal dilatation, to-and-fro barium movement and SMA indentation in barium study were diagnosed as having SMAS. Body mass index (BMI, kg/m²) was calculated. The distance between SMA and aorta, at the location where the duodenum passes from, was measured on CT and ultrasonography. The angle between SMA and aorta was measured on ultrasonography images. Group and gender differences were analyzed with t-test, the relationship between clinical and CT findings was analyzed with Mann Whitney U test and the relations between BMI-CT and CT-ultrasonography measurements were analyzed with Pearson coefficients.

RESULTS

Of 13 cases in Group A, 3 were diagnosed as SMAS. Eight of the cases showed gastric and/or duodenal dilatation. In 6 cases, antrum had an abnormally high location at portal hilus. In Group A, the SMA-aorta distance was 6.6 ± 1.5 mm and the SMA-aorta angle was $18.7 \pm 10.7^\circ$. In Group B, these values were 16.0 ± 5.6 mm and $50.9 \pm 25.4^\circ$, respectively ($p < 0.001$). Cut-off values between SMAS and Group B were 8 mm (100% sensitivity and specificity), and 22° (42.8% sensitivity, 100% specificity). CT and ultrasonography measurements ($p < 0.001$) and SMA-aorta distance and BMI ($p = 0.004$) were significantly correlated. The SMA-aorta distance was significantly shorter in females ($p = 0.036$).

CONCLUSION

Gastric and/or duodenal dilatation and a diminished SMA-aorta distance have a significant correlation with clinical symptoms of SMAS that include postprandial pain, vomiting and weight loss.

Key words: • CT • postprandial pain • ultrasonography • vomiting • weight loss

The superior mesenteric artery syndrome (SMAS) is characterized by the compression of the third segment of duodenum by the mesentery at SMA level, and a resulting duodenal ($\pm$ gastric) dilatation (1-6). This syndrome is variably called as arterial mesenteric duodenal compression, cast syndrome or Wilkie's syndrome. Barium studies of the upper gastrointestinal tract, computed tomography (CT), conventional angiography, CT angiography, and magnetic resonance (MR) angiography are used in the diagnosis (1-6). The purpose of the study was to describe CT and ultrasonographic criteria of SMAS.

Materials and methods

Eighty-nine cases, consecutively referred to our department for CT investigation of the upper abdomen, were enrolled in the study. The study was prospectively conducted after the first case for which the diagnosis of SMAS was achieved radiologically. Thirty-two cases were evaluated with ultrasonographic examination that was performed after CT study; four of these were also evaluated with barium studies. Age, weight, height and clinical history were recorded for all patients. Body mass index (BMI) was calculated as weight (kg)/area (m²). Age, gender and BMI distributions are presented at Table 1.

CT studies were performed after administration of 1.5 L of water which was consumed orally every 15 min at an amount of 250 ml. The water contained 20 ml iodinated (300 mg I/ml) contrast media. The last portion of the iodinated water was administered immediately before the study while the patient was on the scanner's couch. Intravenous (IV) contrast medium was administered in 78 of the cases.

Slice thickness was selected as 10 mm. The minimum SMA-aorta distance was measured on transverse ultrasonography and CT images at the level where the duodenum passes between the specified structures (Figures 1 and 2). The angle between SMA and aorta was measured on sagittal ultrasonography images (Figure 3). Gastric and duodenal dilatation was investigated using CT. A duodenal diameter of more than 3 cm was accepted as indication of duodenal dilatation. Relevant literature did not reveal a CT criterion for gastric dilatation. Therefore the following were accepted as signs of gastric dilatation: The presence of gastric rugal flattening, circumferential gastric wall thinning, and large air-fluid levels after filling the colonic segments with iodinated contrast media. Information with regard to postprandial epigastric pain, sense of repletion, vomiting, and weight loss were obtained through clinical inquiry. Cases who had at least one of these signs were classified as Group A; the rest were classified as Group B. Measurements were performed by one radiologist and clinical inquiry was conducted by another radiologist. Cases that had all of the above-mentioned symptoms, duodenal and/or gastric dilatation at the barium follow-up, to-and-fro movement in the

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Received 17 October 2004; revision requested 30 November 2004; revision received 14 March 2005; accepted 16 March 2005.



Figure 1. a, b. The measurement of the SMA-aorta distance on transverse ultrasonography images. **a.** The distance in the SMAS case was 3.8 mm. Subcutaneous and retroperitoneal fatty tissues were remarkably thin. **b.** The distance for the control subject was 9 mm.

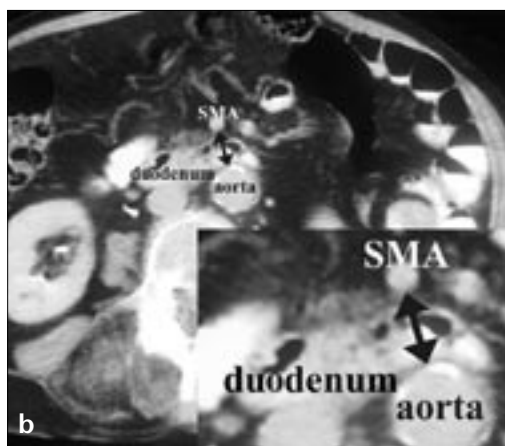
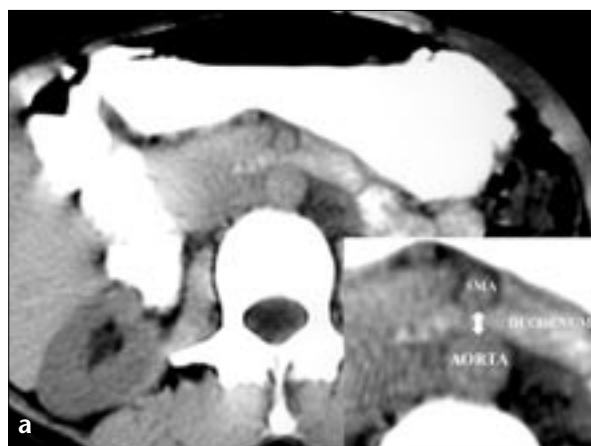


Figure 2. a, b. The measurement of SMA-aorta distance on transverse CT images. **a.** The distance in the SMAS case was 3.8 mm. **b.** The distance in the control subject was 11 mm.

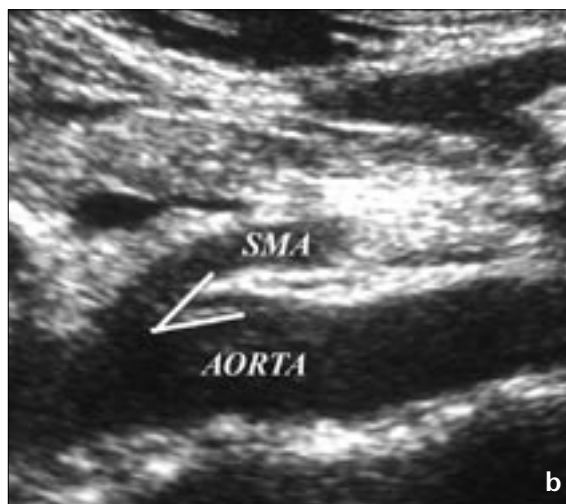


Figure 3. a, b. The measurement of the SMA-aorta angle on sagittal ultrasonography images. **a.** The angle in the SMAS case was 7°. **b.** The angle in the control subject was 32°.

duodenum, and duodenal indentation that was caused by SMA (Figure 4) were accepted as having SMAS.

The difference between Groups A and B regarding the above-mentioned measurements were investigated using Student's t-test. The correlation between clinical and CT findings were tested using Mann Whitney U. The correlation between ultrasonography

and CT findings, and between body mass index and the SMA-aorta distance were tested using Pearson's product moment correlation coefficients. Cut-off values between SMAS patients and normal subjects were calculated using ROC curves. The difference between measurements of male and female patients was tested using t-test.

Results

Clinical and radiological findings are compared in Table 2. In 13 of our cases, there was either one or more of the symptoms that included postprandial epigastric pain, sense of repletion, vomiting, and weight loss. These cases formed Group A, whereas cases without above-mentioned complaints formed Group B. Group A

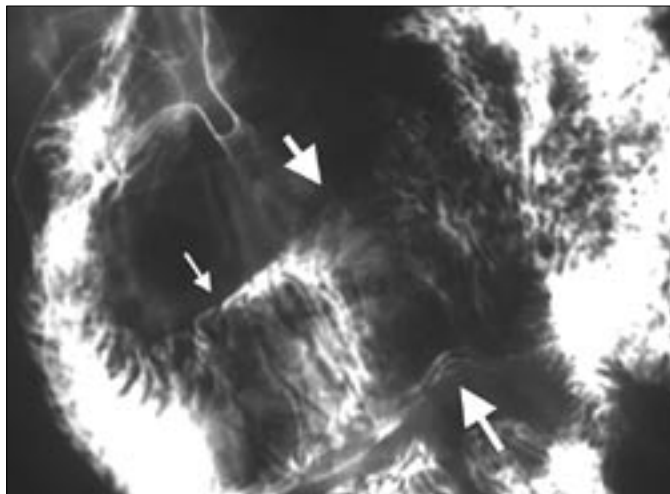


Figure 4. Duodenal dilatation (*thin arrow*) and the indentation caused by the SMA (*thick arrow*) in double-contrast upper gastrointestinal barium study obtained in recumbent position.

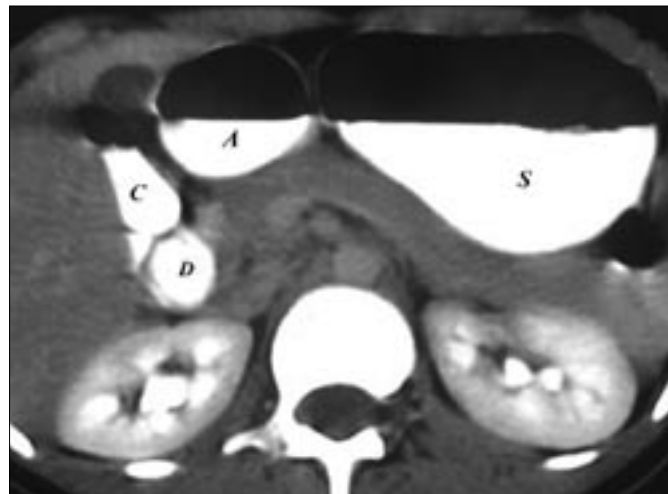


Figure 5. Gastric and duodenal dilatation on transverse CT image. S: stomach, A: antrum, D: duodenum, C: colon.

consisted of 10 females and 3 males, whereas Group B consisted of 34 females and 42 males.

In five cases in Group A, all of the investigated clinical findings (i. e., vomiting, postprandial epigastric pain, and weight loss) were present. One of these patients had severe vomiting since one month, he was unable to eat since 4 days, and he had unintentionally lost 4 kg during a one-month period. One patient had complaints of pain, vomit-

ing, inability to eat, and weight loss of 4-5 kg during the last 2 months. The remaining three cases were unable to eat, they were experiencing pain, sense of repletion and occasional vomiting, and they were unable to gain weight since 2, 15 and 20 years, respectively. The last group of patients experienced weight loss particularly during periods in which their complaints increased.

Endoscopic examinations were performed on 4 out of 5 cases in Group A;

the results were reported to be normal. The CT examinations showed that all of the cases had gastric, and 3 of the cases had gastric and duodenal dilatation (Figure 5). Duodenal lumens of these patients completely disappeared when the duodenum passed behind the SMA. Three of these five patients were additionally investigated with upper gastrointestinal barium studies. In these studies, prominent gastric dilatation was observed. In one case, single- and double-contrast barium studies showed duodenal dilatation and to-and-fro movement. On CT, his duodenum had normal width. Its third part had an impression caused by SMA and SMV. The remaining two cases had to-and-fro movements in their duodenum at erect position; duodenal

Table 1. Patients' demographics and BMI values

	n	Age (mean $\pm$ SD)	BMI (mean $\pm$ SD)
Female	50	45.9 $\pm$ 14.0	25.7 $\pm$ 5.3
Male	39	44.5 $\pm$ 16.1	24.5 $\pm$ 2.9

BMI: body mass index (kg/m²), SD: standard deviation

Table 2. Comparison of clinical findings with CT and ultrasonography findings

Clinical findings		CT findings			Ultrasonography findings
Group	n	Gastric dilatation	Duodenal dilatation	SMA-aorta distance	SMA-aorta angle
A	Postprandial pain, weight loss, vomiting (SMAS)	3	2	5.1 (3.8–7.0)	13.8 $\pm$ 8.5 (5–22)
	Postprandial pain, weight loss, vomiting	2	2	7.1 $\pm$ 1.4 (5.9–8.1)	20.5 $\pm$ 17.6 (8–33)
	Postprandial pain, weight loss	1	1	7	13
	Postprandial pain	4	2	6.6 $\pm$ 2.4 (4.5–10.1)	19.7 $\pm$ 10.3 (5–29)
	Weight loss	2	-	10.5 $\pm$ 3.5 (8.7–13.5)	30.5 $\pm$ 9.2 (24–37)
	Vomiting	1	-	6.5	18
	Total	13	9	6.4	
B	Cases without clinical findings	76	1	16.0 $\pm$ 5.6 (8.2–33.3)	50.9 $\pm$ 25.4 (15–112)
p				<0.001	<0.001

SMAS: superior mesenteric artery syndrome

All values were given as mean $\pm$ standard deviation and range.

p values denote the significant differences between Groups A and B.

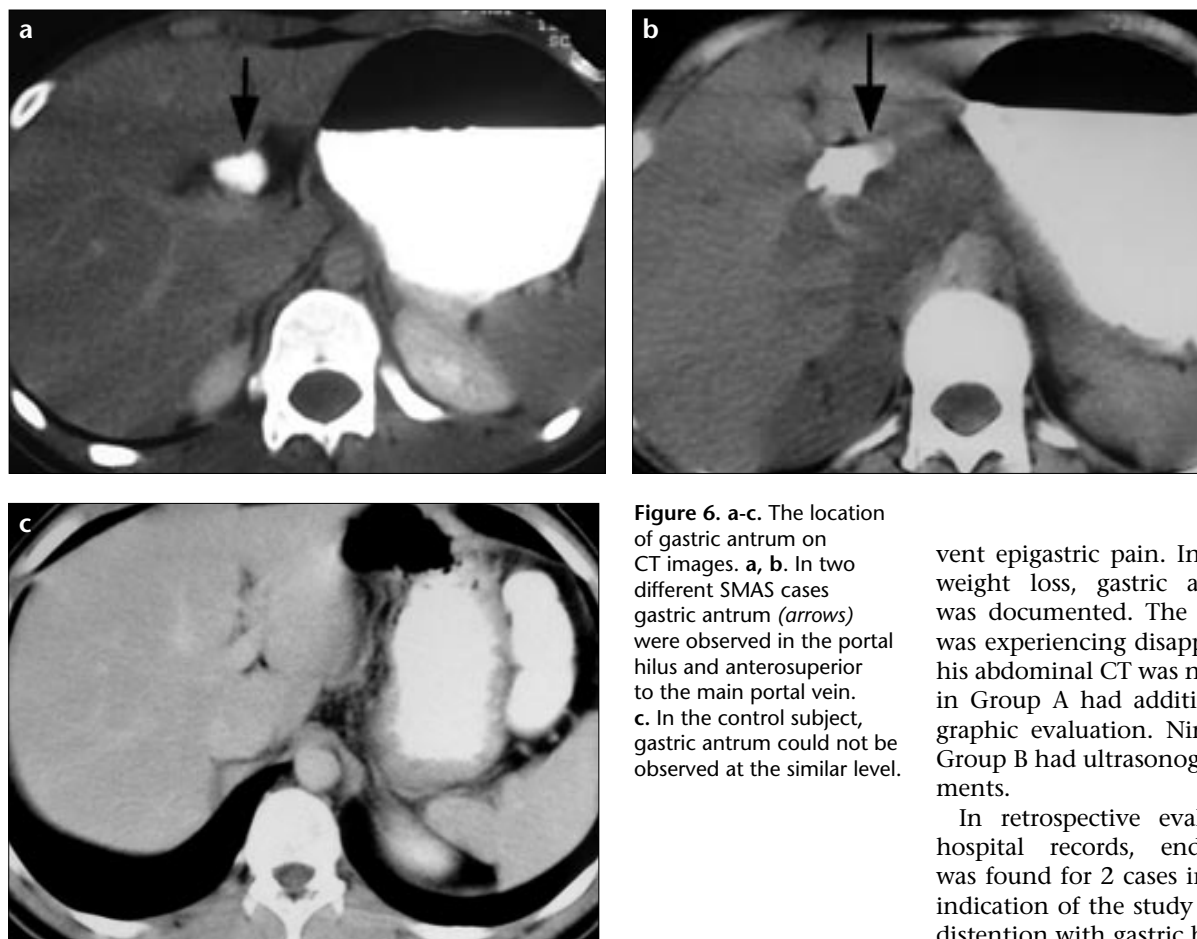


Figure 6. a-c. The location of gastric antrum on CT images. **a, b.** In two different SMAS cases gastric antrum (arrows) were observed in the portal hilus and anterosuperior to the main portal vein. **c.** In the control subject, gastric antrum could not be observed at the similar level.

vent epigastric pain. In one case with weight loss, gastric adenocarcinoma was documented. The remaining case was experiencing disappetite; however, his abdominal CT was normal. All cases in Group A had additional ultrasonographic evaluation. Nineteen cases in Group B had ultrasonography measurements.

In retrospective evaluation of the hospital records, endoscopic study was found for 2 cases in Group B. The indication of the study was abdominal distention with gastric burning. One of them had a duodenal ulcer while the other one had gastritis. One of the cases had gastric wall thickening in CT and was pathologically diagnosed as gastric lymphoma. None of the patients had a sign of neuromuscular disease.

CT images of 3 cases who were diagnosed as SMAS were studied for the localization of gastric antrum. One of the cases had all of the clinical findings but upper gastrointestinal barium study had not been performed. Two cases reported postprandial pain and sense of repletion. In all cases, gastric antrum was located at the level of portal hilus, anterior to the main portal vein (Figure 6).

There was a statistically significant difference between the measurements of Groups A and B ($p < 0.001$) for the SMA-aorta distance and the SMA-aorta angle (Table 2). In cases that had at least one of the clinical symptoms, the average values were 6.6 ± 1.5 mm and $18.7 \pm 10.7^\circ$, respectively. The values for normal subjects were 16.0 ± 5.6 mm and $50.9 \pm 25.4^\circ$, respectively. The respective cut-off values were 8 mm (100% sensitivity and specificity) and 22° (42.8% sensitivity and 100% specificity). Table 3 displays the cut-off

dilatation was not present. However, when examined at recumbent position and when an effervescent agent was orally administered, duodenal dilatation and SMA impression at the third duodenal segment was observed. These two cases also had duodenal dilatation on their CT images. One of the above-mentioned three cases was male (BMI=22), and the remaining two were female (BMI=15 and 19). They were diagnosed as having SMAS.

The remaining two cases were not evaluated with upper gastrointestinal barium studies.

There were postprandial epigastric pain, sense of repletion and weight loss in one of the remaining 8 patients of Group A; postprandial epigastric pain and sense of repletion in 4 patients; weight loss in 2 cases; and vomiting in one case. Cases with postprandial pain and sense of repletion reported that they diminished food intake to pre-

Table 3. Comparison of SMA-aorta distance and clinical-radiological findings

	SMA-aorta distance	n	Clinical finding positive	Duodenal and/or gastric dilatation	BMI
Group A	≤ 8 mm	12	12	8	20.3 ± 2.5
	> 8 mm	1	1	1	23
	Total	13	13	9	20.9 ± 2.9
Group B	≤ 8 mm	2	-	1	20.7 ± 1.0
	> 8 mm	74	-	-	25.9 ± 3.6
	Total	76	-	1	25.7 ± 3.8
p			< 0.001	0.001	0.001

BMI: body mass index (kg/m^2)

BMI values were presented as mean $\pm$ standard deviation

values for the SMA-aorta distance along with clinical and radiological findings. A highly significant relation was found between ultrasonography and CT measurements ($r=0.850$, $p<0.001$).

An evaluation of the total sample showed that gender had a significant effect on the SMA-aorta distance ($p=0.036$). This distance was found to be 13.4 ± 5.7 mm for females and 16.3 ± 6.5 mm for males. Body mass index was significantly correlated with the SMA-aorta distance ($r=0.616$, $p=0.004$).

Discussion

SMAS is a rare pathology. In a series which included 6,000 upper gastrointestinal tract barium studies, Anderson et al. found only 12 (0.2%) SMAS (4). Rosa-Jimenez et al., on the other hand, found 10 (0.78%) SMAS in a total of 1,280 studies (5). Etiological factors included structural and/or acquired factors. Incomplete rotation of the duodenum, abnormally high insertion and shortness of the ligament of Treitz, fast weight loss, anorexia nervosa, scoliosis, body casting were among these factors (1-7). In its acute or chronic forms, the syndrome becomes clinically manifest with predominantly postprandial epigastric pain, sense of repletion, and vomiting (1, 6, 7). Most patients do not exhibit all of the above-stated complaints. Chronic cases may present a clinical history with duration of 15 to 20 years. The diagnosis is usually established by excluding other differential diagnoses. Endoscopic and conventional radiological investigations of these cases are usually normal or they may reveal a slight gastritis and bile reflux. As clinical and radiological findings are transitory, the diagnosis may easily be overlooked if investigations are performed between manifest periods (1). In their retrospective analysis of barium studies, Hines et al. pointed to the overuse of this diagnosis in cases that were normal or were not exactly fulfilling diagnostic criteria (9). Rosa-Jimenez et al. suggested that this pathology should be based on radiological findings as it is not always correlated with clinical findings (5). Conventional barium studies play an important role in the diagnosis of this syndrome, although the findings are not specific. In these studies, duodenal dilatation, the indentation caused by SMA and forward-backward barium movement are important diagnostic

criteria. Lukes et al. suggested that duodenal dilatation may not always be shown. They thus developed the technique of hypotonic duodenography in which duodenal peristalsis was suppressed using antiperistaltic agents (3). In their study on 11 surgically proven cases, Gustafson et al. indicated that upper gastrointestinal barium studies might be preoperatively normal. In that study, hypotonic duodenography revealed positive findings in 10 of their cases. However, some authors consider this technique as nonphysiological as it suppresses peristalsis (6). Wang et al. suggested that the slight duodenal dilatation might be overlooked at conventional barium studies. They have emphasized the importance of duodenal inflation with air (10). Measurement of the angle between the SMA and the aorta using conventional, CT or MR angiography is another radiological diagnostic method. In previous angiographic studies of SMAS cases, this angle was found to be 7° - 22° (normal values were found to be 25° and 60°) and the distance was found to be 2- 8 mm (normal values found to be 10-28 mm) (1-3). Konen et al. pointed to the advantage of 3-dimensional CT angiographic reconstructions which can help to eliminate the erroneous diagnoses that originate from the angulations of SMA (6). Santer et al. and Applegate et al. were among the first researchers to introduce CT findings of SMAS (11, 12). In their cases, they demonstrated gastric and duodenal dilatation, and the reduction of the distance between the SMA and the aorta (11, 12). However, in these studies, the number of the control subjects was not large enough to permit a comparison.

In our study, we observed a reduction in the distance between the SMA and the aorta in SMAS cases in comparison to control subjects. Additionally, we found a high correlation between the distance reduction and clinical symptoms of SMAS. In some cases, we could demonstrate duodenal dilatation with either CT or upper gastrointestinal barium studies. On several occasions, the latter technique could demonstrate the dilatation only after air insufflations. However, CT was able to reveal gastric dilatation and the reduction of the SMA-aorta distance in all subjects. Contrary to the studies by Hines et al. and Rosa-Jimenez

et al., we found that the radiological and clinical findings were closely correlated (5, 9). Accordingly, these two CT findings must create a suspicion in the way of pathology even in those cases where all radiological diagnostic criteria could not be met. We further think that these two CT findings may explain the clinical symptoms of those cases where underlying pathological causes could not be found (6, 10).

In our study, we found that the cases in Group A had lower BMI values when compared to those in Group B. The cases that exhibit clinical findings were mostly females. Two females with SMAS had substantially low BMI values. This observation may be explained by the presence of an insufficient retroperitoneal fat in thin subjects, the concurrent reduction in the SMA-aorta distance, and the occurrence of clinical findings caused by the latter. However, the low BMI values may also be explained by the changing dietary habits after postprandial complaints.

In CT of our cases with SMAS, the gastric antrum was observed at the level of the portal hilus, anterosuperior to the main portal vein. This was observed in only one of the control cases. That subject had an endoscopically diagnosed stricture of the duodenal bulb that was caused by ulceration. In that particular case, the location of the antrum was more inferior in comparison to that of the SMAS cases but more superior to that of the normal subjects. In two patients with antral adenocarcinoma and diffusely infiltrating gastric lymphoma, we have not noticed this finding. This finding was not encountered in normal subjects. We considered this as a CT sign of gastric dilatation (Figure 6). We think that duodenal dilatation might have led to the upward displacement of antrum. For that reason, the aforementioned appearance may really be a sign of distal duodenal obstruction rather than the obstruction of antrum, pylorus or proximal duodenum.

In cases with suspected SMAS, CT measurements are very similar to conventional and CT angiographic measurements and all have a high diagnostic rate. CT is advantageous over upper gastrointestinal barium study because it has a greater patient comfort. Relative noninvasiveness, on the other hand, is its advantage over conven-

tional angiography. The advantage of CT over ultrasonography is its ability to demonstrate additional pathologies along with dilatation of the stomach and the duodenum. If encountered on CT images, the reduction of the distance between the SMA and the aorta, and the dilatation of stomach and/or duodenum should be reported. If clinical findings exist, such cases should be further investigated with upper gastrointestinal barium studies.

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