Duplex Doppler Sonographic Assessment of the Superior Mesenteric Artery in Patients With Mesenteric Panniculitis

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Objectives—We aimed to determine how the hemodynamic parameters of the superior mesenteric artery are affected in mesenteric panniculitis.

Methods—Twenty-one patients with a diagnosis of mesenteric panniculitis on computed tomography were evaluated with duplex Doppler sonography. The control group consisted 20 asymptomatic volunteers. The peak systolic velocity, end-diastolic velocity (EDV), resistive index (RI), pulsatility index (PI), blood flow volume, and body mass index were measured in the group of patients with mesenteric panniculitis, and the findings were compared with those of the control group.

Results—The mean blood flow volume and EDV were significantly higher in the patient group: The mean superior mesenteric artery blood flow volume ± SD was 917.86 ± 228.97 mL/min in the patient group versus 389.73 ± 92.72 mL/min in the control group ($P < .001$). The mean EDV was 31.56 ± 8.44 m/s in the patient group versus 19.27 ± 4.19 m/s in the control group ($P < .001$). The mean RI and PI were significantly lower in the patient group: The mean RI was 0.81 ± 0.04 in the patient group versus 0.85 ± 0.03 in the control group ($P = .001$). The mean PI was 2.69 ± 0.68 in the patient group versus 3.81 ± 1.13 in the control group ($P = .001$). the mean superior mesenteric artery diameter was 7.30 ± 0.67 mm in the patient group versus and 6.46 ± 0.66 mm in the control group ($P < .001$). The mean BMI was 27.95 ± 3.80 kg/m^2 in the patient group versus 23.16 ± 3.47 kg/m^2 in the control group ($P < .001$).

Conclusions—In patients with mesenteric panniculitis, the Doppler spectrum of the superior mesenteric artery shows detectable changes, which are characterized by decreased vascular resistance and increased blood flow.

Key Words—Doppler (abdominal); duplex Doppler sonography; mesenteric panniculitis; superior mesenteric artery

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Abbreviations

BMI, body mass index; CT, computed tomography; EDV, end-diastolic velocity; PI, pulsatility index; PSV, peak systolic velocity; RI, resistive index

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Mesenteric panniculitis is a rare disorder that is characterized by inflammation of the mesenteric adipose tissue.[1] This disorder most commonly involves the mesentery of the small bowel, but the mesocolon may also be occasionally involved.[2,3] The etiology of mesenteric panniculitis remains unclear. The disease may occur in isolation, or it may be associated with other disorders.[1] The suggested causes of mesenteric panniculitis include autoimmune disorders, infection, trauma, prior abdominal surgery, and ischemia of the mesentery.[4,5] Mesenteric panniculitis has also been associated

with malignancy, particularly with lymphoma, gastrointestinal malignancies, and genitourinary malignancies.[6] The association between mesenteric panniculitis and the underlying malignancy is poorly understood, and mesenteric panniculitis has been suggested to be a paraneoplastic condition in some patients.[1] It mostly occurs in middle to late adulthood, with a slight male predominance.[7] Reported prevalence rates for mesenteric panniculitis range between 0.16% and 7.80%.[7,8] The disease may be asymptomatic, or the patients may present with nonspecific gastrointestinal symptoms. In most cases, mesenteric panniculitis is diagnosed incidentally on computed tomography (CT), but it may also be detected on magnetic resonance imaging or sonography.[9]

Hemodynamic changes in the superior mesenteric artery reflect the changes in the intestinal circulation and are influenced by the pathophysiologic mechanisms of the underlying bowel diseases. Of these, intestinal inflammatory diseases cause dilatation and congestion of the mesenteric vasculature. Decreased arterial resistance results in an increase in blood flow velocity and blood volume.[10,11] Similarly, the changes in intestinal vascular impedance in cases of mesenteric panniculitis may be reflected in the Doppler waveform of the superior mesenteric artery.

Duplex Doppler sonography is a noninvasive tool that provides simple and reproducible measurements of blood flow. Measurements of the flow velocity and vessel diameter can be used for assessment of the peripheral vascular resistance detection of arterial occlusive disease. Depending on the size and the anatomic location of the vessel, the superior mesenteric artery can be evaluated with duplex Doppler sonography.[12] We aimed to determine how duplex Doppler sonographic parameters of the superior mesenteric artery are affected in patients with mesenteric panniculitis. We evaluated duplex Doppler sonographic parameters of the superior mesenteric artery in a group of patients with mesenteric panniculitis and compared the findings with those of a group of asymptomatic control volunteers.

Materials and Methods

The patients were referred to our department for CT of the abdomen for various clinical indications. In a total of 26 patients, mesenteric panniculitis was identified on CT. Of these, 5 patients were excluded from the study: One patient had a history of cardiac disease; 1 patient had a history of renal surgery; and 1 patient had a recent history of an adrenalectomy. In 2 patients, duplex Doppler sonographic measurements could not be performed because of noncompliance of the patients. Thus, a total of 21 patients were included in the study. The chief symptom of all included patients was abdominal pain. None of the patients had a suspected diagnosis of mesenteric panniculitis before the CT scan. The control group consisted of 20 asymptomatic volunteers who were selected from the medical staff. None of the participants in the control group had a CT scan. Control group participants were evaluated by sonography for grayscale findings of mesenteric panniculitis. None of the patients in the study had a history of malignancy, major surgery, chronic gastrointestinal or genitourinary disease, or of chronic cardiac disease. The body mass index (BMI) was calculated as the weight in kilograms divided by the square of the height in meters. Written informed consent was obtained from all patients. The approval of the Ethics Board for nonpharmacologic clinical trials was obtained to conduct this study (No. 11-BADK-020).

Computed tomographic scans were performed with 8-slice scanners (LightSpeed Ultra; GE Healthcare, Milwaukee, WI) in the portal venous phase. A positive CT diagnosis of mesenteric panniculitis required the presence of all of the following CT findings: a well-defined mass of inhomogeneous fatty tissue at the root of the small-bowel mesentery with attenuation values higher than those of the subcutaneous or retroperitoneal fat tissue; engulfment of the superior mesenteric vessels or displacement of the bowel loops with no evidence of invasion of these structures; lymph nodes within the mass with a short axis of less than 10 mm; a pseudocapsule surrounding the mass; and fat ring sign (Figures 1 and 2).[7,13] These strict criteria were used to avoid a false-positive diagnosis that may result from alternative causes of increased mesenteric fat density.[1] Thus, after application of the clinical and imaging criteria, the diagnosis of mesenteric panniculitis was only reserved for cases with idiopathic inflammatory infiltration of the mesentery.

All sonographic examinations were performed in the morning after an overnight fast with an ultrasound scanner (LOGIQ 7; GE Healthcare) equipped with a 2–5-MHz convex transducer. The pulse repetition frequency (PRF) was adjusted according to the flow velocity of the studied vessel. A high-pass filter was used to eliminate undesirable low-frequency Doppler signals arising from the arterial wall motion. The Doppler angle

was kept between 30° and 60°, and the sampling gate (sample volume) was adjusted to include as much of the vessel lumen as possible, without including the vessel wall. All examinations were performed with the patient lying in the supine position after a 5-minute rest. The sonographic measurements were obtained in the longitudinal plane from the first 3 cm of the superior mesenteric artery, before the emergence of its branches. The peak systolic velocity (PSV) and end-diastolic velocity (EDV) were measured, and the resistive index (RI), pulsatility index (PI), and PSV/EDV ratio values were determined (Figures 3 and 4). At the point of the Doppler measurements, the diameter of the superior mesenteric artery was measured. The cross-sectional area and blood flow volume of the superior mesenteric

Figure 1. Axial nonenhanced CT shows a heterogeneous mass of hyperattenuated fatty tissue within the small-bowel mesentery. A peripheral curvilinear band of soft tissue (pseudocapsule; arrow) separates the mass from the surrounding normal mesenteric fat. Note that the engorged mesenteric vessels within the mass (arrowheads) are surrounded by the preserved normal fat (fat ring sign).



Figure 2. Transverse grayscale sonography shows a large well-circumscribed heterogeneous hyperechoic mass (arrows) at the small-bowel mesentery. The mass encloses mesenteric vessels without any signs of displacement or invasion.



Figure 3. Color Doppler sonography and duplex Doppler waveform of the superior mesenteric artery in a patient with mesenteric panniculitis. The sampling cursor was placed within the lumen of the vessel, 2 to 3 cm distal to its origin. The superior mesenteric artery displays a low-resistance waveform with disappearance of the reversed flow components and increases in diastolic velocities. AT indicates arrival time; ED, end-diastolic velocity; PS, peak systolic velocity; TAMAX, time-averaged maximum velocity; and TAMEAN, time-averaged mean velocity.

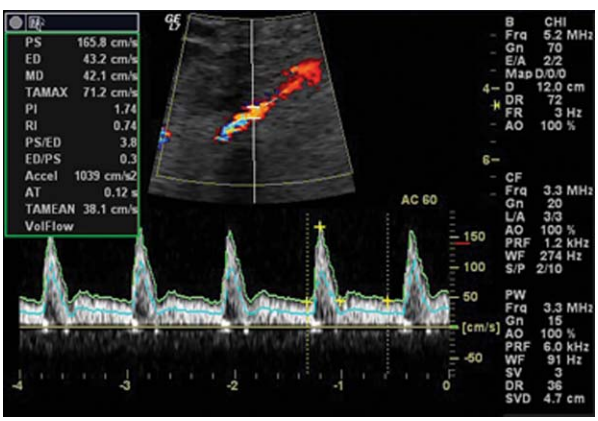
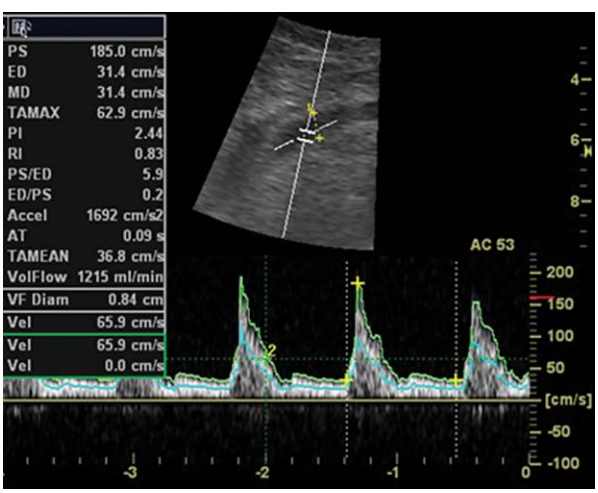


Figure 4. Duplex Doppler sonography of a patient with mesenteric panniculitis shows a low-resistance waveform in the superior mesenteric artery with continuous forward diastolic flow. The blood flow is higher than 1200 mL/min. Abbreviations are as in Figure 3.



artery were then calculated. For standardization of the measurements, all measurements were performed by the same radiologist. For each patient, 3 consecutive measurements were obtained, and the average of 3 measurements was used in the statistical analyses.

Continuous data were expressed as mean ± standard deviation or median (interquartile range), where appropriate. The distributions of the variables across the study groups were tested with the Shapiro-Wilks test. Data were analyzed by the Student *t* test or Mann-Whitney *U* test. The Pearson correlation coefficient or Spearman rank-order correlation coefficient was calculated to evaluate the strength and direction of relationship between variables. In the analysis of categorical data, the Fisher exact χ^2 test was used. Two-tailed $P < .05$ was considered statistically significant. All statistical analyses were performed with SPSS version 21.0 software for Windows (IBM Corporation, Armonk, NY)

Results

There were 13 male (61.9%) and 8 female (38.1%) patients in the patient group (mean age, 50.19 ± 10.87 years; age range, 30–70 years). The control group had 10 male (50.0%) and 10 female (50.0%) participants (mean age, 42.75 ± 7.14 years; age range, 30–60 years). The difference in the sex distributions between the patient and control groups was not significant ($P = .651$, Fisher exact χ^2 test). None of the patients with mesenteric panniculitis had a replaced right or common hepatic artery. Additional abdominal visceral findings on CT scans of the patients with mesenteric panniculitis included 1 simple renal cortical cyst in 3 patients, 1 simple liver cyst in 2 patients, gallbladder calculi in 1 patient, and 1 nonobstructing calyceal calculus in 1 patient. None of the patients in the control group had positive sonographic findings for mesenteric panniculitis.

Of the quantitative duplex Doppler parameters of the superior mesenteric artery in the patients with mesenteric panniculitis, we found statistically significant differences in the PSV, EDV, PI, RI, PSV/EDV, and blood flow volume between the patient and control groups. The mean superior mesenteric artery flow volume was significantly higher in the patient group than in the control group. The mean RI and PI were significantly lower in the patient group than in the control group. The mean EDV was significantly higher in the patient group than in the control group. The mean superior mesenteric artery diameter was statistically significantly higher in the patient group than in the control group. The mean BMI was significantly higher in the patient group than in the control group. The findings are shown in Table 1.

In the analysis of the relationship between BMI and duplex Doppler sonographic parameters among the patient and control groups, we found significant differences in the blood flow volume, EDV, PI, and superior mesenteric artery diameter between the participants with a BMI of greater than the median and less than the

Table 1. Duplex Doppler Parameters of the Superior Mesenteric Artery and BMI

Parameter	Control Group (n = 20)	Patient Group (n = 21)	*P*
Superior mesenteric artery diameter, mm	6.46 ± 0.66 6.70 (5.95–7.00)	7.30 ± 0.67 7.40 (6.90–7.60)	<.001
PSV, m/s	135.21 ± 12.85 135.80 (126.12–174.15)	176.47 ± 38.05 178.70 (136.65–204.55)	<.001
EDV, m/s	19.27 ± 4.19 20.15 (15.57–21.77)	31.56 ± 8.44 31.45 (26.50–37.05)	<.001
PI	3.81 ± 1.13 3.70 (2.76–4.91)	2.69 ± 0.68 2.56 (2.25–3.17)	.001
RI	0.85 ± 0.03 0.86 (0.83–0.88)	0.81 ± 0.04 0.83 (0.78–0.85)	.009
PSV/EDV	7.36 ± 1.74 7.30 (5.96–8.52)	5.85 ± 1.36 6.10 (4.72–6.85)	.004
Blood flow volume, mL/min	389.73 ± 92.72 408.40 (311.20–469.22)	917.86 ± 228.97 836.60 (746.90–1044.00)	<.001
BMI, kg/m^2	23.16 ± 3.47 24.15 (21.62–25.47)	27.95 ± 3.80 27.70 (25.10–29.90)	<.001

Data are presented as mean ± SD and median (interquartile range).

median (Table 2). In the evaluation of the direction and strength of the relationship among the BMI, blood flow volume, and vessel diameter, a moderate positive correlation was found between the BMI and blood flow volume, and a low positive correlation was found between the BMI and vessel diameter. A high positive correlation was found between the blood flow volume and vessel diameter (Table 3).

When the effect of sex on duplex Doppler sonographic parameters among the patient and control groups was evaluated, we found the mean superior mesenteric artery diameter and PI to be significantly higher in the male group than in the female group (Table 4). Also, the mean superior mesenteric artery diameter and EDV were significantly higher in the age group that was older than the median (Table 5). With regard to categorical age and sex, the differences in the other studied duplex Doppler sonographic parameters did not reach statistical significance.

Discussion

Mesenteric panniculitis is an inflammatory condition of the mesenteric fatty tissue.[2] Histologically, mesenteric panniculitis represents a spectrum of changes in the mesentery that are characterized by degeneration, inflammation, and scarring of the fatty tissue.[14]

Computed tomography is the modality of choice for diagnosis of mesenteric panniculitis. On abdominal CT examinations, a "fat ring" sign is representative of mesenteric panniculitis, and it refers to preservation of normal fat density around the mesenteric vessels on a background of increased fat density. A "pseudocapsule" sign on CT refers to the presence of a peripheral band of tissue that separates the mesenteric mass from the surrounding normal folds. A "misty mesentery sign" refers to increased attenuation of the mesentery with small soft tissue nodules and engorgement of the mesenteric vessel. This sign does not include the description of a

Table 2. Duplex Doppler Parameters and BMI

Parameter	≤25.4 kg/m^2 (n = 20)	≥25.4 kg/m^2 (n = 21)	*P*
Superior mesenteric artery diameter, mm	6.60 ± 0.79 6.75 (5.95–7.18)	7.16 ± 0.69 7.20 (6.75–7.55)	.020[a]
PSV, m/s	151.96 ± 34.82 144.10 (128.10–171.00)	160.52 ± 35.89 144.00 (130.75–188.58)	.514[b]
EDV, m/s	22.41 ± 6.52 21.00 (17.60–27.18)	28.59 ± 10.27 29.50 (19.60–34.85)	.028[a]
PI	3.49 ± 0.92 3.53 (2.69–4.15)	3.01 ± 1.19 2.55 (2.25–3.54)	.039[b]
RI	0.85 ± 0.03 0.85 (0.83–0.87)	0.82 ± 0.05 0.83 (0.79–0.86)	.051[b]
PSV/EDV	7.13 ± 1.65 6.75 (5.96–7.98)	6.08 ± 1.67 6.10 (4.73–7.25)	.051[a]
Blood flow volume, mL/min	531.95 ± 250.20 463.65 (336.78–714.50)	782.42 ± 334.45 789.90 (459.70–998.00)	.022[b]

Data are presented as mean ± SD and median (interquartile range).
[a]Independent-samples *t* test.
[b]Mann-Whitney *U* test.

Table 3. Direction and Strength of the Relationships Among BMI, Blood Flow Volume, and Superior Mesenteric Artery Diameter: Combinations of Correlations Among the Parameters

	r (*P*)[a]		
Parameter	BMI	Blood Flow Volume	Superior Mesenteric Artery Diameter
BMI		0.473 (.002)	0.412 (.007)
Blood flow volume	0.473 (.002)		0.633 (<.001)
Superior mesenteric artery diameter	0.412 (.007)	0.633 (<.001)	

[a]Spearman correlation test.

discrete soft tissue mass, and it is not specific for mesenteric panniculitis. Of the CT findings of mesenteric panniculitis, the pseudocapsule sign and the fat ring sign are more specific for the diagnosis of mesenteric panniculitis, as they have not been reported in other mesenteric diseases. These signs are found in up to 60% and 75% of cases, respectively.[15,16]

It has been reported that inflamed bowel segments show certain vascular and microvascular changes. Of these, Crohn disease causes neovascularization; arteritis and ulcerative colitis cause dilatation and congestion of the mucosal and submucosal vessels; and celiac disease causes arteriovenous shunts and dilatation of the subepithelial capillary network.[11] The vascular and microvascular changes in inflamed bowel segments result in a decrease in vascular resistance and an increase in blood flow within the bowel wall or the splanchnic vessels. It is postulated that these changes in blood flow can be used for assessment of disease activity with Doppler imaging.[17]

Using Doppler sonography, several studies assessed the changes in the superior and inferior mesenteric arteries of patients with Crohn disease or ulcerative colitis.[18–20] Sigirci et al[18] found significantly

Table 4. Duplex Doppler Parameters and Sex

Parameter	Female (n = 18)	Male (n = 23)	*P*
Superior mesenteric artery diameter, mm	6.49 ± 0.82 6.35 (5.85–7.23)	7.20 ± 0.61 7.10 (6.90–7.60)	.003[a]
PSV, m/s	147.85 ± 31.01 134.90 (127.10–159.43)	163.00 ± 37.47 149.60 (134.60–188.45)	.152[b]
EDV, m/s	22.93 ± 5.86 22.00 (17.88–28.09)	27.64 ± 10.66 26.20 (19.70–36.90)	.080[a]
PI	2.85 ± 0.74 2.67 (2.39–3.36)	3.54 ± 1.22 3.55 (2.55–4.37)	.032[a]
RI	0.84 ± 0.04 0.85 (0.82–0.87)	0.83 ± 0.05 0.84 (0.81–0.86)	.421[a]
PSV/EDV	6.73 ± 1.56 6.50 (5.66–7.68)	6.48 ± 1.87 6.10 (5.40–7.45)	.657[a]
Blood flow volume, mL/min	577.99 ± 274.79 519.20 (338.93–739.70)	724.61 ± 341.69 773.80 (432.05–1013.00)	.146[a]

Data are presented as mean ± SD and median (interquartile range).
[a]Independent-samples *t* test.
[b]Mann-Whitney *U* test.

Table 5. Duplex Doppler Parameters and Age

Parameter	≤47 y (n = 25)	≥48 y (n = 16)	*P*
Superior mesenteric artery diameter, mm	6.69 ± 0.74 6.90 (6.13–7.20)	7.21 ± 0.76 7.20 (6.59–7.60)	.037[a]
PSV, m/s	147.32 ± 25.35 143.30 (131.63–151.98)	170.45 ± 43.90 171.40 (129.55–206.73)	.152[b]
EDV, m/s	22.78 ± 6.81 21.00 (18.00–27.60)	29.93 ± 10.64 30.48 (22.00–37.13)	.012[a]
PI	3.33 ± 1.08 3.17 (2.51–4.19)	3.10 ± 1.11 2.67 (2.29–3.86)	.500[a]
RI	0.84 ± 0.04 0.85 (0.83–0.87)	0.82 ± 0.05 0.84 (0.78–0.86)	.510[b]
PSV/EDV	6.85 ± 1.65 6.80 (5.83–7.53)	6.18 ± 1.81 6.10 (4.54–7.65)	.232[a]
Blood flow volume, mL/min	548.54 ± 276.03 452.50 (369.75–694.00)	834.78 ± 309.98 807.15 (661.35–1021.25)	.172[b]

Data are presented as mean ± SD and median (interquartile range).
[a]Independent-samples *t* test.
[b]Mann-Whitney *U* test.

higher mesenteric artery blood flow in symptomatic patients with ulcerative colitis than in patients with asymptomatic disease or control participants. Yekeler et al[19] evaluated grayscale, color, and spectral Doppler sonographic findings of the affected bowel segments in patients with Crohn disease and found that the changes in the superior mesenteric artery flow volume and RI were well correlated with disease activity. In the superior mesenteric artery of patients with active inflammatory bowel disease, van Oostayen et al[20] found a statistically significant increase in blood flow and a decrease in the RI.

Other studies assessing the superior mesenteric artery flow parameters in patients with inflammatory bowel disease and celiac disease found an increase in the PSV, EDV, and blood flow volume and a decrease in the RI and PI.[21,22] In a Doppler assessment of patients with celiac disease, Alvarez et al[21] found an increase in superior mesenteric artery blood flow in 18 patients (10 untreated and 8 treated); Arienti et al[22] found an increase in the blood flow volume and EDV and a decrease in the PI in 13 untreated and 9 treated patients.

Erden et al[11] evaluated superior mesenteric artery blood flow parameters in a group of patients with various small-bowel diseases. They found higher PSV, EDV, and blood flow volume values and lower RI values in the diseased group than in a control group. Also, the comparison of various disease groups in their study showed similar Doppler findings (eg, increased blood flow volume, increased PSV, and increased EDV) in the superior mesenteric artery. The authors suggested that these common findings in the superior mesenteric artery of the patients reflected the decreased intestinal vascular resistance and increased bowel perfusion, and these Doppler findings were not specific to a particular bowel disease.

In the evaluation of quantitative duplex Doppler parameters of the superior mesenteric artery in patients with mesenteric panniculitis, we found statistically significant differences in the PSV, EDV, PI, RI, PSV/EDV, and blood flow volume between the patient group and the control group. The diameter of the superior mesenteric artery and BMI showed a significant difference between the patient and control groups. The findings of our study are in accordance with those of the previous studies showing significant changes in quantitative Doppler parameters of the superior mesenteric artery in patients with inflammatory bowel disease. We suggest that this similarity between the findings of our study and the previous studies is largely due to a standardized response of the mesenteric vasculature to inflammation, which is characterized by decreased vascular resistance and increased blood flow. In mesenteric panniculitis, the inflammation of the adipose tissue that surrounds the mesenteric vessels changes the flow characteristics of the superior mesenteric artery in a fashion similar to that of inflammatory bowel diseases.

Our study had certain limitations. In addition to the small number of patients in the study, the sonographic examinations were not performed in a blinded fashion, as the control group individuals were selected from the medical staff. Apart from the subject-dependent variables that may change the superior mesenteric artery flow, such as the functional status of the bowel, medication, and central hemodynamics, blood flow estimations on duplex Doppler sonography of the superior mesenteric artery are influenced by the vessel diameter, which may show systolic and diastolic differences, depending on the elasticity of the vessel.[23] A replaced right or common hepatic artery can change the waveform pattern or flow volume of the superior mesenteric artery. Although the absence of these arterial variations was confirmed with CT in all of the patients with mesenteric panniculitis in our study, the control group participants were only assessed with sonography, and the absence of such arterial variations could not be definitively excluded in this group. Also, the absence of mesenteric panniculitis in the control group could not be confirmed with CT. However, the control group participants were selected from apparently asymptomatic volunteers, and they were evaluated for the presence of signs of mesenteric panniculitis on grayscale sonography before duplex Doppler sonography, and none of them had positive sonographic findings of mesenteric panniculitis. The BMIs of the control and patient groups in our study were not matched, and the groups had significantly different BMIs. Moreover, of the duplex Doppler sonographic parameters studies, we found significant differences in the blood flow volume, EDV, PI, and superior mesenteric artery diameter between the categorical BMI groups. Among the patients and controls, the male group was associated with a greater superior mesenteric artery diameter and an increased PI. Of the categorical age groups among the patients and controls, advanced age was associated with a greater superior mesenteric artery diameter and an increased EDV. Although

we did not find a statistically significant relationship between the blood flow volume and age or between the blood flow volume and sex, the control and patient groups in the study were not balanced with respect to age characteristics. It is possible that the differences in age and BMI characteristics between the patient and control groups may have been independent of the results, since the BMI was also found to be positively correlated with the blood flow volume and vessel diameter. Also, for the same reason, it is possible to suggest that the changes detected in these hemodynamic parameters of the superior mesenteric artery may be preexisting contributing factors for the development of mesenteric panniculitis and not consequences of the disease.

In conclusion, of the quantitative Doppler parameters of the superior mesenteric artery, we found significant increases in the PSV, EDV, and blood flow volume in patients with mesenteric panniculitis. These increases were more pronounced for the blood flow volume. The PI and RI were decreased accordingly. To the best of our knowledge, this work is the first study to document the changes in duplex Doppler flow parameters of the superior mesenteric artery in patients with mesenteric panniculitis, and further studies may confirm our results.

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