

Diagnostic value of color Doppler sonography for spontaneous isolated superior mesenteric artery dissection

SHOUGANG BAO¹, TIEZHENG WANG¹, XING JIN², SHIYI ZHANG², HENGTAO QI¹,
DIANNING DONG², XIAOFEI MOU¹, XIANDONG ZHANG¹ and CHENGLI LI¹

¹Department of Ultrasound, Shandong Medical Imaging Research Institute Affiliated to Shandong University;

²Department of Vascular Surgery, Provincial Hospital Affiliated to Shandong University, Jinan, Shandong 250021, P.R. China

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Abstract. The present study aimed to evaluate the clinical significance of color Doppler sonography (CDS) in the diagnosis of spontaneous isolated superior mesenteric artery dissection (SISMAD). The ultrasonographic images of 19 patients with SISMAD confirmed by computed tomography angiography (CTA) were retrospectively analyzed and the ultrasonographic features were summarized. The paired t-test was used to statistically analyze the differences in parameters determined by CTA vs. CDS, including the minimal inner diameter (MID), cross-sectional area (CSA), diameter and area stenosis rate, and flow rate of the true lumen. Of the 19 patients, 18 (94.7%) were diagnosed with SISMAD with correct classification by CDS. There was no significant difference between CTA and CDS with regard to minimal ID, CSA, diameter stenosis and area stenosis rate, and flow rate of the true lumen (all $P > 0.05$). CDS was indicated to be an effective imaging modality for the diagnosis of SISMAD.

Introduction

Spontaneous isolated superior mesenteric artery dissection (SISMAD) refers to a type of dissecting lesion involving the SMA and its branches. The SISMAD classification proposed by Yun *et al* (1) in 2009 is as follows: Type I, true and false lumen revealing entry and re-entry sites; Type II, true lumen

but no re-entry flow from the false lumen; Type IIa, visible false lumen but no visible re-entry site; Type IIb, no visible false luminal flow, usually accompanied with true lumen narrowing; Type III, SMA dissection with occlusion of SMA. Misdiagnosis of SISMAD is common in clinical practice, which may lead to severe intestinal ischemic necrosis or even death (2,3). With the development of medical imaging, increasing cases of SISMAD are confirmed in patients with acute abdominal pain. At present, the diagnosis of SISMAD is mainly based on computed tomography angiography (CTA) or digital subtraction angiography (DSA) (4,5). Although CTA has served as an effective diagnostic tool for SISMAD, its application in clinical practice is limited by contrast agent allergy, overdose of radiation and high cost (6). DSA has been considered as a 'gold standard' tool for SISMAD and allows for administration of treatments whilst diagnostic evaluation is ongoing (7). However, the application of DSA in emergency settings is limited, as it is invasive, requires a complex preparation process and is time-consuming (8). Therefore, a diagnostic tool that is non-invasive, efficient and cost-effective, and has high sensitivity and specificity is required. Color Doppler sonography (CDS) has been used for peripheral vascular examination (9). However, the application of CDS in the assessment of SISMAD has remained to be fully evaluated (10). The current study did not compare ultrasound with DSA but with CTA in order to identify a more convenient method to diagnose SISMAD. Of note, CTA is more commonly used in the diagnosis of SISMAD and DSA is more valuable as an interventional treatment of SISMAD. According to various studies, CTA is now almost equal to DSA in its diagnostic ability (11) and in fact, may be a faster and more noninvasive method. Furthermore, DSA cannot be effectively used in cases of thrombosis in the false lumen (12). Hence, the current study aimed to assess the value of CDS in the diagnosis of SISMAD compared with CTA.

Materials and methods

Patients. A total of 19 SISMAD patients admitted to the Shandong Medical Imaging Research Institute that were confirmed by CTA between May 2014 and July 2017, were enrolled in the present study. All patients first underwent CDS and then CTA. Demographic and clinical data of

Correspondence to: Dr Hengtao Qi, Department of Ultrasound, Shandong Medical Imaging Research Institute Affiliated to Shandong University, 324 Jingwu Road, Jinan, Shandong 250021, P.R. China
E-mail: qihengtao@126.com

Abbreviations: CDS, color Doppler sonography; SISMAD, spontaneous isolated superior mesenteric artery dissection; CSA, cross-sectional area; SMA, superior mesenteric artery; CTA, computed tomography angiography; DSA, digital subtraction angiography; ID, inner diameter

Key words: color doppler sonography, superior mesenteric artery, dissecting aneurysm

all patients were collected, including age, sex, SISMAAD classification, inner diameter (ID), diameter stenosis, area and area stenosis.

CDS examinations. A GE Vivid 7-dimension Color Doppler ultrasonic imaging instrument (GE Healthcare, Little Chalfont, UK) with an adult cardiac probe was used, with the settings of coronary examination and a tissue harmonic image of 2.0-3.4 MHz. The patient was placed in a supine position with bent knees and the sampling cursor was placed on the abdomen. The patient was scanned from the upper to lower abdomen to assess the aorta, celiac trunk and SMA. The SMA with branches and aorta was studied in its long axis in the sagittal plane to evaluate the ID, echo and blood flow signal. The characteristics and extent of thrombotic false lumen and narrowed true lumen were evaluated when there was hyperecho segmentation. The inlet and outlet of true lumen were identified on cross-sectional scanning. The minimal ID and cross-sectional area (CSA), diameter stenosis and area stenosis rate and flow rate of true lumen were assessed and recorded. The insonation angle was $<60^\circ$. All sonographers who performed the examinations for the present study had >10 years of experience in vascular ultrasonography.

CTA. All SISMAAD patients underwent CTA. An iodine contrast agent allergy test was performed prior to CTA. The iodine contrast solution was administered by bolus injection via the antecubital vein. The CTA examination was performed from the aorta to the bilateral femoral artery. The minimal ID and CSA, diameter stenosis and area stenosis rate, and flow rate of true lumen were evaluated through multiplane reorganization, maximum density projection and volume rendering of captured images.

Statistical analysis. Statistical analysis of the data was performed with SPSS 20.0 (IBM Corp., Armonk, NY, USA). $P<0.05$ (two-sided) was considered to indicate statistical significance. Continuous variables are expressed as the mean \pm standard deviation and differences between the two imaging modalities were analyzed using a paired Student's *t*-test.

Results

Patient data. In the present cohort of 19 patients, the mean age was 60.4 years (range, 39-87 years) and 16 patients were male. All patients were admitted for acute abdominal pain (lasting for 3-4 h), and 7 patients were complicated with ileus. Of the 19 patients, 18 were diagnosed as SISMAAD with correct classification by CDS, except one obese patient [body mass index (BMI), 42.5 kg/m^2] complicated with severe ileus due to intestinal gas and incomppliance (as the patient did not tolerate the pressure exerted on the abdomen by the probe). The success rate of the examination was 94.7%.

Imaging Features. According to the SISMAAD classification mentioned above, the cohort comprised 5 patients with a type I lesion (Fig. 1), 4 with IIa (Fig. 2), 9 with IIb (Fig. 3) and one with a type III lesion (Fig. 4). The demographic data, as well as CDS and CTA evaluation indicators, including minimal ID

and CSA, diameter stenosis and area stenosis rate, and flow rate of true lumen of the 18 SISMAAD patients are summarized in Table I.

On CDS, the 18 SISMAAD patients were characterized by enlarged lumen from the origin of the SMA, dorsal true lumen and ventral false lumen divided by hyperecho segmentation. In addition, it was possible to distinguish the velocity of blood flow in the true lumen and false lumen, with the faster one being that in the true lumen. All dissecting lesions had a large false lumen, parts of which were present as solid echo filling and absence of blood flow signal. The true lumen was subjected to different degrees of compression. A total of 8 lesions had a severely narrowed true lumen, accounting for 10-30% of the entire lumen and with a luminal blood flow velocity of 275-404 cm/sec.

All SISMAAD patients were diagnosed by CTA, which revealed similar characteristics to those identified on CDS, including enlarged lumen from the origin of the SMA, true lumen and false lumen distinguished by hyperecho segmentation and thrombotic false lumen. In certain patients, a clear perforation of the diaphragm was visible on ultrasonic imaging.

Statistical data. Within the cohort, there was no significant difference between CDS and CTA in terms of the mean minimal ID (2.77 ± 1.08 vs. 2.76 ± 1.06), CSA (6.86 ± 6.30 vs. 6.85 ± 6.25), diameter stenosis (64.52 ± 14.33 vs. 67.33 ± 9.15) and area stenosis (85.34 ± 13.82 vs. 85.99 ± 12.19 ; all $P>0.05$; Table II).

Discussion

Patients with SISMAAD always present with atypical clinical symptoms, most of which are sudden abdominal pain (13-16). It is a relatively rare underlying cause of acute abdominal pain. While the pathogenesis of SISMAAD has not been fully elucidated, it may be caused by hypertension, vasculitis, arterial mid-lamellar cystic necrosis, fibromuscular dysplasia and atherosclerosis (2,17-19). According to certain scholars, the anatomical features of the SMA arch may induce focused shear forces, which may ultimately produce a dissecting lesion that is similar to the DeBakey type III aortic dissection (20).

At present, CTA is considered a preferred method for diagnosing SISMAAD, which is able to clearly display the characteristics of the SMA and distal small branch vessels, and facilitate classification (21). However, contrast agent allergy, overdose of radiation and expensive cost hamper the wide application of CTA in SISMAAD (22). CDS is a type of non-invasive, efficient and cost-effective diagnostic tool for SISMAAD, while having a comparatively a higher sensitivity and specificity (23). In the present study, two-dimensional images of the trunk and branches of the SMA were more clearly displayed by using a cardiac probe and the coronary harmonic imaging setting. As the cardiac probe is relatively small, it may effectively squeeze away intestinal gas and is also more sensitive to blood flow than the convex array probe (24). Furthermore, in the present study, that there was no significant difference between mean minimal ID, CSA, diameter stenosis and area stenosis rate determined by CTA and CDS. Therefore, the use of CDS, which is more

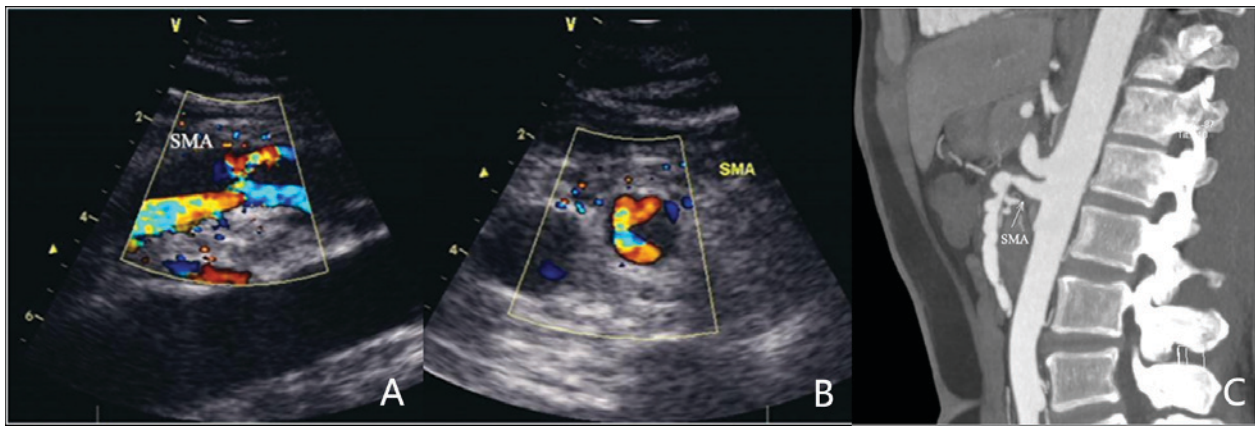


Figure 1. Type I SISMAD. Representative images of a 48 year-old male are provided. The patient was admitted due to sudden abdominal pain for 4 h and was diagnosed with SISMAD by CTA and color Doppler sonography. (A) Blood flow and perforation between true and false lumen on long axis CDS imaging of the SMA revealed the entry site and thrombosis in the false lumen. (B) Blood flow and perforation between true and false lumen on short axis cross-section CDS imaging of the SMA revealing less blood flow and thrombosis in the false lumen. (C) CTA image of type I lesion. SISMAD, spontaneous isolated superior mesenteric artery dissection; CTA, computed tomography angiography.

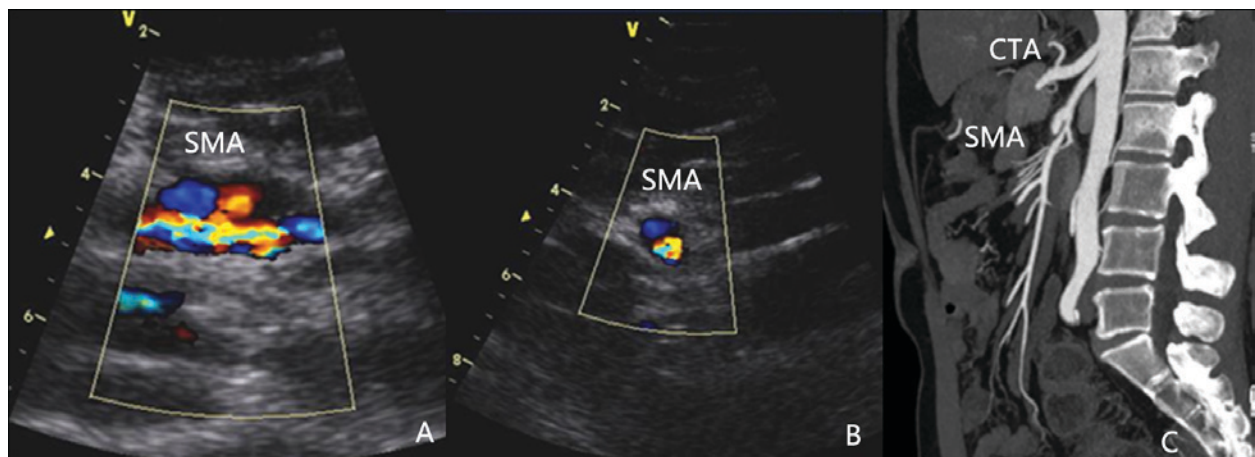


Figure 2. Type IIa SISMAD. Representative images of a 57 year-old female are provided. The patient was admitted due to sudden abdominal pain for 8 h and was diagnosed with SISMAD by CTA and color Doppler sonography. (A) The only perforation between true and false lumen in long axis CDS imaging of SMA revealed the only entry site and Pepsi blood flow in false lumen. (B) The only perforation between true and false lumen in long and short axis cross-section CDS imaging of SMA revealed the dorsal true lumen and ventral false lumen. (C) CTA image of type IIa lesion. SISMAD, spontaneous isolated superior mesenteric artery dissection; CTA, computed tomography angiography.

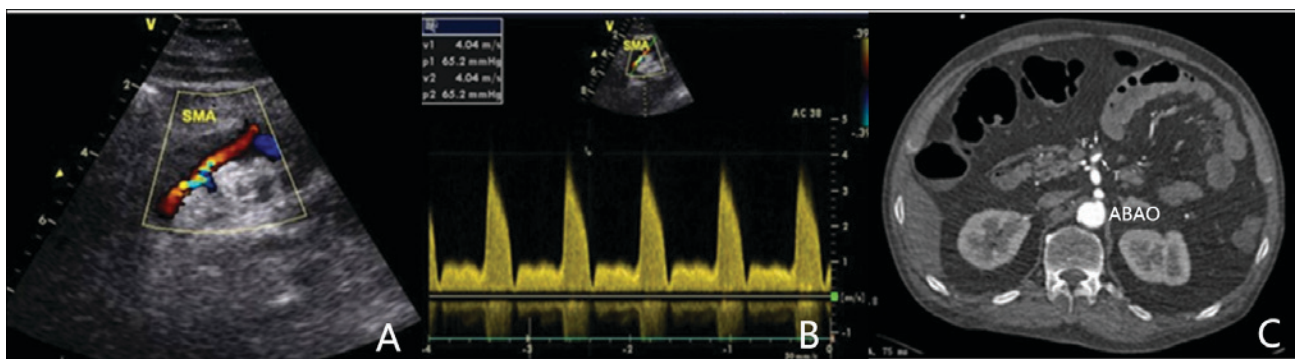


Figure 3. Type IIb SISMAD. Representative images of a 57 year-old male are displayed. The patient was admitted due to sudden abdominal pain for 5 h and was diagnosed with SISMAD by CTA and color Doppler sonography (A and B). (A) Image of thrombotic false lumen and narrowed true lumen. (B) Blood flow velocity in the true lumen was determined as 404 cm/sec by spectral doppler. (C) CTA image of type IIb lesion. ABAO, abdominal aorta; SISMAD, spontaneous isolated superior mesenteric artery dissection; CTA, computed tomography angiography.

convenient and inexpensive compared with CTA, is feasible for the diagnosis of SISMAD.

SISMAD should be distinguished from atherosclerosis, embolism and abdominal aortic dissection involving the

Table I. Characteristics of 18 patients with SISMD.

Case no.	Sex	Age (years)	CTA				CDS				
			ID (mm)	Area (mm ²)	Diameter stenosis (%)	Area stenosis (%)	ID (mm)	Area (mm ²)	Diameter stenosis (%)	Area stenosis (%)	V (cm/sec)
1	M	63	2.01	3.16	74.00	94.00	2.01	3.12	75.00	93.80	293
2	M	60	2.11	3.29	73.65	93.20	2.10	3.25	73.75	93.50	286
3	F	58	3.00	7.50	61.70	83.00	3.11	7.54	61.73	85.00	260
4	M	73	1.79	2.49	77.82	92.10	1.80	2.54	77.78	94.90	321
5	M	72	1.98	3.10	75.10	92.90	2.01	3.13	74.69	93.80	310
6	M	48	1.18	1.15	84.90	96.40	1.20	1.13	84.62	97.70	404
7	M	52	2.32	4.16	70.00	92.10	2.30	4.15	69.74	91.70	286
8	F	57	3.02	7.06	62.60	86.00	3.02	7.06	62.50	85.90	240
9	M	69	2.41	4.55	69.10	90.00	2.42	4.52	70.00	91.00	275
10	M	55	3.48	9.63	55.00	80.20	3.47	9.61	54.95	81.90	200
11	M	63	2.58	5.29	67.35	88.30	2.60	5.30	67.50	89.40	240
12	M	54	3.62	10.14	55.00	80.00	3.61	10.17	57.32	60.92	210
13	M	49	4.00	12.44	52.00	80.00	4.00	12.56	50.00	75.00	190
14	M	57	2.80	6.19	65.66	89.00	2.81	6.15	65.86	87.80	220
15	M	39	2.75	5.73	66.00	86.00	2.72	5.72	66.25	88.60	226
16	M	76	2.45	4.57	70.00	93.00	2.41	4.52	70.00	91.00	280
17	M	87	2.20	3.91	74.00	90.00	2.23	3.80	72.83	92.40	324
18	F	66	6.00	29.00	23.50	41.62	6.10	29.20	23.75	41.88	160

SISAMD, spontaneous isolated superior mesenteric artery dissection; CTA, computed tomography angiography; CDS, color Doppler sonography; M, male; F, female; ID, inner diameter; V, velocity.

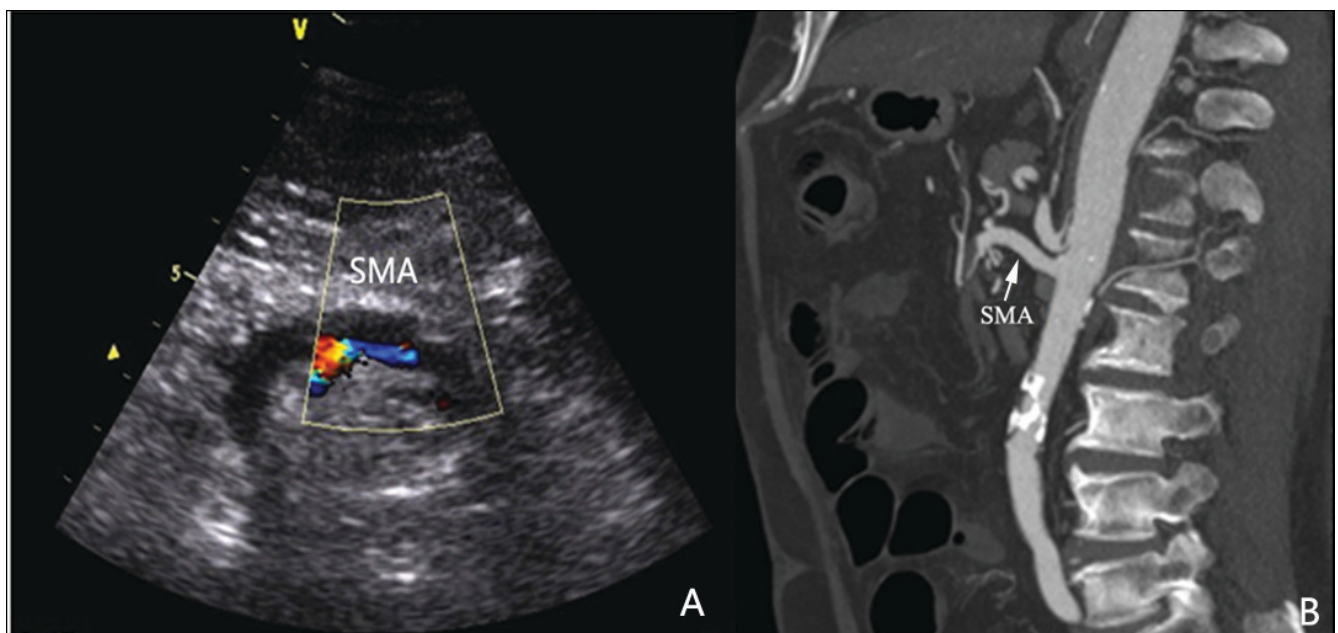


Figure 4. Type III SISMD. The representative images of a 76 year-old male are provided. The patient was admitted due to sudden abdominal pain for 3 h and was diagnosed with SISMD by CTA and color Doppler sonography (A). (A) Image of thrombotic false lumen located at origin of SMA, narrowed true lumen and thrombus without flow. (B) CTA image of type III lesion. SISMD, spontaneous isolated superior mesenteric artery dissection; CTA, computed tomography angiography.

SMA. Atherosclerotic stenosis usually develops at the origin part of the SMA, and is more common in the elderly (25).

The ultrasonic characteristics include a convex plaque located at the origin part of the SMA, narrowing of the lumen and

Table II. Comparison of parameters measured by CDS and CTA for patients with spontaneous isolated superior mesenteric artery dissection.

Parameter	CDS	CTA	t	P-value
ID (mm)	2.77±1.08	2.76±1.06	1.339	0.198
Diameter stenosis (%)	64.52±14.33	67.33±9.15	-0.680	0.507
Area (mm ²)	6.86±6.30	6.85±6.25	0.376	0.712
Area stenosis (%)	85.34±13.82	85.99±12.19	-0.551	0.588

CTA, computed tomography angiography; CDS, color Doppler sonography; ID, inner diameter.

increased blood flow velocity (26). The SMA embolism mostly results from cardiac causes (27). For instance, in patients with atrial fibrillation or myocardial infarction, the left atrial or ventricular thrombus may fall off into the SMA, which may appear on ultrasound as an intraluminal hypoechoic solid tissue filling without blood flow (28). The detached thrombus usually remains at the bifurcation (29). Patients with abdominal aortic dissection involving the SMA feature segmentation in the abdominal aorta extending into the SMA (30). However, in patients with SISMA, the location of the dissecting lesion is only between the beginning and the distal end of the SMA, with a normal abdominal aorta (31).

In the present study, one obese patient (BMI, 42.5 kg/m²) was not able to successfully undergo CDS even after fasting and gastrointestinal decompression due to long disease duration (32), intestinal gas and intolerance to pressure on the abdomen exerted by the probe. In this patient, it was not possible to clearly display the SMA. For such cases, CTA or DSA should be performed if mesenteric arterial dissection is suspected to avoid delay of diagnosis.

Of note, the present study had certain limitations. First, the sample size was relatively small. Furthermore, ultrasound examination was greatly affected by intestinal gas, and it has certain limitations for patients with obvious flatulence.

For the clinical treatment of SISMA, conservative treatment or endovascular repair has been commonly used. In the present study, a total of 9 patients underwent luminal stenting, 9 patients received conservative treatment and 1 patient died due to prolonged bowel ischemia. In the latter case, a marked delay between disease onset and presentation of the patient at the clinic was present, and at the time-point of diagnosis, the patient had developed widespread bowel ischemic necrosis and infection. In the setting of CTA examination, the degree of ischemia may only be quantitatively evaluated according to the proportion of true and false lumens (33). CDS is not only able to evaluate the proportion of true and false lumens, but to also accurately measure the blood flow velocity in the true lumen (34). In particular, the significantly decreased ratio of the CSA of true and false lumen and the blood flow velocity of >275 cm/sec in the fasting state indicates that the true lumen is severely compressed. A higher blood flow velocity is associated with a more severe compression of the true lumen (35), and a greater extend of bowel ischemia. For patients with ultrasonic features of solid echo filling without flow in the true and false lumen, open surgery or endovascular repair is suggested due to severe SMA ischemia. Otherwise,

conservative treatment may be performed first and the blood supply of the SMA should be carefully observed (36,37).

In conclusion, CDS is able to not only diagnose SISMA, but also to measure minimal ID and CSA, diameter stenosis and area stenosis rate, and flow rate of the true lumen. CDS may serve as a useful tool for diagnosis of SISMA.

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Availability of data and materials

The data used and analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

HQ designed the present study, acquired, analyzed and interpreted the data, and approved the final version of the manuscript. CL acquired the data and performed image analysis. SB performed image examinations. DD analyzed the data. XM interpreted the data. TW searched the literature. XJ, SZ and SB prepared the manuscript. XZ performed statistical analysis. All authors have read and approved the final manuscript.

Ethics approval and informed consent

Informed consent was obtained from each patient and the study was approved by the ethics review board of the Provincial Hospital Affiliated to Shandong University (Jinan, China).

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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