Use of hemodynamic parameters in the diagnosis of mesenteric insufficiency

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To evaluate the hemodynamic characteristics of the normal mesenteric circulation, five parameters of the velocity waveforms were measured in 15 normal subjects in the celiac and superior mesenteric arteries (SMA) in the pre- and postprandial periods. It was noted that changes in celiac artery flow after eating was minimal, indicating that this vessel's major supply function is not to the gut. SMA parameters showing the most significant and consistent changes after a meal were the diastolic reverse flow and diastolic forward flow (DFF). Four patients referred with symptoms of intestinal angina underwent scanning and subsequent angiography of their mesenteric circulation. All four exhibited loss of reverse flow in the SMA. The change in DFF in the SMA was statistically significant ($p = 0.01$). Change in peak systolic velocity in the celiac artery was marginally significant ($p = 0.05$). Angiography revealed that three patients had greater than 90% stenosis of both vessels. The fourth patient had a 90% celiac artery and 65% SMA stenosis. The technique described offers the first noninvasive means of identifying mesenteric insufficiency. It is an effective screening method for a disease entity difficult to verify without selective arteriography. The use of velocity waveform parameters giving good discrimination between normal subjects and those with stenoses of the visceral arteries should reduce both the incidence of missed diagnosis and unnecessary angiography. (J VASC SURG 1986; 3:507-10.)

The diagnosis of chronic mesenteric ischemia remains in large part one of exclusion. The rarity of the syndrome combined with the lack of any definitive diagnostic test has undoubtedly contributed to its underdiagnosis. The diagnosis remains principally a clinical one, and a high index of suspicion should be maintained in those patients exhibiting characteristic postprandial pain—so-called intestinal angina accompanied by weight loss who also demonstrate atherosclerotic disease in the cardiac, cerebral, and peripheral vascular circulations. Malabsorption is a variable component of the disease and therefore a nonspecific feature.

Difficulty in delineating the disease on clinical grounds is complicated by the fact that its principal features are mimicked by many other diseases of the gastrointestinal tract that may be relatively common, particularly peptic ulcer disease and carcinoma of the pancreas. Thus diagnosis of this rare and often ill-defined clinical entity has rested for the most part on the willingness of the clinician to proceed with mesenteric angiography; however, the risks and expense of this procedure have precluded its adoption as a screening test, particularly since the low incidence of the disease dictates a low yield of positive diagnoses.

Noninvasive tests used with success in other areas of the peripheral circulation have been inadequate to overcome the difficulties posed by mesenteric vessels, that is, the depth at which they lie, their inconstant position relative to fixed landmarks, and the overlying structures themselves capable of large variation (omentum and bowel loops). Recently, however, techniques developed with duplex scanning of the aortoiliac segment have been able to be successfully applied to the mesenteric circulation.

MATERIAL AND METHODS

To establish the hemodynamic characteristics of the normal mesenteric circulation, the celiac and superior mesenteric arteries (SMAs) were studied in 15 normal subjects (mean age, 36½ years) in the pre- and postprandial periods with a duplex scanner (Honeywell Ultra Imager). The diameter of both arteries was measured on each occasion. Postprandial

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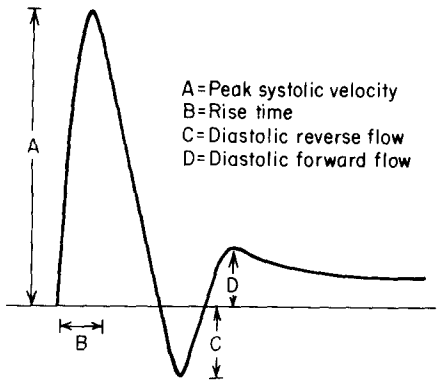

Fig. 1. Parameters measured from waveform exhibit reverse diastolic flow.

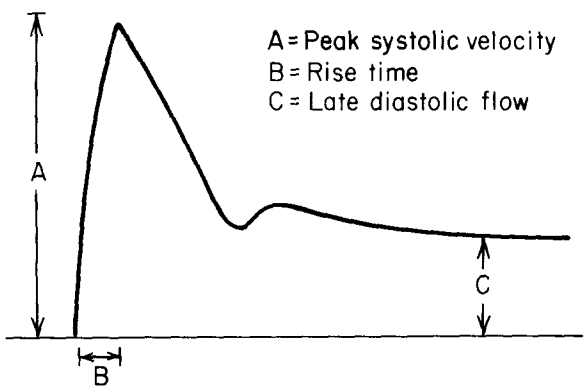

Fig. 2. Parameters measured from waveform exhibit no reverse diastolic flow.

studies were performed 1 hour after a standard meal. Five parameters were measured from the velocity waveforms: (1) systolic rise time, (2) reverse flow time, (3) peak systolic velocity, (4) maximum reverse flow velocity, and (5) diastolic forward flow. The latter was measured as the maximum positive value in diastole after reverse flow and at enddiastole when no reverse flow was present (Figs. 1 and 2). A set of normal mean values with standard deviations was thus established for these parameters.

Four patients referred with symptoms of chronic intestinal ischemia marked by postprandial pain, significant weight loss, and in one patient also postprandial diarrhea were evaluated in the fasting state. In the SMA, signals were measured in both proximal and mid portions of the artery. Subsequently, all patients underwent mesenteric angiography. Angiography revealed that three patients had more than 90% stenosis of both vessels. The fourth patient had a 90% celiac artery and 65% SMA stenosis. The normal established values for the velocity waveforms were then compared with each of the patients to determine

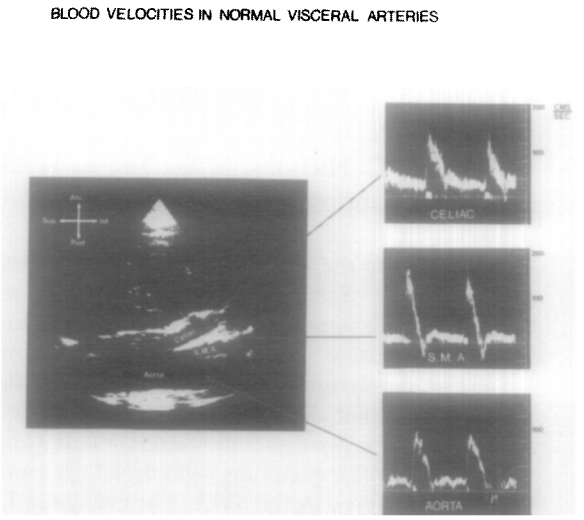

Fig. 3. Comparative waveforms from celiac artery and SMAs in normal fasting individuals. The celiac artery is notable for the absence of reverse flow.

which were good discriminants for the disease. Statistical analysis was performed with Fisher's exact and *t* tests.

RESULTS

Evaluation of normals. Velocity waveforms from the SMA in the fasting state exhibited reverse diastolic flow, whereas those from the celiac artery exhibited forward flow throughout diastole (Fig. 3). No significant postprandial changes were noted in the diameter of either the celiac axis or SMA, and the systolic rise time in each vessel was also unchanged. The velocity waveform in the celiac axis was unchanged postprandially. Reverse velocity in the SMA was reduced or abolished by eating, and this was statistically significant (Fig. 4). Peak systolic velocity was unaffected in the celiac artery, and although a modest rise was seen in the SMA, this did not reach statistical significance. Diastolic forward flow was also unchanged in the celiac artery but almost doubled in the SMA. This was significant ($p < 0.01$). In summary, celiac artery circulation showed no postprandial changes whereas the SMA showed changes in peak systolic velocity, reverse velocity and flow time, and forward diastolic flow. Of these, the latter reached statistical significance (Table I).

Evaluation of patients. Reverse flow was abolished in the SMA in the presence of a stenosis. It remained absent in the celiac axis (Fig. 5). The loss of reverse flow in the SMA in the patient group compared with the healthy state was significant ($p < 0.01$, Fisher's exact test). Peak systolic velocity

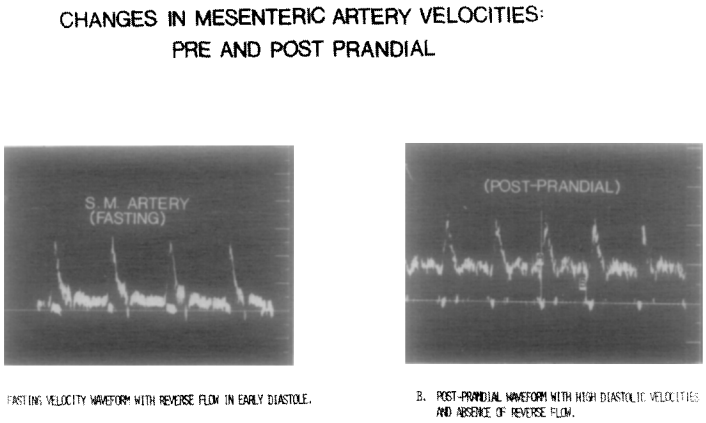

Fig. 4. Waveforms from the SMA demonstrate changes affected by digestion resulting in abolition of reverse flow.

Table I. Normal subjects (n = 15)

		Fasting	*Postprandial*
Diameter (cm)	C	0.53 ± 0.08	0.56 ± 0.08
	S	0.64 ± 0.09	0.64 ± 0.08
Rise time (sec)	C	0.08 ± 0.01	0.09 ± 0.01
	S	0.09 ± 0.02	0.09 ± 0.02
Reverse flow time (sec)	C	0	0
	S	0.08 ± 0.03	0.02 ± 0.03 ($p < 0.01$)
Systolic velocity (cm/sec)	C	163.6 ± 34.4	168 ± 20.3
	S	182.6 ± 48.8	203 ± 42.6
Reverse velocity (cm/sec)	C	0	0
	S	27.8 ± 12.4	9.4 ± 13.9 ($p < 0.01$)
Diastolic forward flow (cm/sec)	C	45.0 ± 7.4	41.7 ± 11.3
	S	42.2 ± 13.2	78.6 ± 25.1 ($p < 0.01$)

S = superior mesenteric artery; C = celiac artery.

and systolic rise time did not show significant change in either vessel, although this was marginal for peak systolic velocity in the celiac artery ($p = 0.05$). Diastolic forward flow showed insignificant change in the celiac artery compared with normal values, but in the SMA this was significant ($p = 0.01$) (Table II).

DISCUSSION

Factors mitigating against the accurate diagnosis of chronic mesenteric ischemia have been its rarity, the overlap of symptoms with many other common diseases of the gastrointestinal tract, and the absence of a screening test for the disease. These difficulties have caused reservations to be expressed about the value in pursuing the diagnosis.[1] Angiography constitutes the definitive diagnostic test, but unfortunately in addition to its known risks, it does not provide quantitative physiologic data. Efforts to quantify splanchnic blood flow in human beings have involved dye-dilution techniques.[2] Reports have noted an ability to discriminate between patients with normal and "intestinal angina."[3] Despite the promise of such reports, the technique is complicated and invasive, involving catheterization of a peripheral artery and vein and a hepatic vein. Not surprisingly, it has failed to gain widespread use despite the theoretic advantages. The implantation of electromagnetic flowmeters as used in research animals is not feasible for human subjects. Flow rates estimated by ultrasonic techniques, although feasible, also produce extra difficulties. Furthermore, velocity waveform parameters are much more sensitive indicators of disease than are flow rates.

The development of collateral vessels makes estimation of disease with only anatomic data highly variable. This accounts for the limited correlation that can be drawn between specific angiographic patterns and symptoms. It has been noted, however, that symptoms are rare in the absence of severe disease in at least two of the three vessels. The observations on celiac artery flow made on the normal subjects in this study suggest that this vessel's contribution to splanchnic blood flow is limited and that

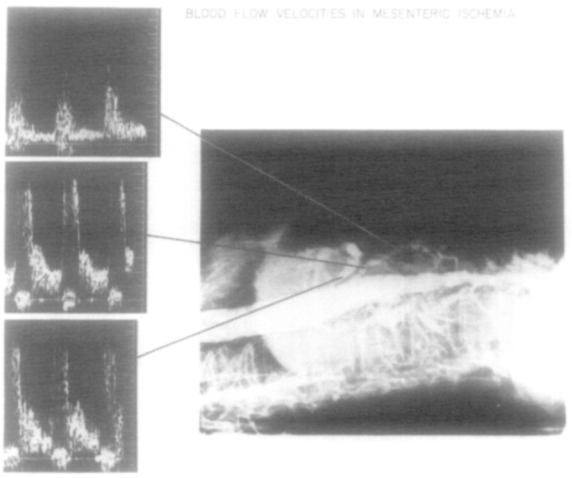

Fig. 5. Velocity waveforms in patient with chronic mesenteric ischemia. Significant changes noted are the increase in peak systolic velocity in the celiac artery and loss of reverse flow in the SMA.

its flow characteristics are determined by the hepatic and splenic runoff. No significant change in flow in this vessel was noted during digestion. In evaluation of the SMA, it is crucial to examine the patient in the fasting state. Digestion may accentuate velocity waveform changes caused by disease (an analogous situation to the use of tolazoline (Priscoline) in the peripheral circulation) and thus increase the sensitivity of the evaluation. In our experience it has not been possible to insonate the inferior mesenteric artery consistently in all normal subjects. Thus failure to identify it does not always imply occlusion of the vessel. Although it is desirable to specifically interrogate the inferior mesenteric artery, it is believed that velocity waveform parameters in the SMA distal to the aortic takeoff reflect flow not only from the stem vessel but flow contributed from significant collateral branches via the pancreaticoduodenal arcade or the arcade of Riolan. This also underlines the importance of taking signals distal to the stenosis at the orifice. This is crucial in evaluating the SMA after a bypass procedure. Furthermore, except in cases in which the inferior mesenteric artery supplies the small bowel via a "meandering" artery, its contribution to blood flow of the small bowel is minimal. In the latter case, it is hypertrophied and in our experience easily examined.

The merit of detecting chronic mesenteric vascular insufficiency to treat prophylactically the possibility of catastrophic bowel infarction remains controversial. It appears that most episodes of acute mesenteric insufficiency are embolic in nature and

Table II. Chronic mesenteric ischemia (n = 4)

		Fasting
Rise time (sec)	C	0.14 ± 0.04
	S	0.11 ± 0.04
Reverse flow time (sec)	C	0
	S	0
Systolic velocity (cm/sec)	C	276 ± 61.2 (p = 0.05)
	S	266 ± 94.4
Reverse velocity (cm/sec)	C	0
	S	0
Diastolic forward flow (cm/sec)	C	86.0 ± 31.1
	S	154.5 ± 37.8 (p = 0.01)

C = celiac artery; S = superior mesenteric artery.

therefore not amenable to such an approach.[4] However, ever since the report of Dunphy,[5] series of patients have been reported in whom bowel infarction has been preceded by symptoms of chronic ischemia,[6] and although it is known that only a fraction of patients with SMA thrombosis have a history of pain, we still do not know how many patients with symptoms go on to an acute infarction. Until we have natural history data, case selection will have to be carefully made,[4,7] weighing the risks of major arterial reconstruction against the presumed outcome. The method described offers the first means of obtaining such data. The experience gained in managing postoperative patients suggests that the technique parallels the accuracy of angiography in evaluating the postoperative course and can play a fundamental role in management.

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