Usefulness of Fasting and Postprandial Duplex Ultrasound Examinations for Predicting High-Grade Superior Mesenteric Artery Stenosis

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PURPOSE: A fasting duplex ultrasound examination of the superior mesenteric artery (SMA) accurately detects high-grade (>70%) stenosis. It has been postulated that postprandial mesenteric duplex scanning may further stratify stenosis and improve the ability of a fasting examination to detect a high-grade stenosis. We performed fasting and postprandial duplex scanning of 25 healthy controls and 80 patients with vascular disease undergoing aortography to determine whether postprandial mesenteric duplex scanning provides information beyond a fasting study alone.

METHODS: Patients with vascular disease were divided into three groups based on lateral aortography results: group 1, 0% to <30% SMA stenosis (n = 61); group 2, 30% to <70% stenosis (n = 10); and group 3, 70% to 99% stenosis (n = 9). Fasting mesenteric duplex scanning was defined as positive for 70% to 99% stenosis if the peak systolic velocity (PSV) was ≥275 cm/s. The ability of either fasting or postprandial mesenteric duplex scanning, and their combination, to predict high-grade (70% to 99%) SMA stenosis was determined using angiographic control.

RESULTS: Mean fasting SMA PSV did not differ among controls and groups 1 and 2. Postprandial PSV increased significantly in all groups, but was not different among controls and groups 1 and 2. Mean fasting PSV was significantly higher, and the postprandial increase in PSV significantly lower, in group 3 compared with controls and with groups 1 and 2. Fasting mesenteric duplex scanning predicted 70% to 99% SMA stenosis, with 89% sensitivity, 97% specificity, 80% positive predictive value, 99% negative predictive value, and 96% accuracy. Corresponding values for postprandial scanning were 67%, 94%, 60%, 96%, 91%, and for the combination of normal fasting and postprandial scanning 67%, 100%, 100%, 96%, 96%, respectively.

CONCLUSION: Postprandial increases in SMA PSVs are blunted in patients with high-grade stenosis, but feeding velocities do not stratify between lesser degrees of stenosis. Both fasting and postprandial PSVs identify high-grade (>70%) stenosis. Their combination marginally improves fasting duplex scan specificity and positive predictive value. Postprandial scanning is not necessary for the diagnosis of high-grade stenosis if a fasting study identifies a PSV ≥275 cm/s. The combination of normal fasting and postprandial mesenteric duplex ultrasound scanning may effectively rule out high-grade SMA stenosis.

Duplex ultrasound scanning of the superior mesenteric artery (SMA) has been the subject of a number of recent reports. Studies of healthy volunteers have characterized fasting, pharmacologically induced, and postprandial blood flow velocities in presumably normal SMA.[1-3] Such studies have shown postprandial hyperemia to be largely limited to the SMA. In addition, studies of patients with mesenteric artery atherosclerosis have demonstrated the ability of fasting duplex examinations to detect high-grade stenoses.[4-6] Specifically, we have found that a SMA peak systolic velocity (PSV) ≥275 cm/s in a fasting patient is an excellent predictor of a 70% to 99% stenosis.[7,8]

It is presently unknown whether postprandial mesenteric duplex ultrasound examinations may provide information relevant to the detection of mesenteric artery stenosis beyond that provided by a fasting study alone.[9] In order to characterize the clinical usefulness of postprandial mesenteric duplex scanning for the stratification of SMA stenosis and for the detection of high-grade stenosis, we performed fasting and postprandial duplex examinations of healthy controls and of atherosclerotic patients undergoing elective arteriography.

PATIENTS AND METHODS

Eighty consecutive patients electively admitted to the Portland, Oregon, Veteran's Affairs Hospital for aortography and runoff for evaluation of symptomatic peripheral arterial occlusive disease underwent complete fasting and postprandial duplex ultrasound examinations of their SMAs. In addition, 25 healthy volunteers without clinical or vascular laboratory evidence of peripheral arterial disease served as a control group and were also studied with fasting and postprandial mesenteric duplex scans, but did not undergo arteriography. The study was approved by the Institutional Review Boards of both the Portland, Oregon, Veteran's Affairs Hospital and the Oregon Health Sciences

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Presented at the 81st Annual Meeting of the North Pacific Surgical Association, November 10–11, 1994, Coeur d'Alene, Idaho.

University. All patients and volunteers signed informed consent forms.

Duplex Examinations

Fasting and postprandial mesenteric duplex examinations were performed by one of two registered vascular technologists with extensive research and clinical experience with splanchnic artery duplex imaging. All patients underwent mesenteric duplex scanning within 2 weeks of arteriography. The technique of mesenteric artery duplex scanning has been previously described.[9] All examinations were performed with a color duplex scanner (Acuson 128; Acuson, Inc., Mountain View, California). Briefly, examinations were performed in the morning after an overnight fast. The patient was positioned supine, with the head of the bed elevated 30°. The SMA was insonated with a 2.5–3.5 MHz transducer using an upper midline approach. The pulse Doppler sample volume varied from 1.5 mm^3 to 3.0 mm^3.

After a fasting peak systolic velocity was recorded from the SMA, the patient rapidly ingested a 250 calorie, 240 mL mixed liquid meal (Ensure, Ross Laboratories, Columbus, Ohio). A meal of similar composition has previously been shown to increase splanchnic artery blood flow within 30 minutes to levels readily detectable by duplex scanning.[2] Postprandial PSVs were recorded 10, 20, and 30 minutes following ingestion of the meal, and the maximum recorded value was calculated as the percentage increase over the fasting value. Doppler angles were kept between 45 and 70 degrees,[10] depending on the angle required to visualize the SMA in a given patient. The Doppler angle was kept constant between readings in individual patients to minimize variability.

Arteriography

Aortography was performed using standard Seldinger techniques. SMA stenosis was determined from a lateral view of the infradiaphragmatic aorta. Percent stenosis was calculated from caliper measurements comparing the width of the contrast column at the point of narrowest vessel diameter with the diameter of the nearest normal distal segment not obviously involved in poststenotic dilation. The patients were divided into three groups based on the percent stenosis of their SMA: group 1, stenosis 0% to <30%; group 2, stenosis 30% to <70%; and group 3, stenosis 70% to 99%.

DATA ANALYSIS

Results for fasting and postprandial PSV were expressed as the mean ± the standard deviation for each of the three patient groups and the control group. Mean fasting and postprandial PSVs were compared within each group using Student's *t*-test. Absolute differences between individual fasting and postprandial PSVs were compared between groups using the Mann-Whitney rank sums test. An alpha error of ≤0.05 was accepted for statistical significance.

The normal postprandial percent increase in SMA PSV was defined as the mean ± the standard deviation and 95% confidence interval (CI) of the postprandial percent increase occurring in the control group. The ability of fasting mesenteric duplex scanning to predict a 70% to 99% stenosis was based on the presence of a fasting PSV >275 cm/s, as previously reported by us,[8] and was calculated in terms of sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy.

It is postulated that high-grade SMA stenosis limits the ability of the splanchnic circulation to respond to feeding. Failure of the postprandial PSV to increase more than the minimum hyperemic response of the control group was therefore considered an abnormal feeding response and was used to calculate the sensitivity, specificity, positive and negative predictive values, and accuracy of postprandial mesenteric duplex scanning to detect a 70% to 99% SMA stenosis. Finally, the combination of a fasting PSV ≥275 cm/s and the failure of a PSV to increase more than the minimum hyperemic response of the control group was used to determine the utility of combining fasting and postprandial mesenteric duplex examinations for predicting the absence of angiographic 70% to 99% SMA stenosis.

RESULTS

The 25 control-group volunteers consisted of 14 men and 11 women with a mean age of 34 years (range 18 to 54). The atherosclerotic patient cohort consisted of 73 men and 7 women, with an average age of 67 years (range 33 to 81). Coexistent patient medical problems were: diabetes requiring insulin or oral hypoglycemic agents in 15 patients (19%), hypertension in 44 patients (55%), and smoking history in 62 patients (78%). Using arteriography, we found 61 patients with normal or mild (0% to <30%) SMA stenosis (group 1), 10 patients with moderate (30% to <70%) stenosis (group 2), and 9 patients with high-grade (70% to 99%) stenosis (group 3).

Peak Systolic Velocities

The mean fasting and postprandial PSV for the control group was 147 ± 30 cm/s and 230 ± 55 cm/s, respectively. The mean fasting and postprandial SMA PSVs for the 80 patients with peripheral vascular disease and varying degrees of stenosis are shown in the **Table**. There were no significant differences in fasting and postprandial PSVs among controls and group 1 patients and group 2 patients ($P > 0.05$). Nor were there significant differences in fasting or postprandial PSVs between patients in groups 1 and 2. Group 3 patients had significantly higher fasting PSVs than did the controls ($P < 0.0001$) and group 1 patients ($P < 0.0001$) or group 2 patients ($P = 0.003$) (**Figure**).

The mean maximum percent increase in postprandial SMA PSVs for the control patients was 57%, and was not significantly different from patients in groups 1 and 2 (Table). In group 3 patients, the mean postprandial PSV was diminished and differed from that of controls ($P < 0.0001$), group 1 patients ($P < 0.0001$), and group 2 patients ($P = 0.02$; Figure).

Predicting Stenosis With Mesenteric Duplex Scanning

Using a fasting peak systolic velocity of ≥275 cm/s to predict a ≥70% angiographically evident SMA stenosis in the 80 patients with peripheral vascular disease,[8] fasting mesenteric duplex scanning predicted a stenosis of 70% to 99% with a sensitivity of 89%, specificity of 97%, a pos-

TABLE

Peak Systolic Velocity (PSV) Profiles of Superior Mesenteric Artery (SMA) Stenosis of Atherosclerotic Patients

	Group 1 (n = 61)	Group 2 (n = 10)	Group 3 (n = 9)
Fasting PSV*	161 ± 56	186 ± 65	355 ± 137
Postprandial PSV*	246 ± 65	280 ± 94	402 ± 125
Mean postprandial increase in PSV	53%	50%	13%

Group 1 = patients with 0% to <30% SMA stenosis; group 2 = patients with 30% to <70% SMA stenosis; group 3 = patients with 70% to 99% SMA stenosis.
*Values expressed as mean ± standard deviation, cm/s.

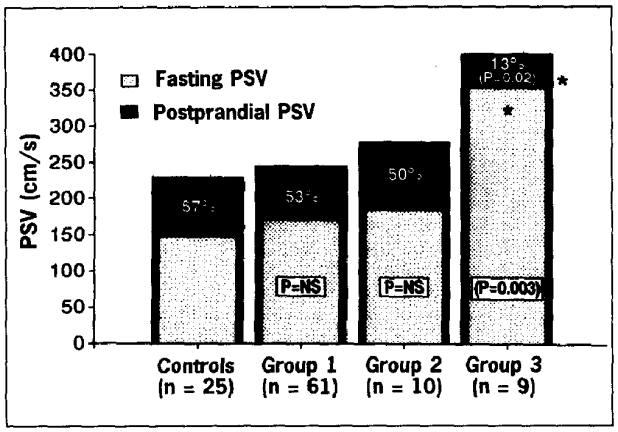

Figure. Fasting and postprandial superior mesenteric artery (SMA) peak systolic velocity (PSV) in controls and in patients with atherosclerosis. *P* values represent comparisons of velocities from one group to the next lower group, namely, the mean fasting PSV of 355 cm/s in group 3 patients is different from the corresponding velocity of 186 cm/s in group 2 patients ($P = 0.003$). There is no significant difference between mean fasting and postprandial PSV among controls and groups 1 and 2. The area above the mean fasting PSV and within the postprandial PSV is the mean postprandial percent increase after test feeding. *$P < 0.0001$, when comparing mean fasting and postprandial velocities in group 3 patients versus values in controls and in group 1 patients. Group 1 = patients with 0% to <30% SMA stenosis; group 2 = patients with 30% to <70% SMA stenosis; group 3 = patients with 70% to 99% SMA stenosis.

itive predictive value of 80%, a negative predictive value of 99%, and an overall accuracy of 96%.

The minimum normal hyperemic response to test feeding was determined to be an increase in peak systolic velocity of ≥20% over the individual patient fasting value. This figure was based on the 95% CI of the hyperemic response obtained in the normal control group (95% CI postprandial PSV % change 20% to 61%). In the 80 patients with atherosclerosis, an abnormal postprandial feeding response (<20% postprandial increase in peak systolic velocity) predicted a 70% to 99% SMA angiographic stenosis with a sensitivity of 67%, specificity of 94%, positive predictive value of 60%, negative predictive value of 96%, and overall accuracy of 91%. Three of the 9 patients with a stenosis 70% to 99% were able to increase their postprandial PSV more than 20%, accounting for the lower sensitivity and positive predictive value of postprandial mesenteric duplex scanning alone in predicting a SMA stenosis of 70% to 99%. Combining fasting and postprandial velocity testing to detect the absence of a stenosis 70% to 99% by duplex scanning as indicated by either a peak systolic velocity <275 cm/s or a ≥20% increase in postprandial peak systolic velocity, rules out a 70% to 99% SMA stenosis with 67% sensitivity, 100% specificity, 100% positive predictive value, 96% negative predictive value, and 96% overall accuracy.

COMMENTS

Duplex ultrasound scanning is widely utilized for the diagnosis of clinically significant carotid artery stenosis and is being increasingly applied to the detection of critical stenoses in other vascular beds, including the splanchnic circulation. Mesenteric duplex scanning offers the opportunity to study the dynamics of intestinal blood flow and to reveal quantitative differences between normal and abnormal visceral circulations.

Mild or moderate SMA stenosis is well-tolerated and essentially never associated with symptoms of chronic intestinal ischemia. High-grade stenosis of the artery is, however, virtually always present in patients with unequivocal symptoms of chronic intestinal ischemia. In our series of SMA reconstructions, the minimum amount of angiographically evident SMA stenosis associated with symptoms of chronic intestinal ischemia is about 70%.[11] Based on this, we have previously reported and prospectively validated fasting duplex scanning criteria for detection of a stenosis 70% to 99%.[7,8] Despite documented high accuracies of fasting duplex scanning for detecting a high-grade stenosis,[6,9] we and others have wondered about the potential added utility of provocative testing with postprandial mesenteric artery duplex scanning for stratifying SMA stenosis and identifying patients with high-grade stenoses.

Our data indicate that patients with SMA stenosis 70% to 99% have diminished ability, compared with healthy persons and atherosclerotic patients with lesser degrees of stenosis, to increase their peak systolic velocity in response to a feeding stimulus (Figure). However, while this observation makes intrinsic sense and is statistically valid, it does not appear that routine changes in postprandial SMA PSVs effectively stratifies the stenosis or substantially increases the already high diagnostic accuracy of fasting duplex scanning for detecting SMA stenosis of 70% to 99%. In fact, failure of the postprandial peak systolic velocity to increase the minimum value found in healthy persons is less sensitive (67%) than a fasting peak systolic velocity ≥275 cm/s (89%) for detecting high-grade SMA stenoses. That may be due to the formation of an extensive mesenteric collateral blood supply in asymptomatic patients with a high-grade stenosis and may explain why some patients (3 of 9) with a ≥70% stenosis increase their postprandial peak systolic velocity beyond the minimum level expected in a normal population.

It is interesting to speculate that failure of the postprandial SMA PSV to increase ≥20% over baseline may be a confirmatory test that patients with a hemodynamically significant (≥70%) stenosis and symptoms compatible with intestinal ischemia will have resolution of their abdominal complaints after intestinal revascularization. Testing this

hypothesis, however, will be prolonged, as the number of patients treated each year for chronic intestinal ischemia in any one center is small.

It currently appears the greatest usefulness of postprandial mesenteric duplex scanning is to exclude high-grade SMA stenosis. Our data suggest that if the SMA PSV is <275 cm/s and increases more than 20% postprandially, there is virtually no chance (specificity 100%) that the patient will have a >70% angiographically documented stenosis. Patients with abdominal pain and normal fasting and postprandial SMA PSVs should have a thorough workup for etiologies other than mesenteric ischemia.

Mesenteric duplex scanning provides a means for noninvasively detecting hemodynamically significant visceral artery stenosis. Our data suggest a fasting duplex examination of the SMA has a greater sensitivity than a postprandial study for identifying a stenosis 70% to 99%. If the fasting duplex examination identifies a high-grade stenosis, there is currently no need to proceed with a mesenteric feeding examination. If the fasting study is normal, documentation of a normal postprandial increase in SMA PSV excludes the presence of a ≥70% stenosis.

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