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Role of duplex Doppler ultrasound in the assessment of patients with postprandial abdominal pain

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Abstract

In 10 patients with postprandial abdominal pain thought likely to be the result of mesenteric ischaemia Doppler ultrasound examinations of the superior mesenteric and coeliac arteries were performed both after fasting and a standard meal of 800 kcal. Compared with control values Doppler waveform analysis suggested seven abnormal vessels. Two patients had abnormal fasting superior mesenteric artery waveforms manifested by very high peak systolic velocities together with spectral broadening (one also had evidence of coeliac artery stenosis), and one patient had normal velocities but an abnormal signal and evidence of proximal superior mesenteric stenosis was supported by colour Doppler imaging and confirmed by angiography. Postprandially, two patients showed very high peak systolic and end diastolic velocities in the superior mesenteric artery (one had had a normal fasting waveform signal) and one in the coeliac artery, suggestive of vascular stenosis, while one patient showed a fall in peak systolic velocity. The diagnosis of mesenteric ischaemia in two of these patients was supported by digital subtraction angiography and abdominal computed tomography. Doppler ultrasound may be a useful non-invasive investigation for patients with postprandial abdominal pain that helps to select patients for angiography. Patients with tight vascular stenosis may have abnormal fasting Doppler waveform patterns but in symptomatic patients further information may be obtained after the haemodynamic stress of feeding. Additional information to enhance the diagnostic sensitivity of the test may be obtained by colour Doppler imaging.

Atherosclerosis of the coeliac, superior, and inferior mesenteric arteries is claimed to affect up to 50% of people over the age of 45 years and is even more frequent when there is coexistent vascular disease elsewhere.[1-4] Despite the fact that chronic abdominal pain is a common complaint, 'intestinal angina' is diagnosed only infrequently. It is generally accepted that at least two of the three splanchnic vessels need to show haemodynamically significant stenoses or complete occlusion[2] for symptoms to occur, and ultrasound, which is being used increasingly in the investigation of abdominal disease, may have a role in selecting patients for more invasive investigations such as angiography.

While splanchnic ischaemia is usually caused by progressive atherosclerosis of proximal arteries, the same symptoms may result from external compression, fibromuscular hyperplasia, or small vessel disease typified by collagen vascular disease.[5] Similarly, symptoms may arise from reduced blood flow – the so called non-occlusive mesenteric ischaemia – usually as a consequence of massive blood loss but also in those with very poor cardiac reserve.

Doppler ultrasound has become increasingly important in investigating abdominal vascular disease. Both the coeliac and superior mesenteric vessels have been studied in detail in response to physiological stimuli such as feeding and exercise.[6-12] Dubbins[13] has reported its use in diagnosing renal artery stenosis, and a few anecdotal reports have discussed the potential role of ultrasound in investigating both superior mesenteric artery and coeliac artery stenosis.[14-16] These papers found abnormal velocity profiles across stenosed vessels, and the non-uniform velocities within the sample volume which may occur in areas of turbulence or stenosis[17] have been termed 'spectral broadening,' an additional indicator of high grade stenoses.[13-15]

This study aimed to assess the likelihood of mesenteric ischaemia (used collectively to describe stenosis of either the superior mesenteric and coeliac arteries and assuming stenosis or occlusion of the inferior mesenteric artery) in a group of patients with postprandial abdominal pain in whom previous investigations had proved unhelpful. From a knowledge of the velocity waveform changes seen postprandially in normal subjects,[6-7 10-11] it might be expected that digestion would accentuate the velocity waveform changes seen in vascular stenosis. While a number of authors have commented that a meal would be a useful circulatory stress test of the gut, this is the first paper to describe the effects of a meal in patients with a high possibility of actually having mesenteric ischaemia using duplex Doppler ultrasound.

Patients and methods

Subjects were drawn from both hospital inpatients and outpatients. Ten patients of mean (SEM) age 67 (2) years (three women, 64–77 years) were studied. All complained of postprandial epigastric pain occurring between 30 and 60 minutes after a meal, with seven patients commenting that symptoms were related to the size of the meal. Two had lost weight and one had complained of a change in bowel habit (this patient had had a normal barium enema save for the presence of scattered diverticulae). All had evidence of some form of cardiovascular disease: hypertension (2), ischaemic heart disease (5), cardiac failure (2), the presence of carotid bruits/ or peripheral vascular disease or both (2), and one patient had a 4 cm abdominal aortic aneurysm. Eight of the 10 patients had undergone upper gastrointestinal endoscopy as part of their

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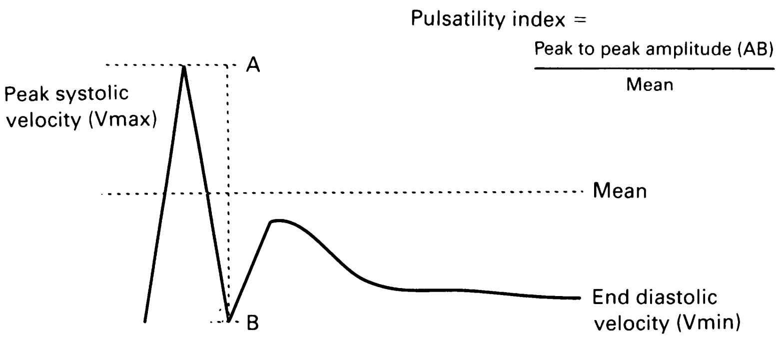

Figure 1: Doppler waveform parameters measured in both the superior mesenteric and coeliac arteries (time averaged velocity not shown).

diagnostic assessment and in each case this was normal. Haematochemical parameters in all patients were also normal. In view of the associated cardiovascular diseases, mesenteric ischaemia was considered a distinct possibility to explain their symptoms. Although formal angiography was not performed routinely, the diagnosis of mesenteric ischaemia in three patients was supported by additional investigations, and these included: a digital subtraction angiography study; abdominal computed tomography to look for evidence of pancreatic disease, which showed a very narrow superior mesenteric artery with pancreatic ischaemia, and angiography, at the same time as coronary angiography was performed.

Twenty volunteers aged 26–68 years (mean (SEM) age 46 (3) years; 20 superior mesenteric and 10 coeliac arteries) were similarly studied to establish normal values. Previous studies have shown that there is no relation between parameters of superior mesenteric artery blood flow and age.[16]

All subjects were asked to fast overnight and the following morning abdominal ultrasonography was performed after 30 minutes' supine rest on an examination couch. Superior mesenteric and coeliac arteries were identified by duplex

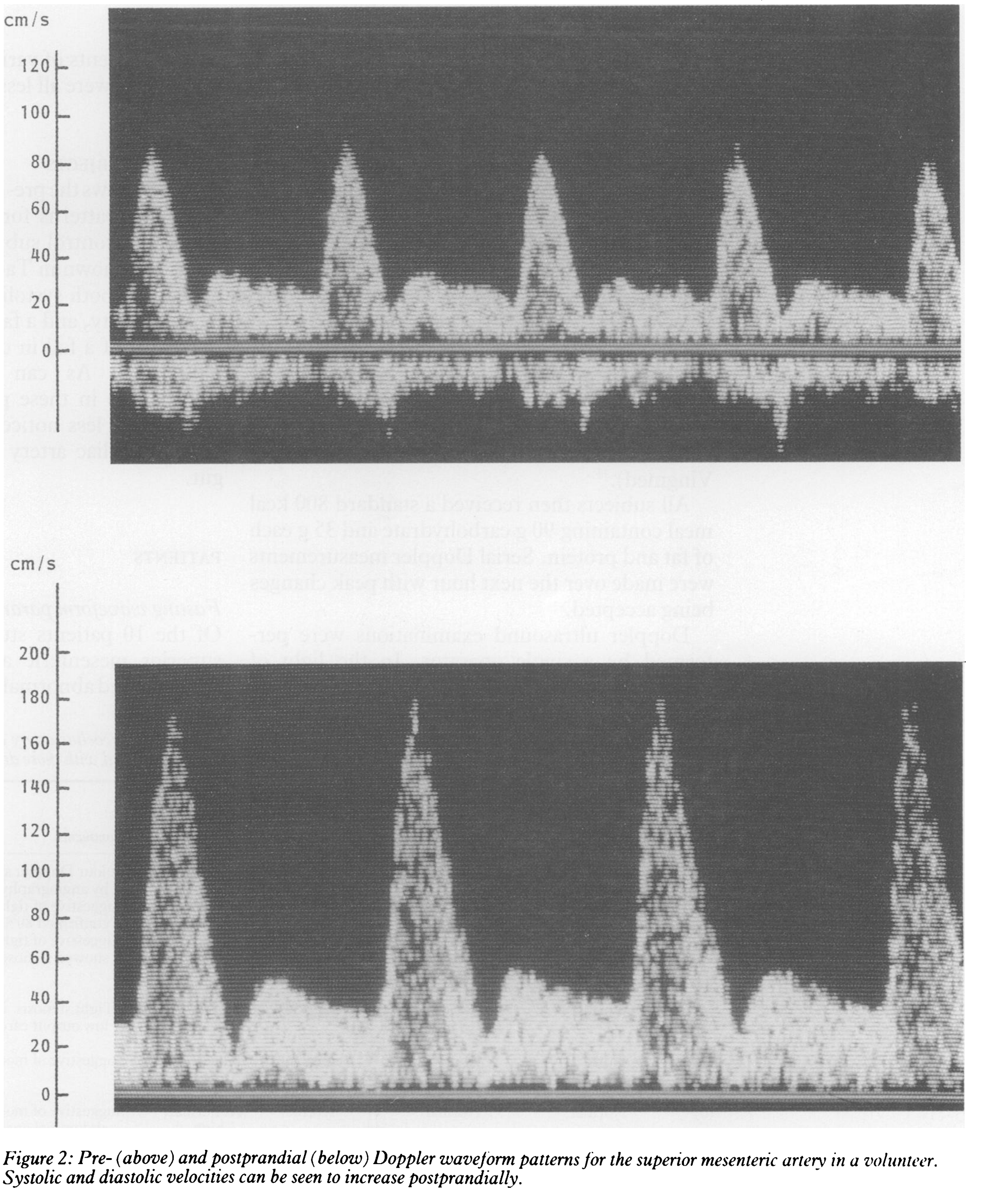

Figure 2: Pre- (above) and postprandial (below) Doppler waveform patterns for the superior mesenteric artery in a volunteer. Systolic and diastolic velocities can be seen to increase postprandially.

TABLE I *Mean (SEM) values for Doppler waveform parameters of the superior mesenteric (n=20) and coeliac (n=10) arteries in control subjects before and after an 800 kcal meal with the respective changes seen in the patients thought to have abnormal waveforms. Except for pulsatility index (PI), units are cm/second*

	Superior mesenteric artery							
	Pre-meal				*Post meal*			
	Vmax	*Vmin*	*TAMV*	*PI*	*Vmax*	*Vmin*	*TAMV*	*PI*
Normal subjects	100·5 (4·2)	16 (0·9)	35 (1·1)	3·6 (0·2)	154 (7·8)	46 (2·5)	59 (5·2)	1·8 (0·3)
Patient no, age (yrs)/sex:								
(1) 68/F	97	24	33	2·7	95	30	40	1·2
(2) 73/M	162	22	36	3·7	(No postprandial signals)			
(3) 74/M	145	47	50	1·7	310	131	116	1·3
(4) 77/F	96	14	25	3·2	63	26	22	1·9
(5) 65/M	108	20	28	3·1	312	78	70	2·4
	Coeliac artery							
Normal subjects	120 (7)	30 (3·3)	30 (3·3)	1·5 (0·2)	130 (2·2)	40 (4·8)	41 (3·3)	1·5 (0·1)
Patient no, age/sex:								
(2) 73/M	156	53	66	1·5	(No postprandial signals – pt 2 above)			
(6) 68/F	127	36	40	1·5	225	70	69	1·4

Vmax=peak systolic velocity; Vmin=end diastolic velocity; TAMV=time averaged mean velocity; PI=pulsatility index.

ultrasound of the upper abdomen, either longitudinally or transversely. Both a 5 MHz curvilinear probe or sector scanner were used, each with 2 MHz offset Doppler, keeping the angle of insonation of the Doppler beam as low as possible and constant for repeated measurements. The proximal portion of each vessel was scanned initially, having adjusted the sample volume size to the diameter of the vessel. After this, the vessels were scanned along their visible length. Fasting measurements were made on three occasions. The inferior mesenteric artery was inconsistently visualised. Figure 1 shows the parameters of blood flow that were measured by Doppler (Doptek Ltd). These included peak systolic and end diastolic velocities, mean velocity, and pulsatility index, a measurement of distal vascular impedance.[9 19] To enhance the diagnostic assessment, two patients with abnormal waveforms were also studied using a ultrasound machine with integral colour flow imaging facilities (Diasonics, Sonotron Vingmed).[18]

All subjects then received a standard 800 kcal meal containing 90 g carbohydrate and 35 g each of fat and protein. Serial Doppler measurements were made over the next hour with peak changes being accepted.

Doppler ultrasound examinations were performed by a single operator. In the light of previous reported changes in superior mesenteric and coeliac artery blood flow postprandially it was not possible for the operator to be blinded as to whether subjects had been fed or not.

Results

The coefficients of variation for repeated fasting parameters were all less than 10%.

CONTROL SUBJECTS

Figure 2 shows the pre- and postprandial Doppler waveform patterns for the superior mesenteric artery in a control subject. Mean results for the group are shown in Table I. The meal caused an increase in both systolic and diastolic velocities, mean velocity, and a fall in the pulsatility index, indicative of a fall in distal mesenteric vascular impedance. As can be seen in Table I, the changes in these parameters in the coeliac artery were less noticeable confirming that the bulk of coeliac artery blood flow is not to the gut.

PATIENTS

Fasting waveform parameters

Of the 10 patients studied, seven vessels (five superior mesenteric and two coeliac arteries) were deemed abnormal by Doppler criteria either

TABLE II *Author's assessment of pre- and postprandial superior mesenteric and coeliac artery Doppler waveforms. Only those patients thought to have abnormal vessels are quoted. Patient numbers correspond with those described in Table I*

	Superior mesenteric artery		*Coeliac artery*		
Patient no	*Fasting*	*Post meal*	*Fasting*	*Post meal*	*Comments*
(1)	Abnormal waveform	Abnormal	Normal	Normal	Colour Doppler showed proximal stenosis confirmed by angiography. (See Figs 3 and 4)
(2)	Abnormal waveform	No signal	Abnormal	No signal	Suggestive of tight proximal stenoses. DSA scan confirmed 80% SMA and 50% coeliac stenosis
(3)	Abnormal waveform with spectral broadening	Abnormal, spectral broadening	Normal	Normal	Suggestive of tight proximal stenosis. CT scan showed stenosed SMA with pancreatic ischaemia
(4)	Normal	Abnormal, fall in Vmax and Vmin	Normal	Normal	? Tight stenosis ? Non-occlusive ischaemia. (Pt with low output cardiac failure)
(5)	Normal	Abnormal, spectral broadening	Normal	Normal	Suggestive of moderate SMA stenosis
(6)	Normal	Normal	Normal	Abnormal, high velocities	Suggestive of moderate coeliac stenosis. (Pt with abdominal aneurysm)

DSA=digital subtraction angiography; SMA=superior mesenteric artery; CT=computed tomography.

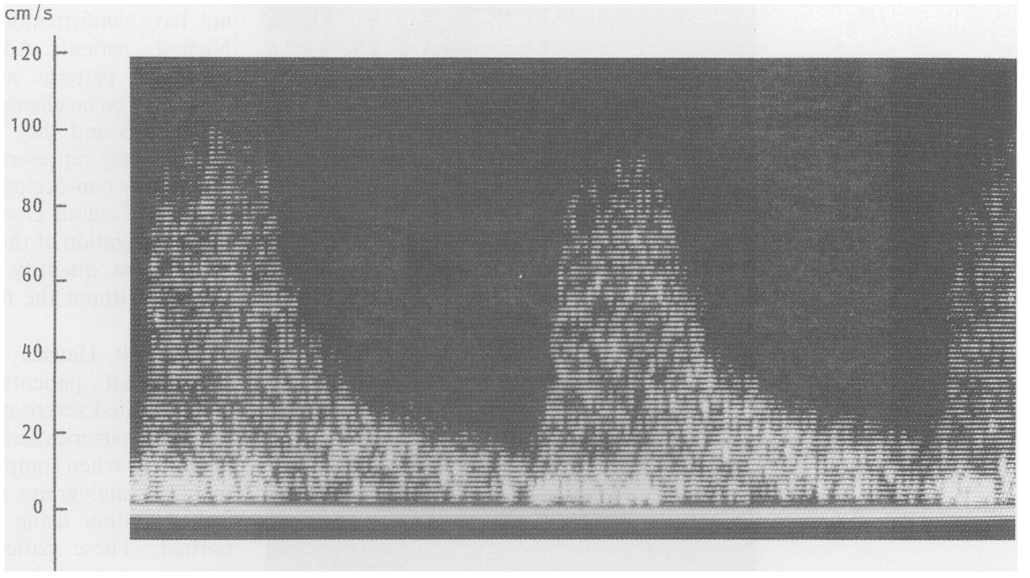

Figure 3: The abnormal fasting Doppler waveform pattern in patient 1 which changed little postprandially. Stenosis was confirmed by colour Doppler (Fig 4) and angiography.

pre- or postprandially, or both (Table I). Table II shows the author's assessment of the pre- and postprandial waveforms for each of the vessels for the patients numbered in Table I.

Two patients were found to have abnormal fasting superior mesenteric artery waveforms manifested by high peak systolic velocities, with one of these patients showing a high diastolic velocity with spectral broadening. These changes were thought to represent moderate to severe superior mesenteric artery stenosis. One of these patients (patient 2) was also shown to have resting coeliac waveform parameters considerably higher than those of any of the control subjects, suggesting coeliac artery stenosis as well. This patient was investigated further by digital subtraction angiography and shown to have proximal stenosis of both vessels (superior mesenteric artery 80%, coeliac >50%).

The other three patients had normal fasting parameters for the superior mesenteric artery but the waveform pattern was deemed abnormal in patient 1 (Fig 3). This patient was studied again using colour Doppler and was shown to have proximal superior mesenteric artery stenosis with appreciable turbulence in comparison with the expected colour picture in a control subject (Fig 4). This patient suffered from ischaemic heart disease, aortic stenosis, peripheral vascular and carotid vascular disease for which she had had both femoral angioplasties and carotid endarterectomies on two occasions. The failure to alter significantly parameters of postprandial superior mesenteric artery blood flow was taken to suggest a severe stenosis which was confirmed by an angiogram at the time of cardiac catheterisation.

Postprandial waveform changes

Because all subjects showed a postprandial fall in the pulsatility index of an order similar to that seen in the controls, this was not found to be a useful measurement in defining abdominal vascular stenosis. Satisfactory postprandial signals could not be obtained in one patient but the fasting parameters for both coeliac and superior mesenteric arteries were abnormal (Table I). In two subjects there was a noticeable increase in both systolic and diastolic velocities, far in excess of that seen in the controls. One of these subjects had been identified from fasting traces as being likely to have mesenteric stenosis (Fig 5) but in the other the fasting traces were thought to be normal. One patient was thought to have shown an abnormal response postprandially in the coeliac artery suggesting stenosis but at present has not undergone further investigation to confirm the diagnosis. Patient 1 showed little change in peak systolic velocity postprandially but was thought to have an abnormal waveform, and a colour ultrasound examination that was highly suggestive of superior mesenteric artery stenosis. In patient 4, systolic velocity together with mean velocity fell postprandially. This lady had complained of weight loss and postprandial abdominal pain for more than two years without obvious cause and had troublesome cardiac failure. It was thought that this result was suggestive of either severe stenosis or non-occlusive mesenteric ischaemia from a low output cardiac failure. Abdominal ultrasound, chest *x* ray, and haematochemical parameters were normal but further invasive investigation was not performed because of her medical problems.

Discussion

These results suggest that for patients with symptoms of postprandial abdominal pain in which other (often extensive) investigations have proved unhelpful, Doppler ultrasound may have an important role in confirming the possibility of mesenteric ischaemia and enable a more appropriate selection of patients for angiography. Fasting Doppler signals may be abnormal but in subjects with apparently normal fasting signals, the use of a meal as a circulatory stress test to the gut will provide additional information.

For symptoms of mesenteric ischaemia to occur, at least two of the three splanchnic arteries need to be stenosed or occluded.[2] Because the inferior mesenteric artery is frequently asymptomatically occluded and in most patients is a difficult vessel to visualise satisfactorily using

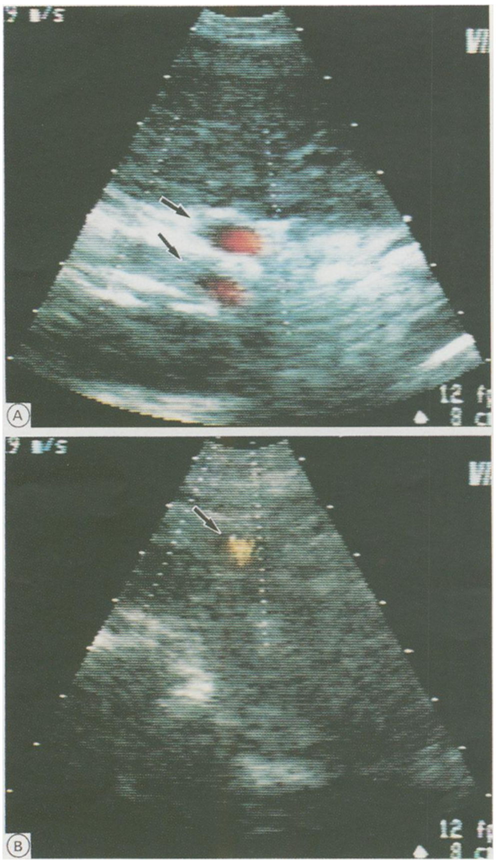

Figure 4: Fasting colour Doppler pictures of the superior mesenteric and coeliac arteries (arrowed) in (A) a control subject, and (B) a patient with mesenteric stenosis. Flow towards the ultrasound probe is shown in red. The white coloration seen results from turbulence around a proximal superior mesenteric artery stenosis (arrowed).

ultrasound, the coeliac and superior mesenteric arteries, which can be more easily examined, should be analysed carefully for evidence of proximal stenosis. The results presented for abnormal fasting Doppler signals agree with those of others[14 16]: patients with ischaemia may show abnormal waveforms, manifested by high peak systolic velocities, and spectral broadening and these two features have been taken to represent high grade stenoses. Jager[14] confirmed this impression in one patient by digital subtraction angiography. Nicholls[16] examined a number of different Doppler waveform parameters in both normal subjects and four patients with symptoms thought to be caused by mesenteric ischaemia that was subsequently confirmed by angiography. In his subjects, who were studied in the fasting state, a loss of reverse diastolic flow in stenotic superior mesenteric arteries compared with controls and considerably higher values for systolic and diastolic velocities were observed.

Previous reports have established an ultrasound diagnosis in the fasting state and none have reported the effects of a meal in such a group of patients. The additional information provided by this work illustrates how a test meal may provide evidence of splanchnic vascular stenosis even in subjects that have 'normal' fasting waveform parameters. It is possible that such a finding represents a less severe stenosis but this remains speculative as this group of patients did not have confirmation by angiography, unlike Nicholls' patients. Additionally, even if fasting waveform patterns are normal or abnormal, there may be no change in postprandial Doppler parameters and they may actually fall. These findings may represent a tight vascular stenosis or possibly non-occlusive mesenteric ischaemia. The use of colour Doppler imaging may help in the investigation of these patients and it may be possible to quantify the degree of vascular stenosis without the need for Doppler spectral analysis.[20]

Buchardt Hansen, *et al*[21] have previously shown that patients with angiographically demonstrated severe stenoses affecting the three splanchnic arteries had normal fasting splanchnic blood flow when compared with control subjects in whom angiograms measured by hepatic vein catheterisation using indocyanine green were normal. These patients, however, failed to increase their splanchnic blood flow postprandially but were shown to do so after splanchnic vascular reconstruction. In patients with less severe arterial lesions, flow did increase postprandially but the authors could not determine whether these patients had intestinal ischaemia as the cause of their pain. While this is open to question, Poole, *et al*,[22] using tonometry as an indirect measurement of intramural pH, showed that when greyhounds were subjected to partial occlusion of the superior mesenteric artery there was a precipitous decrease in tissue pH as a consequence of a decrease in oxygen delivery and the addition of a meal into the stomach resulted in a more severe acidosis. They proposed this as the mechanism for the symptom of pain that patients experience. If this is true, even moderate stenoses may, under certain circumstances, result in symptoms.

Patients with tight vascular stenosis of the splanchnic arteries may have abnormal fasting Doppler waveform signals. More moderate degrees of stenosis may be found in symptomatic patients after the haemodynamic stress of feeding. Doppler ultrasound is a useful tool in assessing the evidence for mesenteric ischaemia and newer technology such as the use of colour flow imaging may make this easier. The availability of a non-invasive screening test will help to select those patients that need to be considered for angiography. For patients that have undergone either surgery or transluminal angioplasty[23] for this condition, Doppler ultrasound may also be expected to be of value in predicting further stenosis.

Preliminary results from this study were presented at the autumn meeting of the British Society of Gastroenterology, Southampton 1990.

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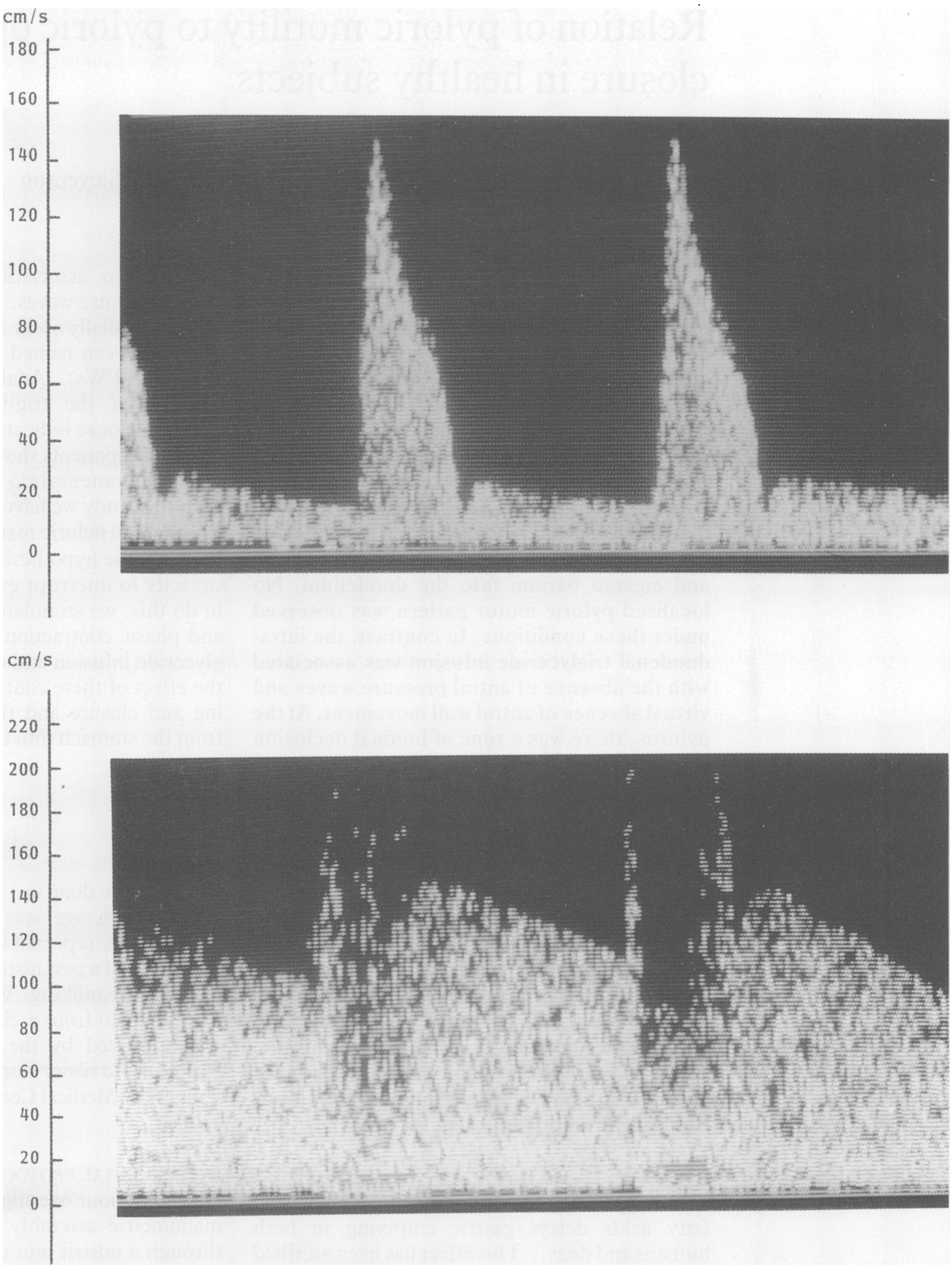

Figure 5: Pre- (A) and postprandial (B) Doppler waveform patterns in a patient with superior mesenteric artery stenosis. The abnormal fasting waveform shows a high peak systolic velocity. This is accentuated in the postprandial signal and accompanied by very high peak systolic and diastolic velocities.

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