Splanchnic Blood Flow in Patients with Abdominal Angina Before and After Arterial Reconstruction

A Proposal for a Diagnostic Test

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The diagnostic value of determining the splanchnic blood flow (SBF) and oxygen uptake before and after a test meal in patients suspected of abdominal angina was investigated in 15 patients with unexplained abdominal pain. Six patients with typical abdominal angina and occlusive lesions of two or three splanchnic arteries were investigated before and after successful arterial reconstruction. Five patients with less severe arterial lesions were classified as suspected of abdominal angina and four patients with eventual normal arteriography served as controls.

No significant difference was found in fasting SBF between the three groups. Postprandial SBF rose in the controls and in the abdominal angina suspected group, but not in the patients with abdominal angina. After arterial reconstruction fasting SBF was higher than before and postprandial SBF rose to the level of the controls. No difference in oxygen uptake before or after test meal was seen in any of the groups or after arterial reconstruction.

THE DIAGNOSIS OF ABDOMINAL angina is based on clinical symptoms, arteriographic demonstration of occlusive processes in the splanchnic arteries and exclusion of other gastro-intestinal disease. The symptoms postprandial pain, loss of weight and changes of the stools may not be very typical during the early stages of the disease. The finding of occlusive lesions of the main stems in at least two of the three mesenteric arteries is a prerequisite for the diagnosis, but no unambiguous criterion. As no specific diagnostic test of abdominal angina is available, these patients often suffer abdominal angina and emaciation a long time before the correct diagnosis is established.

It has been the purpose of this study to investigate the diagnostic value of determining the splanchnic blood flow (SBF) in the fasting patient and its subsequent changes after a test meal. SBF is here defined as the total flow through the three splanchnic arteries and eventual extra-splanchnic collaterals. As splanchnic blood passes through the liver it can be measured as the hepatic blood flow.

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Materials and Methods

Materials

A total of 15 patients were investigated. Six had abdominal angina, they were investigated before and after successful arterial reconstruction. Five patients were classified as suspected of abdominal angina. They had unexplained abdominal pains and arteriographic changes of the splanchnic arteries, though less severe than usually seen in patients with abdominal angina. Four patients having unexplained abdominal pains and normal mesenteric arteriography served as a control group.

All patients had aorto-mesenteriography performed in lateral as well as in frontal view. The arteriographic findings are seen in Table 1. In all patients other gastro-intestinal diseases which conceivably could influence SBF were excluded.

Methods

SBF was determined with indocyanide-green as described by Jacobsen et al.[8] according to the modification by Caesar et al.[3] of the method introduced by Bradley et al.[1] In the fasting patient catheters were placed in the radial artery and in an arm vein. Liver vein catheterisation was performed through a cubital vein. The correct position of the catheter tip was secured by fluoroscopy. After a priming dose of 1.25 mg of indocyanide-green (Hynson, Westcott and Dunning®) infusion was continued with 250 μg/min. After an equilibration period of 30 minutes arterial and venous blood samples were taken thrice with 10 minutes interval for determination of the fasting SBF. Thereafter the patient was given a standard meal consisting of 1000 calories divided equally between carbohydrates, proteins and lipids. After the meal blood samples were taken for determination of SBF seven times with 10 minute interval.

Samples were also taken for measurement of hemoglobin and oxygen saturation in arterial and hepatic venous blood. Oxygen uptake was calculated from SBF and arterio-venous oxygen difference.

Results

None of the patients had any complications related to the arteriography or to measurements of SBF.

SBF-Measurements

The flow-increase after the test meal was calculated as the difference between the mean of the fasting flow values and the mean of the postprandial maximum—and the two neighboring flow-values. The results for each patient, and the mean-values for the groups are seen from Table 2. The mean flow values from patients with suspected abdominal angina and abdominal angina are shown in Figure 1 together with those of the controls (mean ± SEM). The flow values before and after arterial reconstruction are seen in Figure 2. The actual flow curves from two patients before and after surgery are shown in Figure 3.

Control Group

These four patients had a mean fasting SBF of 1172 ml/min. increasing significantly ($p < 0.05$) after the test meal by 40%. The mean flow during the postprandial period was 1553 ml/min or 32% higher than the fasting flow.

Suspected Abdominal Angina

The mean fasting SBF for these five patients was 966 ml/min and increased significantly ($p < 0.001$) by 50% after the test meal. The postprandial mean flow of 1336 ml/min was 38% higher than the fasting flow. None of these values differed significantly from those of the control group.

Abdominal Angina Group Before Operation

These 6 patients had a mean fasting SBF of 981 ml/min, not significantly lower than that of the control group. After the test meal there was an insignificant flow-increase of 8%. The difference of 587 ml/min between the maximal postprandial flow in the control group and in this group is significant ($p < 0.01$). Also the mean flow during the postprandial period of 1006 ml/min was significantly lower than in the control group ($p < 0.0005$).

TABLE 1. *Angiographic Findings in Patients with Suspected Intestinal Ischemia*

	Pat. No.	CA	SMA	IMA
Abdominal angina suspected	5	†	†	*
	6	‡	*	*
	7	†	*	*
	8	‡	*	*
	9	*	†	‡
Abdominal angina	10	†	†	‡
	11	‡	†	‡
	12	‡	†	*
	13	‡	‡	*
	14	‡	‡	‡
	15	‡	‡	†

* Normal
† Stenosis
‡ Occlusion

Abdominal Angina Group After Operation

The fasting SBF of 1302 ml/min in mean was significantly higher than before operation ($p < 0.0005$), but not significantly higher than the fasting flow in the control group. After the meal the maximal SBF increase was 324 ml/min ($p < 0.025$) over the fasting flow, and 570 ml/min higher than the postprandial flow before arterial reconstruction ($p < 0.005$). The postprandial mean flow of 1528 ml/min was significantly higher ($p < 0.0005$) than before operation and nearly identical with that of the control group.

Oxygen Consumption

Oxygen consumption expressed as $mmol \cdot min^{-1}$ and the oxygen extraction as $\mu mol \cdot ml \cdot min^{-1}$ are shown in Table 2. The postprandial oxygen uptake is calculated for the highest SBF value. In all patients the oxygen uptake increased significantly ($p < 0.02$) after the test meal. Any significant difference in the oxygen uptake, could not be demonstrated, between the groups. Postprandial oxygen extraction on the other hand was significantly ($p < 0.05$) higher in patients with abdominal angina than in any other group, but attained normal values after arterial reconstruction.

Discussion

The maximal splanchnic flow is determined by the flow capacity of the three mesenteric arteries and, if such exist, by additional extra-splanchnic collaterals. If occlusive processes are present in the main stems

TABLE 2. *Splanchnic Blood Flow and Oxygen Consumption Before and After Standard Meal*

			Flow* ($ml \cdot min^{-1}$)				Oxygen Consumption† Total ($m\,mol \cdot min^{-1}$)				Oxygen Consumption† Per ml ($\mu mol \cdot min^{-1}$)			
Pat. No.	Sex	Age	B	A	Δ	p value	B	A	Δ	p value	B	A	Δ	p value
							Controls							
1	F	63	849	1259	410		1,48	2,76	1,28		1,7	2,3	+0,6	
2	F	65	1075	1954	879		2,69	3,74	1,05		2,5	1,9	−0,6	
3	M	72	1513	1789	276		2,69	3,18	0,49		1,8	1,8	0	
4	M	40	1250	1571	321		2,73	3,61	0,88		2,2	2,3	+0,1	
Mean		60	1172	1643	471	$p < 0,05$	2,39	3,32	0,93	$p < 0,02$	2,1	2,1	0,03	n.s.
SD			280	300			0,61	0,44			0,37	0,26		
							Abdominal Angina Suspected							
5	M	54	1158	1605	447		2,26	3,31	1,05		2,0	2,1	+0,1	
6	M	67	693	1202	509		2,36	3,52	1,16		3,4	3,0	−0,4	
7	F	51	951	1393	442		1,50	1,64	0,14		1,6	1,3	−0,3	
8	M	67	909	1456	547		2,50	3,38	0,88		2,8	2,4	−0,4	
9	F	46	1120	1579	459		1,98	2,61	0,63		1,8	1,7	−0,1	
Mean		57	996	1447	481	$p < 0,001$	2,12	2,89	0,77	$p < 0,01$	2,3	2,1	−0,2	n.s.
SD			186	162			0,40	0,78			0,75	0,65		
							Abdominal Angina Preoperatively							
10	F	65	948	1229	281		2,33	2,85	0,52		2,5	2,3	−0,2	
11	F	36	1002	—	—		1,57	—	—		1,6	—	—	
12	M	61	920	1050	130		1,64	2,89	1,25		1,8	2,8	+1,0	
13	M	54	759	793	34		2,47	3,26	0,79		3,3	4,6	+1,3	
14	M	66	1114	1132	18		2,65	3,45	0,80		2,4	3,6	+1,2	
15	F	56	1143	1079	−64		2,24	3,02	0,78		2,0	2,8	+0,8	
Mean		56	981	1056	80	n.s.	2,15	3,09	0,83	$p < 0,005$	2,3	3,2	0,8	$p < 0,05$
SD			140	162			0,44	0,25			0,6	0,9		
							Abdominal Angina Postoperatively							
10			1091	1744	653		2,46	3,39	0,93		2,3	2,0	−0,3	
11			1302	1469	167		2,33	3,07	0,74		1,8	2,3	+0,5	
12			1304	1377	73		1,96	2,15	0,19		1,5	1,6	+0,1	
13			1092	1521	429		2,38	3,13	0,75		2,2	2,2	0	
14			1535	1932	397		2,38	3,15	0,77		1,6	1,7	+0,1	
15			1490	1714	224		2,06	2,92	0,86		1,4	1,9	+0,5	
Mean			1302	1626	324	$p < 0,02$	2,26	2,96	0,70	$p < 0,005$	1,8	1,9	0,1	n.s.
SD			188	206			0,20	0,42			0,4	0,3		

* Flow: B: average of flow before meal.
A: average of maximum flow and two neighboring flows after meal.
† Oxygen consumption: B: average of oxygen consumption before meal.
A: oxygen consumption after meal at the time of max. flow.

of the mesenteric arteries inter-splanchnic anastomoses gives ample possibilities for redistribution of flow and for receiving the supply from extrasplanchnic collaterals.[6] Knowledge of the total splanchnic flow therefore, is of main interest when chronic arterial insufficiency of the gastro-intestinal tract is suspected in patients with postprandial pains. Marston[9] in 1967 expressed the opinion that measurement of splanchnic flow would be of limited value, as no information could be obtained about regional distribution of the total flow. In our opinion knowledge of the total SBF is most important, as possibilities for redistribution of blood-flow probably always exist, when the total inflow is sufficient. Knowledge of regional flow distribution would be of diagnostic importance only in rare cases of small vessel disease, or embolism to the branches of the mesenteric arteries.

For all practical purpose hepatic blood-flow, as determined by Bradley et al.[1] in 1945, may be considered equal to SBF. Information on SBF in the normal fasting subject is available from few and rather small series (3,8,11). Mean values are of the same order as found for the control group of the present study, i.e. 1000–1200 ml/min.; the scatter, however, is considerable, the values ranging from approximately 800 to 1900 ml/min. Some clinical studies[4,11] on the effect of digestion on splanchnic flow have shown but a modest increase after 500–600 cal given as a glucose solution. Following a mixed meal of 700 cal. Norryd et al.[10] found a maximal increase of 60% in the superior mesenteric artery flow of five persons. In comparison direct flow measurements on the superior mesenteric artery or the portal vein in dogs have shown a postprandial increase in flow of 75–125% [2,5,7] As the flow increase is carried mainly by the superior mesenteric artery[7,11] the corresponding increase in SBF was presumably somewhat less.

In patients with abdominal angina no study on SBF seems to have been published. In the present series no significant difference in fasting SBF could be demonstrated between the control group, the patients suspected of abdominal angina and the patients who had abdominal angina, but after arterial reconstruction this last group had a higher fasting SBF than before. Two explanations can be offered for this increase: the operation may have resulted in partial sympathetic denervation of the small intestines, or the resistance vessels in the splanchnic area may not have regained their ability to regulate flow according to nutritional needs during the first few weeks after the operation.

The 1000 cal test meal resulted in an increase of SBF in all patients without abdominal angina. The inability of the angina patients to increase SBF much over fasting values will be seen from the obtained maximal flows and becomes even apparent when fasting SBF is compared to the mean SBF of the whole postprandial period. For the control group mean postprandial flow rose 32% (12 to 70%) above fasting values, while in the abdominal angina group the rise was 3% (−5 to 27%). After operation mean postprandial SBF and also maximal SBF became nearly identical with that of the control group.

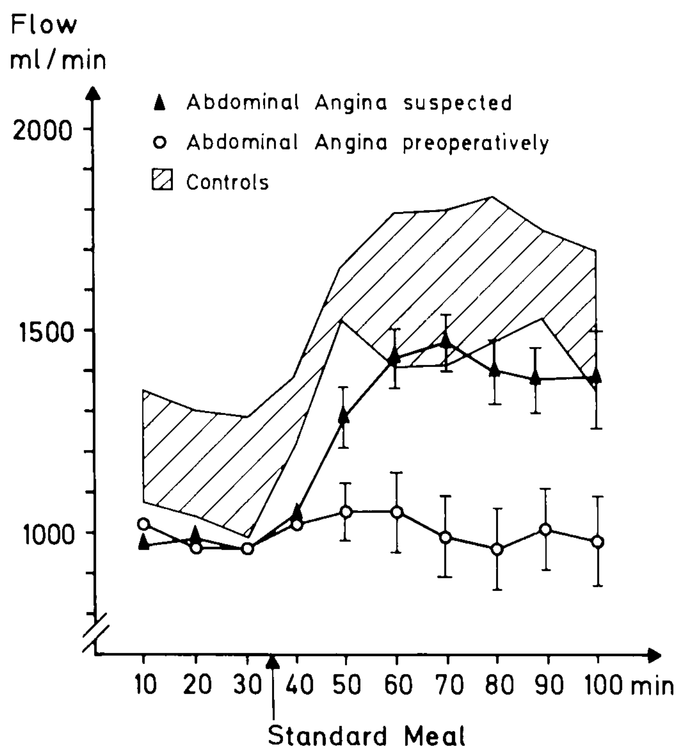

FIG. 1. Average splanchnic blood flow before and after a standard meal in control patients (cross-hatched area), patients with suspected abdominal angina and patients with abdominal angina. Mean ± SEM.

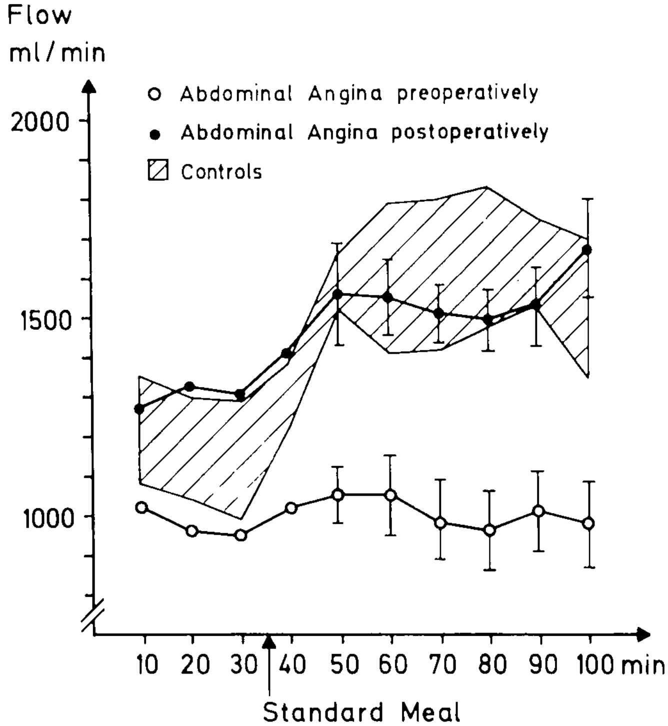

FIG. 2. Average splanchnic blood flow before and after a standard meal in patients with abdominal angina pre- and postoperatively compared to controls (cross-hatched area). Mean ± SEM.

In the individual case both fasting SBF and the increase after the meal should be considered. Thus case 3 of the control group had the high fasting SBF of 1513 ml/min, but an increase of 18% only, while case 10 of the angina group has a fasting flow of 948 ml/min and an increase of 30%. This means the patient from the control group had a maximal postprandial flow about 550 ml/min higher than the patient with abdominal angina.

The patients in the group suspected of abdominal angina all had lesions of the mesenteric arteries, but less severe than those demonstrated in the abdominal angina group. The maximal and also the fasting flow were lower, but not significantly, than in the control group. This weight against the diagnosis, though it cannot be known with certainty that none of the group had ischemic pain during digestion. The hemodynamic significance of the arterial lesions are underlined from the fact, that the maximum flow also occurred later in this group.

The splanchnic arterio-venous oxygen difference

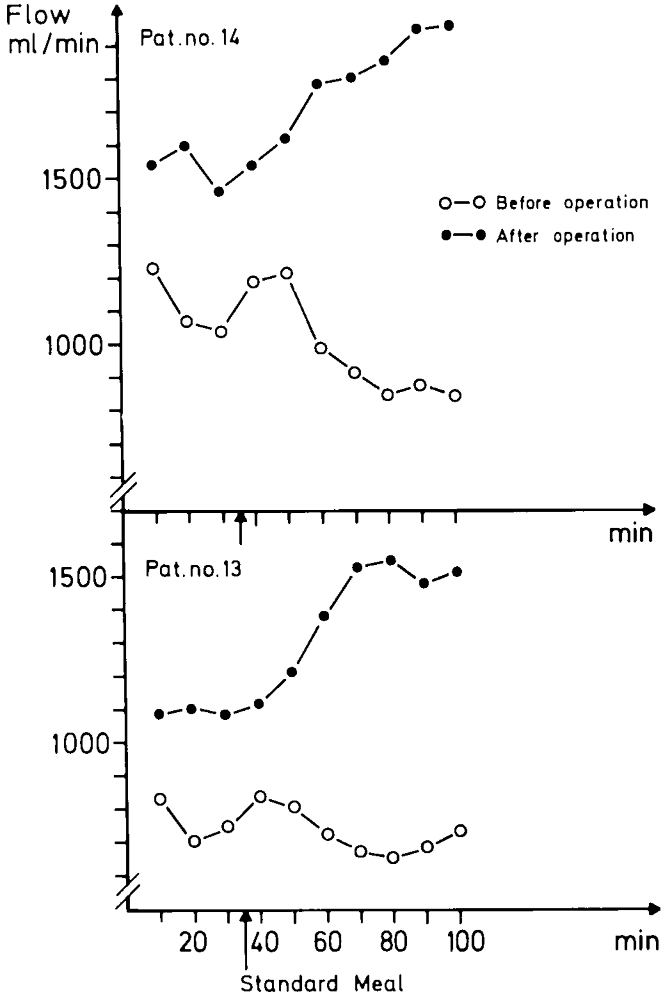

FIG. 3. Flow curves before and after arterial reconstruction from two patients with abdominal angina.

may render some additional information. The calculated oxygen uptake during fasting and the increase by approximately 40% after the meal is virtually the same for all groups. Consequently the postprandial arterio-venous oxygen extraction is highest in patients with adominal angina, who cannot increase their SBF, but postoperatively the oxygen extraction is normalized, indicating that SBF and oxygen extraction vary inversely allowing constant oxygen uptake under varying flow conditions.

How far SBF and changes in oxygen extraction in relation to a test meal can be taken as diagnostic of abdominal angina is difficult to assess from this small series. At present our proposition is: 1) A low (< 1000 ml/min) fasting SBF with no increase in maximal or mean SBF over a 70 min period after a 1000 cal. test meal and with an increased arterio-venous oxygen extraction weighs heavily in favour of the diagnosis of abdominal angina. 2) A low (< 1000 ml/min) fasting SBF with an increase of at least 40% in maximal flow and 30% in mean SBF after the test meal and no increase in arterio-venous oxygen extraction speaks against abdominal angina. 3) A high (1200 ml/min) fasting SBF with a small increase in mean and maximal SBF after the test meal points against abdominal angina provided the arterio-venous oxygen extraction remains in the low range.

These criteria are met, where sufficient data are available, by the members of the control group, the abdominal angina group pre- and postoperatively, who having no postprandial pain, can be considered "normals" with a high fasting flow. As for the patients suspected of abdominal angina we have at present no way to ascertain whether intestinal ischemia caused their pain. According to the proposed criteria none of them should have abdominal angina.

Measurement of SBF before and after a test meal is a rather demanding procedure in terms of laboratory facilities and expertise. The information obtained seems, however, though of sufficient importance to merit further studies as to its diagnostic value considering the often very long time and many hospital admissions these patients at present suffer before the diagnosis of abdominal angina is established or disproved.

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