Intestinal Perfusion Studies Using ^{133}Xe During Correction of Mesenteric Vascular Insufficiency: Case Report

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Radioxenon clearance studies of bowel perfusion were obtained during laparotomy in a patient with mesenteric vascular insufficiency. These studies were obtained both before and immediately after bypass of the occluded superior mesenteric artery. Although clearance rates improved after the bypass surgery, normal rates were not achieved.

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An inert radioactive gas, usually ^{133}Xe, injected intra-arterially or interstitially, is widely employed in perfusion studies of the extremities, kidneys, or brain. Animal studies have shown that the clearance rate of ^{133}Xe, placed interstitially in the bowel wall, varies with the degree of superior mesenteric artery occlusion and vasopressin infusion (*1*). This report illustrates the value of this technique in the study of mesenteric vascular obstruction in man.

CASE REPORT

A 66-year-old white man was admitted because of severe abdominal pain with a weight loss of 50 lb over the previous 6 months. Ingestion of food, especially warm liquids, resulted in severe constant mid-abdominal pain. The past history included claudication due to peripheral vascular disease involving the aortoiliac bifurcation. Two years before admission, a bilateral aortofemoral Dacron graft had been placed, with some relief of claudication.

On physical examination, blood pressure was 135/70, pulse rate was 84, and temperature 37°C. The patient was 72 in. tall and weighed 118 lb. The heart and lungs were normal. The abdomen was scaphoid with no guarding or rigidity, although mild diffuse abdominal tenderness was present. Femoral pulses were present bilaterally, but there were no distal pulses.

Laboratory data included a white blood count of 13,600/mm^3 and a hematocrit of 45% with normal differential. An upper gastrointestinal series and barium enema were within normal limits. A retrograde femoral aortogram (Fig. 1A) indicated 90% stenosis of the celiac axis and almost total occlusion of the superior mesenteric artery (SMA). The inferior mesenteric artery was absent. The clinical diagnosis was mesenteric vascular ischemia, and abdominal exploration was performed.

The mesentery of the bowel was pulseless and no flow was recorded in the SMA with the electromagnetic flowmeter. Clearance of ^{133}Xe from the bowel wall was greatly prolonged (Table 1). A bypass was performed from the aorta to the SMA distal to the occlusion, resulting in good pulsatile flow in the mesenteric vessels. Repeat xenon clearances were carried out after revascularization.

Postoperatively, the patient's course was uncomplicated, and in the 6 months since discharge he has gained 50 lb. A postoperative arteriogram indicated the aorta–SMA graft to be patent with excellent bowel perfusion (Fig. 1B). The patient is now asymptomatic except for persisting one-block claudication.

TECHNIQUE AND RESULTS

Approximately 250 μCi of ^{133}Xe in a volume under 0.1 ml was injected with a 25-gage needle into

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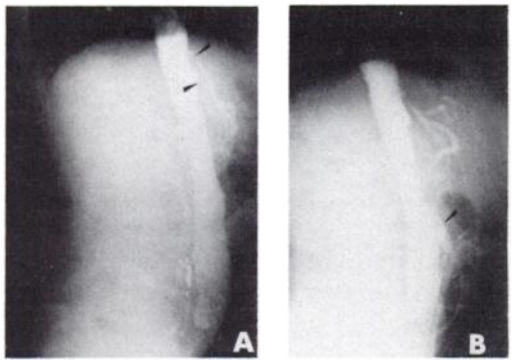

FIG. 1. (A) Preoperative aortogram. Markers indicate sites of obstruction in celiac and superior mesenteric arteries. (B) Postoperative aortogram. Marker indicates bypass from aorta to superior mesenteric artery.

TABLE 1. CLEARANCE OF ^{133}Xe FROM BOWEL WALL BEFORE AND AFTER SMA BYPASS

	Half-times (min)	
Organ	Before	After
Stomach	39, 33	14
Small bowel	18, 26	7, 10
Colon	7.5, 8	9

the muscular layer of the bowel on the antimesenteric border in various sites from stomach to colon. Immediately after each injection, the activity level was recorded digitally every 15 sec for about 5 min by a 2-in. NaI crystal attached to a scaler–ratemeter. The crystal was recessed 5 cm into a 1-cm-thick lead collimator and shielded by a sterile plastic drape so that it could be placed directly over the injection site. Replicate studies were performed at least 8 cm apart, the previous site being shielded by metal retractors to minimize background activity. This counting was done in duplicate both before and immediately after the arterial bypass. The data were plotted on semilogarithmic paper and clearance rates were calculated as the half-time of the fastest component of the curve (Table 1).

After the bypass procedure, clearance rates improved greatly in the stomach and small bowel, where initially they had been most prolonged, but the colon showed no change. Utilizing the Kety formula and assuming a tissue-to-blood partition coefficient of 0.7, a $T_{1/2}$ of 7 min yields a calculated blood flow of 7 cc/100 gm per min.

DISCUSSION

Intra-arterial instillation of an inert tracer such as ^{133}Xe has been used to study the regional circulation in such well-defined organs as the brain and kidney (*2*). In addition, interstitial instillation has been employed in such diverse structures as thyroid nodules, testis, skin flaps, uterus, and myocardium (*3–7*). Aside from some isolated physiologic studies, little has been done with either technique in the bowel (*8–10*). Although access to the mesenteric circulation can be obtained at angiography, a radioactive tracer instilled intra-arterially will reach a heterogeneous assortment of bowel and other structures so that external monitoring of washout rates is likely to prove confusing.

Provided that the volumes used are small enough not to disturb local circulatory dynamics, the clearance rates of interstitially injected inert tracers provide an accurate measurement of regional perfusion (*11*). Such measurements should prove to be of equal clinical value in the bowel. As we have previously shown (*1*), the mesenteric vessels normally carry a great deal of excess flow. Xenon-133 clearance rates from bowel, which probably reflect nutritive cellular perfusion, do not slow significantly until total mesenteric flow has fallen by 70% or more; the clearance rates then fall off rapidly. The test thus provides a relatively sharp end point between nutritionally adequate and inadequate perfusion.

In the present case, the maximum flow rate of 7 cc/100 gm per min, which was the highest either before or after revascularization, was considerably lower than the values derived by Selkurt et al. (*2*) and ourselves (*1*) from the mucosa of anesthetized dogs. This low rate was more consistent with the rates obtained from the slower compartments: the muscle and connective tissue of the submucosal, muscular, and serosal layers. Although the tracer was instilled through the serosal surface into the muscular layer, our experience using this site in animals and in two control human subjects has shown that diffusion into the mucosa is normally sufficient for rapid washout to be obtained (Fig. 2). The absence of such a component in this patient, even after successful revascularization, may mean that during chronic ischemia the mucosa may atrophy to the point where this compartment is not represented in the perfusion curve. Malabsorption in the course of this disease is, in fact, ascribed to atrophy of the mucosal villi (*12,13*). Days or weeks may be needed before regeneration occurs.

Note that little improvement in washout rate was seen in the colon following bypass. Since the inferior mesenteric artery had been sacrificed in the previous aortofemoral bypass procedure, the circulation in the colon was probably maintained by collateral channels through the internal pudendal arteries. Thus, opening the superior mesenteric artery would be unlikely to increase circulation to the colon.

Radioactive perfusion studies, as anticipated, were thus distinctly abnormal in this case of mesenteric vascular disease and provided new insights into the process. The technique is relatively simple and yields far more detailed information than can be obtained by angiography, especially since bowel ischemia may occur in the absence of grossly visible arterial disease, as seen in chronic low-output cardiac failure, polyarteritis nodosa, or venous thrombosis (*14–16*).

Besides their use in evaluation of vascular occlusive disease of the bowel, as illustrated by this case, these radioxenon techniques should be useful in various other disease states, particularly such idiopathic inflammatory conditions as colitis and ileitis. Currently, these techniques can be applied to the bowel only at laparotomy, with the exception of limited regions such as the rectal mucosa. However, the advent of flexible fiberoptic scopes should eventually make possible access to more central bowel areas through the bowel lumen.

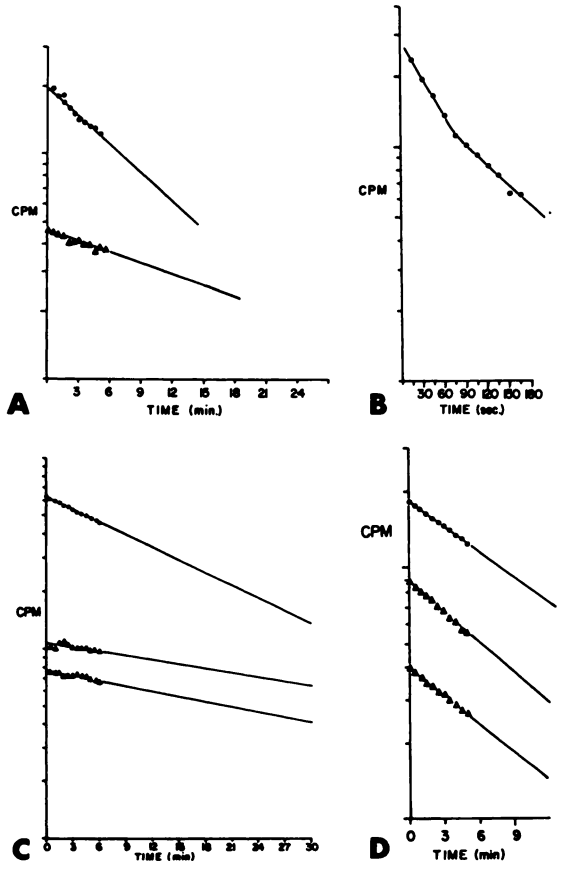

FIG. 2. (A) Clearance curve from patient's small bowel before (triangles) and after (circles) bypass. (B) Clearance from normal small bowel. Note faster rate (different time axis) and biexponential character. (C) Clearance from patient's stomach before (triangles) and after (circles) bypass. (D) Clearance from patient's colon before (triangles) and after (circles) bypass. Note lack of change.

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