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Rapid Diagnosis of Steatorrhea by External Counting of Abdomen After Iodine-131-Labeled Fat Administration

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A laboratory test should give its answer quickly and require little help from the patient. Current methods for diagnosis of abnormal fat absorption present problems both with respect to prolonged test duration and dependence upon patient cooperation. Quantitative chemical determination of fecal fat requires that all stools be collected for a period of at least three days and that the patient maintain a normal dietary intake of fat before and during this period. Iodine-131-triolein fecal excretion measurement does not give information any more quickly, since it likewise requires three days of total stool collection. It eliminates the need for normal dietary fat intake, but it demands even more careful stool collections than the chemical method does, strictly avoiding contamination of feces with urine. Though measurement of blood radioactivity for several hours after oral administration of ^{131}I-triolein avoids the drawbacks of three-day stool collections, many investigators have found that this procedure does not give diagnostically reliable evaluation of fat absorption (1-3).

Several years ago, the author and his co-workers (4) devised a method in which the intestinal absorption of ^{131}I-triolein was estimated by measuring externally over the abdomen the radioactivity remaining 8 hours after oral administration of labeled fat. This procedure can furnish results in one day. A minimum of stool collection and cooperation by the patient is required. Diagnostic validity is comparable to the fecal excretion method for measuring ^{131}I-triolein absorption. Independent confirmation of our findings has been provided by others using a substantially similar method (5). The present report describes our technique of external abdomen counting and considers its advantages and limitations in detail.

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METHOD

Patients are prepared for this fat absorption test by fasting overnight and omitting drugs that may influence gastrointestinal motility or function. Thyroidal ^{131}I uptake is blocked by prior administration of Lugol's solution.

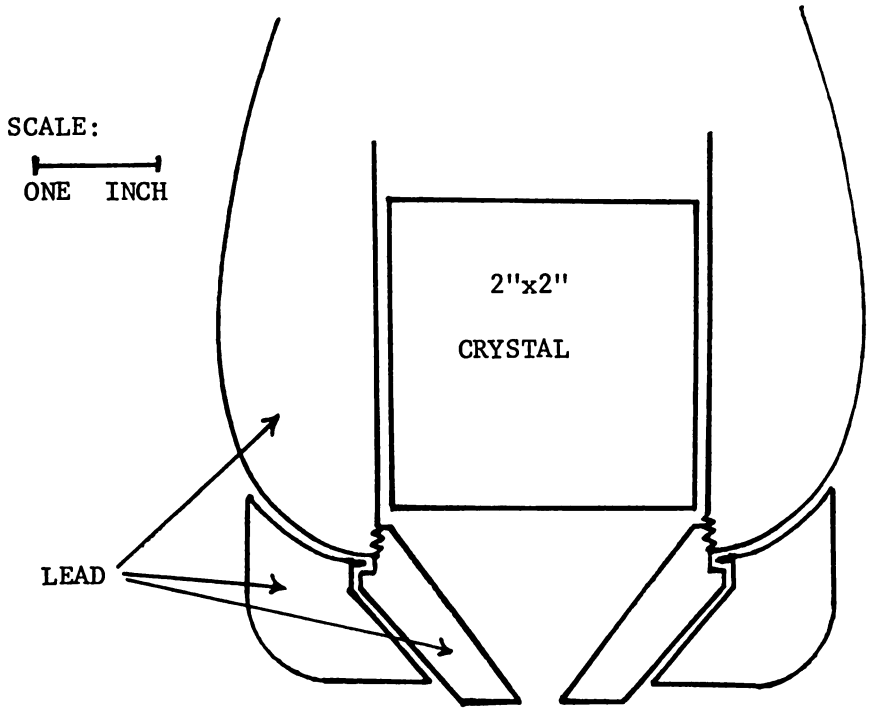
The test capsule of labeled fat is given in the morning, along with several capsules of barium sulfate in case a check on gastric emptying as described below is needed. No "test meal" of carrier fat is given (1). No food is allowed for the next four hours, after which the patient's usual diet is resumed. Patients are intructed to save any stool excreted from the time the labeled fat is given until the test is completed.

Six hours after administration of the test dose, a preliminary count of radioactivity remaining in the abdominal area is performed in accordance with the geometry and technique described below. Just before this count, the patient is instructed to urinate. If any stool has been excreted by this time, its ^{131}I activity is measured, using the same geometry and apparatus, and this fecal radioactivity is added to that measured externally over the abdomen. The result, after appropriate corrections for background and decay, is expressed arbitrarily, relative to the activity that was administered, as "per cent of administered dose". If this value is over 35 per cent, a plain film of the abdomen is obtained just before performing the final count, because if barium is still present in the stomach at that time, an abnormally high final result may simply be due to gastric retention.

The final abdomen count is done eight hours after administration of the test dose. Again the patient should empty his bladder just before the count. Any stool excreted from the start of the test to this time is counted also, and its activity is added to the abdomen count. This activity is then expressed again in relative form as "per cent of administered dose".

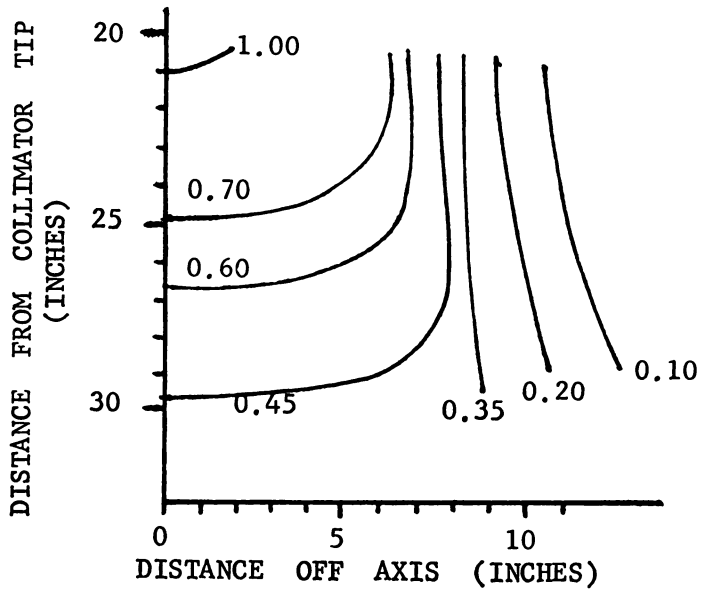
All radioactivity measurements in the present report were made with a 2×2 inch Tl-activated NaI scintillation crystal and gamma spectrometer, counting the ^{131}I 0.364 MeV peak to a statistical accuracy of at least three per cent. The scintillation crystal was equipped with a 20-degree flat-field collimator of the inverted-cone type, with supplementary shielding (Nuclear-Chicago DS5-1P, K5S and J5S). A cross-section of the collimator and diagram of its response are shown in Figure 1. For external measurement of abdomen radioactivity, the collimator orifice was centered over the midline of the abdomen of the supine patient, midway between xiphoid and symphysis pubis. At this level the distance between the anterior and posterior surfaces of the body was measured and the collimator tip was placed 25 inches above the middle of the anteroposterior distance. With the counter collimated and positioned in this way, the geometric distribution of radioactivity within the abdomen had little effect on counting rate, and the response to radioactivity outside the abdominal area was slight.

In some instances, lead-rubber shielding equivalent to 2.5 mm. lead (one half-value layer for the ^{131}I gamma peak) was placed over the upper half of the thighs and the lower portion of the thoracic cage. This additional shielding did not improve discrimination between normal and abnormal results, affecting both to the same slight extent, and therefore was superfluous.



CROSS-SECTION OF COLLIMATOR AND SHIELDS

(RESPONSE AT 21 INCHES, ON AXIS =1.00)



COUNTER DISTANCE-RESPONSE DIAGRAM

Fig. 1. Collimator construction and response.

In the present study, ^{131}I-triolein or ^{131}I-oleic acid was given in capsule form (Squibb) in dosage ranging from 75 to 100 microcuries. Just before administration, the activity was measured by placing each capsule 25 inches below the collimator tip, within a plastic cube thyroid phantom. A reference standard of ^{131}I was similarly measured at the same time and at the time of each subsequent count. An abdomen phantom was unnecessary, since the external abdomen counts cannot avoid representing relative rather than absolute values of activity remaining within the gastrointestinal tract, as discussed below.

For the cases in this report, stool collection was continued for 72 hours after administration of the test capsule. Fecal radioactivity was measured by centering the gallon cardboard container used for the collection so that its bottom was 25 inches below the collimator tip. With this geometry, the distribution of activity in stool within the container was found to have a negligible effect on the counting, and the results could be directly compared to the external abdomen counts.

RESULTS

Iodine-131-triolein tests were done in 42 men ranging in age from 24 to 71 years and divided into the following 6 groups:

A. *Controls:* These 21 patients had no clinically evident abnormality of digestion or absorption, of gastric or small intestinal motility, or of splanchnic circulation. Nine had diabetes mellitus, seven had uncomplicated peptic ulcer, three presented psychogenic gastrointestinal symptoms, two had lymphoma, and one had eczematoid dermatitis. Their test results are shown in Figure 2.

Ioidine-131-triolein fecal excretion results in 20 of these 21 patients averaged 3.6 per cent, with a standard deviation of 3.1 per cent. One subject had unexplained high radioactivity in the stool collection, and urinary contamination of the specimen was suspected.

External measurements of abdominal radioactivity in these subjects ranged from 15 to 38 per cent, with a mean of 23.3 per cent and a standard deviation of 6.6 per cent.

B. *Gastric retention:* Patients with gastric atony and delayed emptying, following vagotomy or due to diabetic visceral neuropathy, who had normal fecal ^{131}I-triolein tests, had elevated abdominal activity measurements (Figure 3a). These results would have been misleading if gastric retention had not been recognized. In each case the roentgenogram of the abdomen taken as described above was an important guide in avoiding misinterpretation.

C. *Congestive failure:* Two patients studied while in congestive failure, manifested by hepatomegaly and dependent edema, had fecal excretion results within normal limits, while abdomen counts were elevated (Figure 3a). It should be noted that abdomen counts in both of these cases were done with additional lead shielding over chest and thighs. Possible significance of these results will be discussed.

D. *Subtotal gastrectomy:* Four patients with post-gastrectomy "dumping" or diarrhea and marked weight loss had elevated fecal radioactivity excretion and likewise showed correspondingly abnormal external abdomen results, ranging from 39 to 64 per cent (Figure 3B). Seven other such patients had fecal

results in normal range, and in this group the external abdomen counts were correspondingly normal, averaging 21.3 per cent.

There was fecal excretion of radioactivity during the eight-hour test in three of the four patients with abnormal test results. In two of these cases the eight-hour external abdomen radioactivity by itself was high enough to give a result in the abnormal range, even without taking into account the fecal excretion. Failure to collect stools would therefore not have caused any error in interpretation of their results.

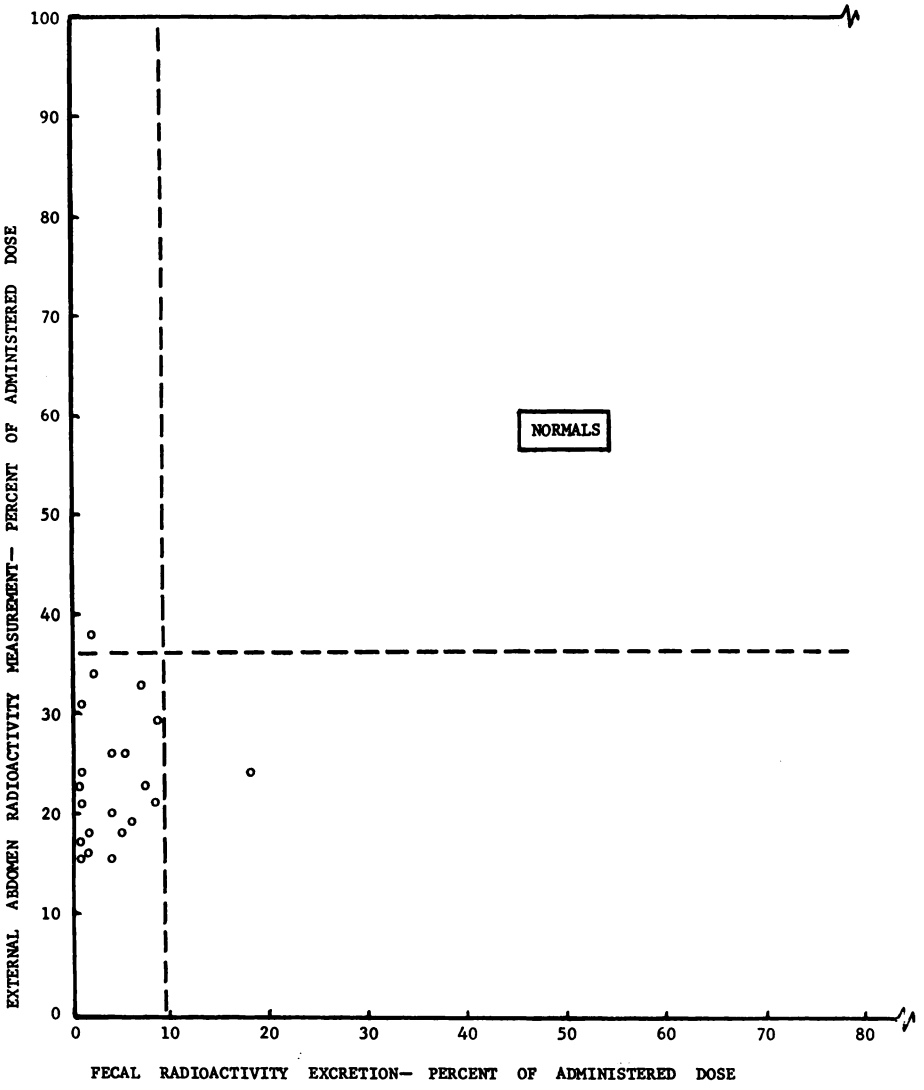


Fig. 2. Results of external abdomen activity measurements and fecal ^{131}I excretion in control subjects. The broken lines indicate Mean + 2 S.D. and are shown in subsequent figures as limits of normal.

E. *Pancreatitis:* Five patients with acute or chronic pancreatitis were studied (Figure 3b). Two of them had normal ^{131}I-triolein fecal excretion and normal external abdomen measurements. One patient had slight elevation of fecal ^{131}I excretion, but an abdomen measurement just within the upper limit of normal, while another, studied during pancreatin treatment of previously-demonstrated steatorrhea, had an elevated external abdomen result of 38 per cent, but a normal fecal excretion test. In one patient both techniques gave distinctly abnormal findings on two occasions, with fecal excretion of 23 and 43 per cent and abdomen results of 57 and 100 per cent (the mean of these two tests for this patient is plotted in Figure 3b).

None of the patients excreted significant radioactivity in stools during the eight-hour test period.

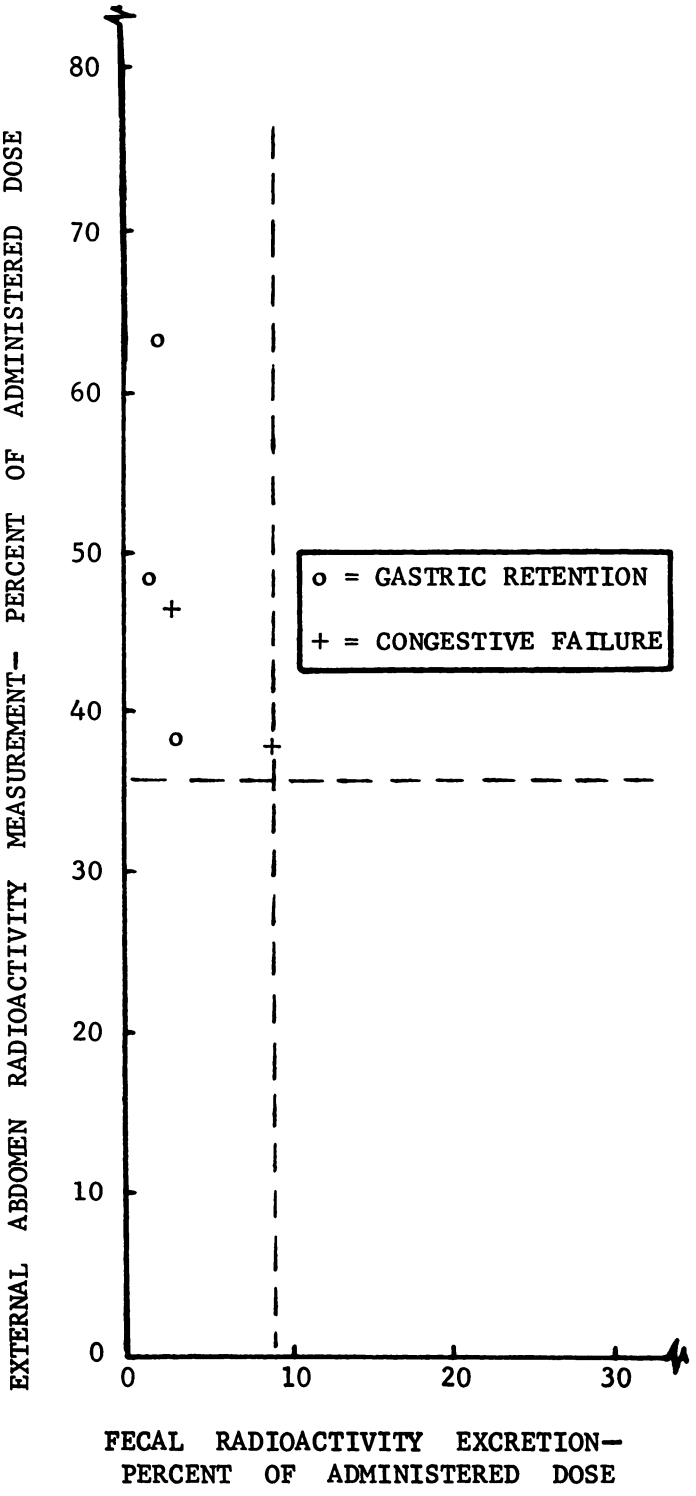
F. *Malabsorption:* Only one patient in this category was available for study. He had had resection of 43 cm. of ileum because of mesenteric vascular occlusion. Two tests were done, with three-day fecal excretion of 37 and 80 per cent and with eight-hour abdomen results of 62 and 74 per cent. Although significant radioactivity was excreted in the stools within eight hours (25 per cent in the first test and 34 per cent in the second), the external abdomen counts themselves (37 per cent and 40 per cent) would have been sufficient to indicate abnormality.

In addition to the ^{131}I-triolein tests done on the groups of patients listed above, twelve ^{131}I-oleic acid absorption tests were done on various subjects selected from the above groups. The relationship between external abdomen results and three-day fecal radioactivity excretion (Figure 4) was similar to that found with ^{131}I-triolein. In three cases there was fecal excretion of radioactivity within the eight-hour test period, but only in one was the quantity (15 per cent) enough to effect interpretation of the test result.

DISCUSSION

This method for detecting steatorrhea has noteworthy practical advantages over fecal excretion measurements. The external abdomen test is completed within one day. Started in the morning, its results can be furnished by the end of the afternoon. The patient is then available for further studies or for appropriate treatment, without waiting several days while collecting stools for analysis. In the method presented here, the only stools that must be saved are any that may be excreted during the eight-hour test period. The short time of stool collection minimizes the degree of intelligent cooperation required of the patient, reducing opportunities for loss of specimens and for urinary contamination (an important source of error in incontinent patients and females). Besides this limited need for stool collection, the only other cooperation demanded of the patient is that he not vomit the test dose.

The validity of this external counting method as a means of estimating intestinal absorption depends upon two assumptions. The first of these is that the isotope is removed from abdominal viscera to other parts of the body after absorption from the intestinal lumen. The second assumption is that radiation from



(A)

Fig. 3A. Discrepancies between external abdomen measurements and fecal excretion tests in patients with gastric retention and congestive failure.

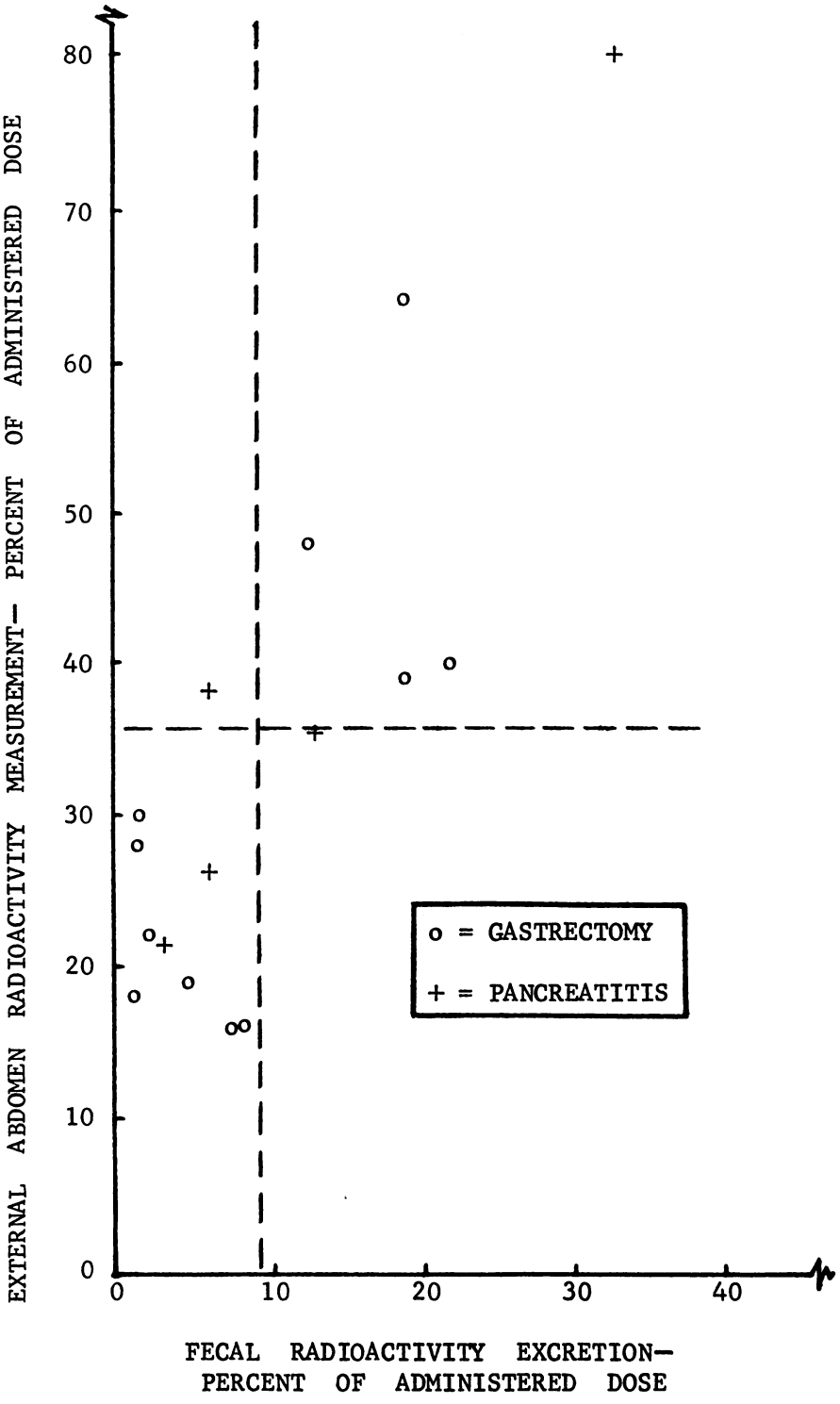
these other areas of the body is excluded from the counter as it measures the activity remaining in the abdomen. The method described here fulfills these two conditions well enough to constitute a clinically useful test. Departure from ideal conformity with these two assumptions is shown by the results in control subjects, where external abdomen counting, though presumably made at a time when all absorption had taken place, detected nearly one-fifth of the administered radioactivity in addition to the amount that was subsequently excreted in feces.

Major factors in this excess of eight-hour abdomen activity over three-day fecal excretion can be appreciated by considering the fate of ^{131}I-triolein after its absorption from the intestinal lumen. During the process of absorption some labeled fat is present in the intestinal mucosa and within lacteals and other abdominal lymph channels. The liver also contains some of the isotope, although less than expected on the basis of normal fat metabolism, because of differences between the metabolism of iodinated fat and dietary triglycerides (6). Peripheral blood six to eight hours after oral administration of ^{131}I-triolein contains two to three per cent of the administered dose of isotope per liter and in mesenteric and portal veins concentrations may be higher. The contents of the abdominal aorta, inferior vena cava and associated vessels, as well as the entire splanchnic vascular bed, thus contribute significantly to the externally measured radioactivity. Some radioactivity is present in kidneys and ureters and in the bladder if there is residual urine. Radioactivity may also be present in adipose tissue and skeletal muscle in the abdominal and lumbar regions (7). These are the various sources of externally measured radioactivity in the abdominal area, in addition to the fraction of labeled fat remaining unabsorbed within the digestive tract.

The collimation of the counter used in this study, as shown in Figure 1, excludes with sufficient effectiveness radiation from extra-abdominal sources. The insignificant effect of activity within the heart, lungs and upper thighs was shown by the studies done with extra shielding over these areas.

The method of external abdomen counting used in this study has received some independent validation from the report of Berkowitz and associates (5). Instead of taking a single count with a sharply collimated detector, they made multiple counts using an open collimator placed close to the abdomen at various sites, so that little extra-abdominal radiation would be detected. In spite of this marked difference in counting geometry, their results agreed closely with ours. In control subjects their findings, which they expressed as "per cent absorbed per hour", indicated an average amount of radioactivity equivalent to 40 per cent of the administered dose remaining in the abdomen after six hours. Our six-hour counts gave similar results.

Two disorders can invalidate this external abdomen counting method for the diagnosis of abnormal fat absorption. One is urinary retention, but there must be a large volume of residual urine before its presence in the bladder can raise the eight-hour external abdomen count significantly. The second and more important disorder is gastric retention, which can make a significant amount of the radioactive fat stay in the stomach even after eight hours. In a patient known by previous x-ray studies to have gastric retention, this external abdomen count-



(B)

Fig. 3B. Correspondence between external abdomen and fecal excretion tests in post-gastrectomy patients and in pancreatic insufficiency.

ing procedure should not be used. Administration of a contrast medium along with the labeled fat in the method outlined above allows an additional check on gastric emptying to guard against unsuspected errors on this basis.

Marked delay in small intestinal transit is unlikely to be a source of error in this test, since conditions that cause severe motility abnormality, such as obstructing regional enteritis, progressive systemic sclerosis, or sprue, also are associated with steatorrhea. With normal small intestinal motility, transit is essentially complete and absorption fully accomplished by seven to eight hours. In every subject in the present study, the decline in radioactivity measurable externally over the abdomen, rapid during the first few hours after oral administration of the labeled fat, leveled off by seven hours. These observations prompted the choice of eight hours as the time of the final count and, within the range of 7½ to 8½ hours, timing was not critical.

Discrepancies between the results of external abdomen radioactivity tests and ^{131}I fecal excretion measurements were encountered in both of the two patients with congestive heart failure included in the present study. Their abnormal abdomen counts may have been false positives, resulting from increased radioactivity within lungs, heart, and splanchnic bed because of increased blood volumes in these areas. On the other hand, in patients with severe cardiac decompensation abnormal fat absorption has been demonstrated both by chemical determinations of stool fat and by ^{131}I fecal excretion tests (8,9). It is possible that the factors implicated in the etiology of this steatorrhea (e.g., impaired pancreatic function, mucosal edema and anoxia, increased lymphatic pressure, and decreased splanchnic blood flow) may, at some stages of congestive heart failure, slow the *rate* of fat absorption and yet not reduce the fraction of ingested fat ultimately absorbed. The discrepancies between fecal excretion of ^{131}I-trilein and external abdomen measurement of absorption may reflect a greater sensitivity of the latter procedure, but further work is required to support this speculation.

No attempt has been made in this study to correlate the results with chemical determinations of fecal fat. Iodine-131-triolein fecal excretion tests have been subjected to much criticism and even have been rejected entirely by some authorities, because of discrepancies between the results of these tests and chemical determinations of the stool fat (10-12). Some of these objections have been strengthened by the demonstration of impurity of commercial ^{131}I-triolein preparations, although the principal investigation of this problem (13) only studied blood radioactivity curves, rather than making the more valid measurements of fecal excretion. It is by no means clear that the impurity of commercially available ^{131}I-triolein is sufficient to invalidate its use for clinical diagnosis. It is also not logically self-evident, as some have assumed, that discrepancies between ^{131}I-triolein fecal excretion tests and chemical determinations of stool fat necessarily indicate the error of the former. Since the two methods involve somewhat different phenomena, i.e., the fate of a single test dose versus the average state over a period of several days, some differences might be expected. The assumed superiority of chemical fecal fat determinations arises simply from the definition of "steatorrhea" as an increase in chemically measured stool fat content. This

accepted but arbitrary definition should not be used as a basis for rejecting the possibility that some patients may have clinically significant disorders of intestinal function that are more clearly detectable by ^{131}I-triolein absorption measurements than by chemical fecal fat determinations. One indication of the limitations of fecal fat determinations is their imperfect correlation with the severity of illness in patients with sprue or pancreatic insufficency (14). Further evidence is given by the reports of patients with gluten-sensitive celiac disease in relapse and normal stool fat measurements (15-18).

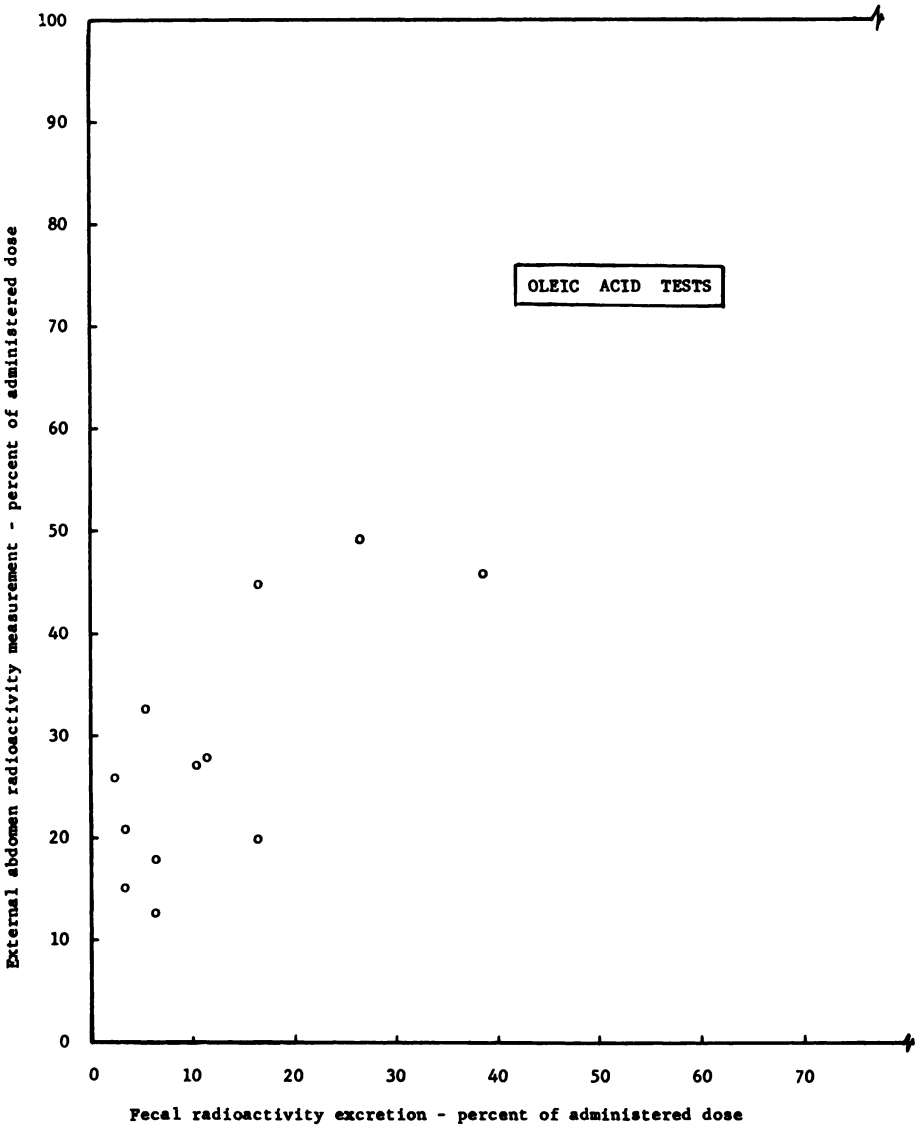


Fig. 4. Relationship between external abdomen and fecal excretion measurements for ^{131}I-oleic acid tests.

SUMMARY

External measurement of radioactivity remaining in the abdomen eight hours after oral administration of ^{131}I-triolein or ^{131}I-oleic acid offers a rapid method for detecting abnormal fat absorption. With counter collimation and geometry as described in this study, eight-hour external abdomen radioactivity counts in 21 subjects with normal digestion and absorption averaged 23.3 per cent of the administered dose (standard deviation 6.6 per cent). In 21 patients with various abnormalities of gastrointestinal function, the results of the external abdomen absorption measurements were correlated with the clinical status and with fecal radioactivity measurement of ^{131}I labeled fat absorption.

The experiences of this study indicate that this method can detect abnormal fat absorption rapidly. Because the test can be completed in one day, the need for cooperation by the patient is minimized. A normal dietary intake is not required, and stool specimens are saved only during the eight-hour test period. Patients with gastric retention or marked urinary retention are not suitable for this test, however.

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