ABSORPTION AND SECRETION OF IODIDE BY THE INTESTINE OF THE RAT[1]

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THE study of the absorption of iodide by the intestinal tract was initiated by Cohn (1), who showed that iodide was well absorbed by the ileum, jejunum and colon of the dog, and poorly by the stomach. Albert *et al.* (2) found that the rat also absorbed iodide well from the small and large bowel and only slightly from the stomach. Pearlman, Morton and Chaikoff (3) demonstrated in the rat that the tissue of the entire small intestine accumulated at the end of one hour 0.6% of the I^{131} administered into the stomach. The studies of Johnson and Albert (4) revealed I^{131} in the contents of the small intestine of the rat in significant concentrations, but they did not establish whether it was gastric iodide being passed down the intestinal tract or actively secreted at that site. Furthermore, Honour *et al.* (5) concluded that while the iodide concentration of stomach secretions was thirty times that of plasma, the iodide concentration of duodenal secretions was approximately equal to that of plasma.

Bearing in mind the demonstration by Kremin *et al.* (6) that removal of the distal but not the proximal one-half of the small bowel of the dog greatly interfered with fat absorption, a further investigation of the absorption and secretion of iodide by various segments of the intestinal tract was undertaken.

EXPERIMENTAL

Male albino rats weighing 200–300 gm. were used in this study. Each animal was anesthetized with pentobarbital, the abdominal cavity was opened, the bile duct was tied, and ties were placed around the intestines dividing the small intestine into five or six separate segments (consecutively numbered 1 to 5 or 6) and the large intestine into cecum and two other segments. The ties were placed so as to interfere with blood supply as little as possible. One microcurie of I^{131} in 0.1 cc. was injected into the lumen of each bowel segment. The dose of I^{131} when given subcutaneously was 50–80 μc. In some animals sodium perchlorate was injected subcutaneously 30 minutes before the bowel was tied. Those animals receiving propylthiouracil were injected subcutaneously 90 minutes before the bowel was tied. One hour after the tracer was injected the animals were sacrificed and the unopened bowel segments removed, placed in paper cups and

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counted at a distance of 22 cm. from a scintillation crystal. The bowel segments were then weighed with their contents. In a number of animals the small intestines were washed free of their contents with 50 cc. of saline that was injected through the pylorus and allowed to run out through an incision in the terminal ileum. The remaining saline was milked out. The bowel was then ligated and I^{131} injected subcutaneously. After the segments were weighed and counted, they were opened, washed free of accumulated secretions, blotted, reweighed, and recounted.

RESULTS

To establish the ability of various isolated intestinal segments to absorb iodide, I^{131} was injected into their lumina. Table 1 shows the percentage of the injected dose remaining in each segment after one hour. In two segments iodide was slowly removed. One of these was just beyond the middle of the small intestine, and the other was the cecum. The other areas absorbed iodide quite rapidly.

TABLE 1. THE PER CENT OF ADMINISTERED DOSE OF I^{131} LEFT IN THE INTESTINAL SEGMENTS AT THE END OF ONE HOUR. THE RANGE OF VALUES OF EACH SEGMENT IS FOR THREE RATS

Duodenum	Small intestine				Cecum	Colon	
1	2	3	4	5	6	7	8
8–13	9–36	16–27	74–86	33–40	48–84	16–25	13–16

TABLE 2. THE AMOUNT OF I^{131} ACCUMULATED IN ISOLATED INTESTINAL SEGMENTS AND THE EFFECT OF 10 MG. OF SODIUM PERCHLORATE ON THIS ACCUMULATION. UNITS ARE THE FRACTIONAL RADIOACTIVITY ACCUMULATED IN EACH SEGMENT DIVIDED BY THE FRACTIONAL WEIGHT OF EACH SEGMENT[1]

Drug	No. rats	Duodenum	Small intestine					Cecum	Colon	
		1	2	3	4	5	6	7	8	9
A. ———	8	1.75	0.93	1.73	2.30 ± .222*	1.05	.53	.40	.77	.71
B. perchlorate	6	1.66	1.42	.89	1.36 ± .200*	.97	.88	.72	1.58	1.08

* = S.E. of mean (reported only where a significant difference existed).
[1] See text footnote 2.

To measure the rate of secretion of iodide by various segments of the intestine, radioiodine was injected subcutaneously after the ligatures had been placed. The values were expressed as the fractional radioactivity accumulated in each segment divided by the fractional weight of each segment.[1] Thus if the secretion of each segment were the same, each value would equal one. Table 2 shows that the accumulation of iodide was most rapid near the center of the small intestine and also quite rapid in the duodenum. The accumulation in the cecum, on the other hand, was slow.

The administration of sodium perchlorate prior to the injection of I^{131}

[2] $$\frac{\text{Radioactivity in segment}}{\text{Total radioactivity in bowel}} \div \frac{\text{Weight of segment}}{\text{Total weight of bowel}}$$

TABLE 3. THE RATIO OF THE CONCENTRATION OF I^{131} IN ONE GRAM OF INTESTINAL SECRETIONS (S) AND INTESTINAL TISSUE (I) TO THE CONCENTRATION OF I^{131} IN ONE CC. OF PLASMA (P). VALUES ARE THE MEAN VALUES OF 5 RATS

Small intestinal segment	1	2	3	4	5
S/P	.85 ± .13*	1.84 ± .68*	8.60 ± 2.22*	4.74 ± 1.55*	1.98 ± .89*
I/P	.35 ± .045*	.44 ± .067*	.85 ± .155*	.53 ± .099*	.25 ± .032*

* = S.E. of mean.

caused the accumulation of I^{131} by the central segment of the small intestine to fall to about three-fifths of the control value. This is shown by Table 2. In this type of experiment perchlorate had no demonstrable effect on reducing accumulation of iodide by any other of the intestinal segments.

In order to measure the concentration of iodide in intestinal secretions uncontaminated by food, the small intestines were washed out with saline, the saline milked out and the ligatures placed. I^{131} was then injected subcutaneously, and one hour later the weight of each segment, the weight of its secretions, the radioactivity of the secretions, and the radioactivity of the intestinal wall were determined. In addition, the radioactivity of plasma samples was obtained. That iodide was actually secreted into the lumen of the small intestine and secreted by the central segments in concentrations in excess of that of plasma is shown by Table 3. The secretion of I^{131} by segment 3 (reflected in the S/P ratio) was significantly greater than that of segments 1, 2, and 5. Furthermore, the accumulation of I^{131} in the wall of segment 3 (reflected in the I/P ratio) was significantly greater than that of segments 1, 2, and 5.

Finally, 5 mg. of propylthiouracil was given to inhibit organic binding of iodide. A comparison of the data of Tables 3 and 4 shows that it had no significant effect on iodide secretion by the small intestine. Perchlorate reduced the entry of iodide into the lumen of all the segments to a uniform level, and also lowered the amount of iodide accumulated in the wall of these segments to a uniform level.

TABLE 4. THE RATIO OF THE AMOUNT OF I^{131} IN ONE GRAM OF INTESTINAL SECRETIONS (S) AND INTESTINAL TISSUE (I) TO THE AMOUNT OF I^{131} IN ONE CC. OF PLASMA (P) IN ANIMALS PRETREATED WITH PROPYLTHIOURACIL, WITH THE EFFECT OF SODIUM PERCHLORATE ON THIS RATIO

	Drug	No. rats	Small intestinal segment				
			1	2	3	4	5
S/P	—	5	1.08 ± .17*	2.39 ± 1.21	5.12 ± .74	2.44 ± .57	1.34 ± .29
S/P	$NaClO_4$	6	.64 ± .07	.66 ± .07	.76 ± .11	.68 ± .12	.55 ± .09
I/P	—	5	.31 ± .03	.99 ± .26	1.81 ± .40	.77 ± .20	.52 ± .10
I/P	$NaClO_4$	6	.21 ± .03	.24 ± .05	.19 ± .02	.16 ± .02	.19 ± .02

* = S.E. of mean.

DISCUSSION

Iodide was not uniformly absorbed by the small and large intestine, but was relatively poorly absorbed in the middle of the small intestine and in the cecum. This effect was apparently masked by the rapid uptake of nearby intestinal tissue in the earlier study of Albert *et al.* (2).

The ability of the mid-portion of the small intestine to secrete iodide is shown by Table 2. This portion behaves like the stomach which absorbs iodide poorly although it secretes it rapidly (1, 2). Clearly the cecum does not fit this pattern, since it secretes iodide as poorly as it absorbs it. This poor absorption may be due to poor mixing of the bulky cecal contents as the cecum had little observable motility. The ability to secrete iodide tapered off on each side of the middle segment of the small intestine.

The data of Table 3 show that the accumulation of iodide in isolated intestinal segments had two components. Although most of the iodide was secreted into the lumen of the intestine, a small amount remained in the intestinal wall. That segment which had the greatest secretory ability also had the largest amount of iodide in its wall.

Perchlorate has been shown to be a potent inhibitor of the iodide-concentrating mechanism of the thyroid (7), salivary glands in man (8) and stomach (9). Perchlorate also inhibits the iodide-concentrating mechanism of the small intestine, reducing the iodide transport of not only the central segments but all segments to a uniform level. This was not shown by the data in Table 2 because of the variations in weight produced by varying amounts of feces in the bowel segments. The entry of iodide into the intestine after the administration of perchlorate can be accounted for on the basis of diffusion.

It has been demonstrated in man that 15 to 20% of Meckel's diverticula have areas of ectopic gastric mucosa (10). Since these areas secrete acid and behave as gastric mucosa, it would seem reasonable that they might secrete iodide. However, no evidence of a Meckel's diverticulum in the rat could be found. Histological sections of this new iodide secretory site were prepared, but no difference in structure from other sites could be found with a hematoxylin and eosin stain.

SUMMARY

The ability of the rat intestine to absorb and secrete iodide has been studied. It has been shown that not only does the mid-portion of the small intestine absorb iodide poorly, but it also secretes it rapidly. This is accomplished by a specific secretory mechanism that is possessed to a lesser extent by the rest of the small intestine and is similar to that already described for stomach and thyroid and salivary glands of man.

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