Effect of vagotomy on intraluminal digestion of fat in man

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EDITORIAL SYNOPSIS The diminished amounts of bile acids and lipase found in the intestinal lumen after vagotomy may lead to a reduced absorption of fat by altering the formation of the micellar phase of fat digestion and absorption.

Vagotomy combined with either pyloroplasty or gastrojejunostomy is now widely used in the surgical treatment of duodenal ulcer. It has been claimed that these operations avoid some of the undesirable nutritional after-effects of partial gastrectomy which was formerly the operation of choice. However, vagotomy plus a drainage procedure has been followed by some looseness of the bowels and spells of diarrhoea which may be incapacitating. Opinions are widely divided on the incidence and severity of this complaint. Another disorder which sometimes follows vagotomy is a small rise in faecal fat excretion. The effect of vagal denervation on various aspects of human alimentary function, especially lipid digestion, is not clearly defined. This paper reports an investigation of the effects of vagotomy on the digestion and absorption of lipids in man. The changes shown following total abdominal vagotomy are less frequent with pyloroplasty than when gastrojejunostomy is the drainage procedure.

MATERIAL AND METHODS

Thirty-two patients with chronic duodenal ulceration were tested after vagotomy, 12 after vagotomy and gastrojejunostomy and 20 after vagotomy and pyloroplasty. Total abdominal vagotomy had been performed. An insulin test was carried out to prove the completeness of the vagal dissection in 20 patients. The 20 normal subjects tested were hospital patients who had no gastrointestinal disorder. The patients and the normal subjects were all aged between 30 and 60 years, except for two normal subjects aged 19 and 71.

INTESTINAL INTUBATION AND SAMPLING OF INTESTINAL CONTENTS The method of intestinal intubation introduced by Blankenhorn, Hirsch, and Ahrens (1955) was used. A long narrow polythene tube, 2 mm. in external diameter with a small bag containing 2 to 3 ml. mercury

at its tip, was allowed to pass through the stomach and intestine. Samples were collected from four intestinal levels, the length of tubing being measured from the tip of the nose to the duodenum, 0.6 to 1.0 m.; the proximal jejunum, 1.1 to 1.5 m.; the distal jejunum, 1.6 to 2.0 m., and the proximal ileum 2.1 to 2.5 m. Twenty-four tests were performed in normal subjects, 24 tests in patients after vagotomy and pyloroplasty, and 28 tests in patients after vagotomy and gastrojejunostomy. The post-operative tests were performed 10 to 14 days after the operation. Thirteen additional tests were performed in patients after vagotomy and pyloroplasty, the tip of the tube being placed in the stomach. In most tests, the tube was left in position for three to four days to allow sampling from different intestinal levels. The samples were obtained by continuous suction at 8 to 9 cm. of mercury pressure and were collected on ice for four 30-minute periods after giving the test meal.

TEST MEAL After being starved for 12 hours, each subject drank 300 ml. of a well-homogenized test meal described by Ahrens, Dole, and Blankenhorn (1954) and consisting of a balanced liquid formula of the following composition.

Corn oil	74 g.
Skimmed milk powder	126 g.
Dextrose	138 g.
Polyethylene glycol	5 g.
Water	1,000 ml.

The non-absorbable substance polyethylene glycol (molecular weight 4,000) was used as an indicator in the test meal. This substance has been found neither to be digested nor to be absorbed in the intestine, and by knowing its composition in the test meal and by measuring its composition in each sample, it was possible to get some information about the dilution of the test meal and the absorption of the fat. The concentration of polyethylene glycol in the test meal was 0.43% and that of corn oil 17 mg. per ml. About 90% of the corn oil was in the form of glycerides.

ESTIMATIONS Pancreatic lipase activity and the concentrations of bile acids, polyethylene glycol, total fat and

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its composition and pH were estimated on each sample. The lipolytic activity was assessed by the method of Sammons, Frazer, and Thompson (1956). The bile acids were estimated by a modification of the method of Charbrol, Charonnet, Cottet, and Blonde (1934). The non-phospholipid fat was extracted and purified by the method of Folch, Lees, and Sloane Stanley (1957), using chloroform: methanol 2 : 1 as a solvent system. The dry residue of lipids was extracted with hexane and was separated to cholesterol ester, triglycerides, diglycerides, monoglycerides, and free fatty acids on a column of florasil (Carroll, 1961). After dilution the solvents were evaporated to dryness and the lipid residues were weighed. Determination of polyethylene glycol in intestinal samples was carried out by the turbidometric method described by Hyden (1956). Knowing the concentration of fat and polyethylene glycol in the test meal and in the intestinal contents, the ratio between the two values was calculated and the percentage of fat absorbed was deduced.

The amount of taurine and glycine conjugates of the bile acids was calculated assuming that they are present in a 3 : 1 ratio (Sjövall, 1959). Then the amount of monoglyceride which could be rendered soluble by the quantity of conjugates was obtained from the data of Hofmann (1963). The values in normal subjects were compared with those in patients after vagotomy and a drainage procedure.

SEPARATION OF INTESTINAL CONTENT INTO OILY AND MICELLAR PHASES Twelve intestinal samples were obtained from the proximal jejunum of normal subjects and 12 samples from the same intestinal level in patients after vagotomy and pyloroplasty. The usual test meal was given and the samples obtained as described above. After removing an aliquot for estimation of pancreatic lipase, the sample was heated at 70°C. for 10 minutes to destroy lipase activity. Thereafter, further aliquots of each sample were taken to estimate total fat, bile con-

centration, and polyethylene glycol. The remainder was centrifuged for two and a half hours at 2,500 g. At the end of this period the bottom of the tube contained a thick pellet and the top a layer of tiny oily droplets. The remaining volume was occupied by a solution which was sometimes clear and sometimes turbid. The concentration of bile acids, the content of total fat, and its hydrolytic products were estimated in both the total sample and the remaining volume using the methods detailed above. The remaining volume was taken to be the 'micellar' phase.

RESULTS

INTESTINAL INTUBATION Little difficulty was experienced in the passage of the fine polythene tube through the intestine, except in the case of patients after vagotomy and pyloroplasty. In these patients the tube often remained in the stomach for as long as two to three days. Once in the intestine, the samples flowed freely in the duodenum and in the upper jejunum but in the distal jejunum and proximal ileum samples were frequently scanty and often intestinal content did not flow freely until between one and two hours after the meal.

INTESTINAL CONTENT The detailed results of the estimations are laid out in Tables I-III.

Bile acids In the normal subjects a high concentration of bile acids occurred in the first half hour following the test meal. The levels reached were 3.1 mg. per ml. in the duodenum, 2.6 mg. per ml. in the proximal jejunum, and 3.3 mg. per ml. in the distal jejunum. The concentration rapidly decreased and remained between 1 and 3 mg. per ml. during the remainder of the test. In patients

TABLE I
MEAN VALUES $\pm$ STANDARD ERROR OF MEAN FOR ANALYSIS OF INTESTINAL CONTENT
OBTAINED VIA A LONG INTESTINAL TUBE IN FOUR 30-MINUTE PERIODS AFTER THE INGESTION
OF A TEST MEAL CONTAINING FAT AT FOUR INTESTINAL LEVELS IN NORMAL SUBJECTS

Intestinal Level	Time after Meal (min.)	No. of Tests	pH	Lipase (units)	Bile Acids (mg./ml.)	Total Fat (mg./ml.)	Poly-ethylene Glycol (%)	Fat Absorption (%)	Fractionation of Total Fat					Cholesterol (%)	Cholesterol Ester (%)
									Free Fatty Acid (%)	Mono-glyceride (%)	Di-glyceride (%)	Tri-glyceride (%)			
Duodenum	30	5	6.6	40.0±3.9	3.1±0.7	17.7±2.6	21.4±3.1	5.3±2.8	45.9±5.9	22.0±6.4	4.8±1.7	15.1±3.2	8.3±1.1	2.5±0.7	
	60	5	6.6	42.5±3.5	1.7±0.2	12.8±2.5	42.9±12.4	45.7±16.5	45.1±5.6	23.7±4.5	9.7±5.5	15.4±4.0	7.0±1.5	2.5±1.0	
	90	5	6.2	38.0±3.2	1.3±0.2	13.9±3.4	47.9±8.9	53.6±14.6	45.5±8.8	15.9±4.1	9.3±4.5	19.8±4.3	7.2±1.6	2.4±1.1	
	120	5	6.0	36.8±4.6	1.3±0.2	11.0±1.8	46.7±10.9	56.2±8.6	48.1±5.4	18.8±4.0	8.4±3.0	19.1±2.7	7.4±2.2	2.5±1.0	
Proximal jejunum	30	6	6.6	42.2±7.1	2.6±0.6	13.5±2.4	26.7±2.6	18.2±6.3	53.3±4.2	19.4±4.4	3.3±0.5	10.6±2.7	7.3±1.4	3.4±2.4	
	60	7	6.4	42.4±5.4	1.8±0.2	9.8±1.5	37.9±4.7	58.2±10.5	52.2±2.9	18.9±3.1	6.5±2.8	9.7±1.7	7.9±0.7	4.6±2.9	
	90	7	6.0	41.5±5.4	1.4±0.2	11.1±2.5	45.0±5.7	61.1±8.8	50.4±5.0	16.4±2.7	5.9±1.9	14.9±3.9	7.8±1.7	7.0±4.6	
	120	7	6.1	40.2±4.5	1.3±0.2	10.8±2.8	28.8±6.2	34.3±11.3	44.2±10.7	13.2±2.4	5.8±1.4	22.5±6.7	8.4±2.0	4.3±6.7	
Distal jejunum	30	6	6.8	33.3±4.9	3.3±0.7	8.8±1.4	29.6±3.1	36.0±14.9	52.5±4.2	16.7±4.2	4.1±0.2	14.4±3.0	10.5±1.7	3.2±1.0	
	60	6	6.7	35.9±4.3	2.3±0.2	7.9±2.0	69.6±8.7	78.4±5.6	50.7±3.5	21.1±4.8	6.1±1.5	11.8±2.4	9.1±0.8	3.1±1.2	
	90	6	6.6	39.8±5.2	1.9±0.2	5.6±1.0	75.3±5.6	89.0±3.5	54.5±5.0	11.2±1.9	4.2±0.7	13.2±2.4	8.3±0.6	4.0±4.3	
	120	6	6.5	38.3±4.6	1.8±0.2	10.9±2.6	69.8±8.9	71.8±8.9	48.2±3.7	21.9±3.2	4.9±1.0	13.1±2.7	7.9±1.4	1.9±0.5	
Proximal ileum	30	6	7.0	25.0±4.0	1.5±0.5	4.3±1.1	14.2±3.6	49.8±11.4	68.0±4.4	6.6±1.5	3.2±0.3	11.0±2.2	11.6±0.9	1.6±0.2	
	60	6	7.0	36.6±4.0	2.4±0.6	6.2±1.0	66.8±10.6	79.4±10.4	62.1±5.3	10.9±2.9	2.9±0.3	10.7±1.9	12.0±1.7	2.8±0.8	
	90	6	7.0	31.6±4.9	2.0±0.2	3.7±1.7	89.9±4.2	93.3±0.7	61.3±5.0	11.3±3.2	3.2±1.1	10.1±1.8	11.7±2.1	3.6±1.8	
	120	6	6.8	28.9±6.0	1.8±0.2	5.8±1.5	81.3±1.1	88.6±0.9	56.2±3.9	10.4±2.6	5.8±1.3	15.3±1.8	10.7±0.6	2.3±0.4	

TABLE II

MEAN VALUES $\pm$ STANDARD ERROR OF MEAN FOR ANALYSIS OF INTESTINAL CONTENT OBTAINED VIA A LONG INTESTINAL TUBE IN FOUR 30-MINUTE PERIODS AFTER THE INGESTION OF A TEST MEAL CONTAINING FAT AT FOUR INTESTINAL LEVELS IN PATIENTS AFTER VAGOTOMY AND PYLOROPLASTY

Intestinal Level	Time after Meal (min.)	No. of Tests	pH	Lipase (units)	Bile Acids (mg./ml.)	Total Fat (mg./ml.)	Poly-ethylene Glycol (%)	Fat Absorption (%)	Fractionation of Total Fat					
									Free Fatty Acid (%)	Mono-glyceride (%)	Di-glyceride (%)	Tri-glyceride (%)	Cholesterol (%)	Cholesterol Ester (%)
Duodenum	30	8	6.5	19.9±3.7 ₃	1.2±0.5	14.7±3.0	20.4±4.9	8.6±5.0	42.7±4.6	17.5±3.8	7.4±1.9	20.8±3.7	9.6±2.4	1.4±0.4
	60	8	6.7	21.8±3.5 ₃	1.2±0.3	14.7±2.1	31.5±2.6	36.0±7.8	49.0±4.4	19.2±4.5	6.6±1.4	13.6±1.8	9.6±1.2	1.7±0.4
	90	6	6.8	27.0±4.6	2.7±1.0	6.2±0.9 ₂	22.4±3.2	57.8±5.2	61.8±6.4	17.2±4.0	6.6±2.7	9.6±1.9 ₁	6.9±1.4	3.5±0.8
Proximal jejunum	120	6	6.9	31.9±6.1	1.0±0.1	9.5±2.3	27.6±5.9	42.1±10.1	53.8±8.2	17.3±5.4	5.0±1.6	14.0±3.1	6.9±1.4	3.1±1.2
	30	7	6.7	15.5±3.2 ₃	1.1±0.3	16.8±4.2	24.4±3.9	19.4±9.8	48.7±5.9	15.9±3.2	8.4±1.9	14.9±3.9	12.5±1.9	0.2±0.01
	60	7	7.0	26.4±3.3 ₁	1.6±0.3	14.6±3.8	46.4±8.1	60.4±8.2	58.8±5.5	16.1±3.8	6.4±2.0 ₁	10.4±1.8	7.1±1.2	1.7±0.6
	90	4	7.2	28.7±6.6 ₁	1.1±0.3	6.2±0.4	38.4±7.3	70.7±9.2	64.6±5.1	11.7±4.2	3.3±1.4	10.0±1.8	6.9±1.3	2.1±0.7
	120	5	7.1	25.1±3.8 ₁	1.3±0.3	7.4±2.1	38.1±4.9	68.1±14.0	64.6±9.0	11.6±5.8	4.0±2.3	9.3±2.6	7.6±1.1	1.3±0.3
Distal jejunum	30	3	6.6	17.7±6.4	0.9±0.4	17.7±6.5	28.8±10.9	28.3±17.2	51.6±10.8	9.8±3.3	6.6±2.2	19.1±4.0	11.7±3.8	2.0±0.1
	60	3	6.8	18.3±6.6 ₁	1.0±0.6	8.6±3.4	28.1±18.6	39.9±21.1	62.7±0.6	4.2±1.4 ₃	3.3±0.5	19.7±4.3	8.7±5.7	1.2±0.9
	90	3	6.8	16.3±1.6 ₂	1.6±0.5	4.2±0.6	32.0±10.7 ₃	78.5±5.9 ₁	65.8±9.9	5.4±3.1	2.4±0.7	14.2±5.9	9.6±2.6	2.3±1.8
	120	2	6.8	12.2±7.7 ₂	1.7±1.5	3.9±2.6	22.1±10.2 ₃	61.4±32.9	50.0±5.0	3.7±1.4 ₂	11.3±9.0	15.1±4.9	14.1±3.9	3.5±1.5
Proximal ileum	30	6	6.1	9.5±1.9 ₃	0.8±0.2	12.3±2.2	18.5±5.0	11.2±9.7	37.3±5.5	13.6±2.8	8.0±1.7 ₂	25.9±7.9	11.3±3.1	1.7±1.0
	60	4	6.5	18.1±3.7 ₂	1.3±0.4	13.1±1.4 ₃	45.6±13.3	48.6±16.6	55.2±8.5	8.6±2.7	5.2±1.6	20.5±2.9 ₁	7.5±2.1	1.6±0.4
	90	3	6.4	24.1±9.9 ₂	1.2±0.2	17.1±11.2	49.8±5.6 ₄	53.7±26.7	44.1±9.6	14.1±5.3	8.1±3.3	20.6±1.3 ₃	11.0±2.6	1.1±0.2
	120	3	6.8	26.6±4.3	1.2±0.4	13.5±6.0	37.2±7.2	48.3±25.5	49.9±10.3	13.0±5.8	4.9±2.1	19.7±5.2	10.9±2.8	1.1±0.4

The subscripts indicate values which are significantly different from normal as follows: ₁, $P < 0.05$ ₂, $P < 0.02$ ₃, $P < 0.01$ ₄, $P < 0.001$

after vagotomy and pyloroplasty, the peak level was 2.7 mg. per ml. in the duodenum and was only reached after one and a half hours. A similar delay in reaching the peak level was seen in the proximal jejunum where the level was 16 mg. per ml. after one and a half hours. A significant decrease in the concentration of bile acids compared with the normal was seen in the proximal three intestinal levels (Table II). After vagotomy and gastrojejunostomy, a lowered concentration of bile acids was found at all intestinal levels. The difference from normal was significant at some time intervals at all levels (Table III). The peak concentration of bile acids was again reached later than in the normal subjects and was in all cases less than 2 mg. per ml.

Lipase High lipase activity was found in all intestinal samples within 30 minutes of giving the test meal in the normal subjects. This high activity was maintained for the two hours, the values ranging from 42.5 units in the duodenum to 25 units in the proximal ileum. After vagotomy and pyloroplasty a lowered lipase activity was observed at all intestinal levels. The difference from normal was significant at some time intervals in the duo-

denum, jejunum, and ileum (Table III). The peak level of activity of the enzyme was reached during the second hour of the test, that is, slightly later than normal. After vagotomy and gastrojejunostomy, a similar pattern was seen in that a low activity of lipase and a delay in reaching the peak level was found in all intestinal samples. The difference from normal was again significant at some time intervals at all intestinal levels (Table III).

Total fat In the normal subjects, a slow, constant decrease in concentration of total fat was seen from 17.7 mg. per ml. in the first sample in the duodenum to 5.8 mg. per ml. in the last sample in the ileum. A significant increase in the concentration of fat was found in the distal intestine, especially the proximal ileum, in the first hour of the test in patients after vagotomy and pyloroplasty, in contrast to the normal subjects in whom the highest concentration of fat was in the upper parts of the small intestine (Tables I and II). After vagotomy and gastrojejunostomy, a similar increase of total fat was noted in the distal jejunum during the first hour of the test and during the first 90 minutes in the proximal ileum (Table III).

TABLE III
MEAN VALUES $\pm$ STANDARD ERROR OF MEAN FOR ANALYSIS OF INTESTINAL CONTENT
OBTAINED VIA A LONG INTESTINAL TUBE IN FOUR 30-MINUTE PERIODS AFTER THE INGESTION OF
A TEST MEAL CONTAINING FAT AT FOUR INTESTINAL LEVELS IN PATIENTS AFTER VAGOTOMY
AND GASTROJEJUNOSTOMY

Intestinal Level	Time after Meal (min.)	No. of Tests	pH	Lipase (units)	Bile Acids (mg./ml.)	Total Fat (mg./ml.)	Poly-ethylene Glycol (%)	Fat Absorption (%)	Fractionation of Total Fat						Cholesterol (%)	Cholesterol Ester (%)
									Free Fatty Acid (%)	Mono-glyceride (%)	Di-glyceride (%)	Tri-glyceride (%)				
Duodenum	30	12	6.4	15.4 $\pm$ 2.2 ₄	1.2 $\pm$ 0.2 ₃	17.1 $\pm$ 3.4	19.0 $\pm$ 6.1	4.7 $\pm$ 2.5	39.8 $\pm$ 5.2	15.7 $\pm$ 2.0	7.9 $\pm$ 1.4	22.9 $\pm$ 4.9	9.9 $\pm$ 4.4	2.7 $\pm$ 0.9		
	60	12	6.7	27.8 $\pm$ 2.1 ₃	1.6 $\pm$ 0.3	17.6 $\pm$ 4.6	21.9 $\pm$ 6.8	19.8 $\pm$ 7.7	43.4 $\pm$ 5.1	12.1 $\pm$ 1.6	7.3 $\pm$ 0.8	19.6 $\pm$ 3.3	11.7 $\pm$ 1.9	3.7 $\pm$ 0.9		
	90	11	6.8	20.3 $\pm$ 2.2 ₄	1.4 $\pm$ 0.2	7.9 $\pm$ 1.5	18.8 $\pm$ 5.5 ₂	17.8 $\pm$ 7.8 ₁	47.1 $\pm$ 4.4	13.2 $\pm$ 2.5	9.0 $\pm$ 1.7	14.0 $\pm$ 3.1	8.2 $\pm$ 1.3	4.3 $\pm$ 1.4		
	120	10	6.5	18.9 $\pm$ 3.8 ₂	1.3 $\pm$ 0.2	8.0 $\pm$ 2.6	12.7 $\pm$ 5.9 ₂	30.4 $\pm$ 10.5	50.4 $\pm$ 6.2	11.7 $\pm$ 2.3	9.0 $\pm$ 2.2	21.4 $\pm$ 3.7	7.8 $\pm$ 2.1	4.5 $\pm$ 1.3		
Proximal jejunum	30	5	6.5	7.9 $\pm$ 2.5 ₃	0.7 $\pm$ 0.1 ₂	10.6 $\pm$ 4.3	13.0 $\pm$ 6.6	12.7 $\pm$ 12.7	44.9 $\pm$ 3.2	13.9 $\pm$ 3.4	5.1 $\pm$ 1.7	21.6 $\pm$ 6.3	11.9 $\pm$ 3.2	1.8 $\pm$ 0.8		
	60	5	6.9	20.0 $\pm$ 4.4 ₂	0.7 $\pm$ 0.2 ₂	11.9 $\pm$ 3.6	32.2 $\pm$ 7.5	45.1 $\pm$ 8.2	45.2 $\pm$ 10.1	19.7 $\pm$ 4.3	5.9 $\pm$ 2.4	18.3 $\pm$ 7.8	9.2 $\pm$ 2.7	1.0 $\pm$ 0.1		
	90	5	7.2	30.3 $\pm$ 6.3	1.3 $\pm$ 0.4	5.2 $\pm$ 1.4	30.2 $\pm$ 16.4	37.1 $\pm$ 21.3	56.1 $\pm$ 6.6	13.8 $\pm$ 3.8	5.9 $\pm$ 0.8	11.9 $\pm$ 2.0	9.4 $\pm$ 1.6	2.8 $\pm$ 0.5		
	120	6	7.3	24.6 $\pm$ 3.1 ₂	0.8 $\pm$ 0.2	4.2 $\pm$ 0.8	31.3 $\pm$ 13.7	45.5 $\pm$ 13.4	54.2 $\pm$ 8.2	14.1 $\pm$ 4.5	5.4 $\pm$ 2.2	11.1 $\pm$ 1.7	8.9 $\pm$ 1.5	4.3 $\pm$ 1.0		
Distal jejunum	30	5	6.5	12.5 $\pm$ 2.5 ₃	0.9 $\pm$ 0.2 ₂	17.8 $\pm$ 3.8 ₁	21.6 $\pm$ 45.8	0 $\pm$ 0	33.6 $\pm$ 3.3 ₃	25.6 $\pm$ 1.9	8.4 $\pm$ 2.4	17.5 $\pm$ 1.2	16.3 $\pm$ 1.7	1.3 $\pm$ 0.1		
	60	5	7.0	19.9 $\pm$ 5.3 ₁	0.8 $\pm$ 0.2 ₃	19.5 $\pm$ 3.7 ₁	41.6 $\pm$ 7.3	30.3 $\pm$ 8.9	37.4 $\pm$ 4.5	25.3 $\pm$ 3.5	6.1 $\pm$ 1.1	15.9 $\pm$ 1.6	11.5 $\pm$ 2.3	1.7 $\pm$ 0.5		
	90	5	7.3	28.5 $\pm$ 5.5	1.8 $\pm$ 0.5	6.3 $\pm$ 1.8	45.9 $\pm$ 3.5 ₃	77.9 $\pm$ 5.8	38.4 $\pm$ 8.4	25.3 $\pm$ 6.7	6.2 $\pm$ 3.4	23.6 $\pm$ 12.5	7.8 $\pm$ 1.2	1.8 $\pm$ 0.9		
	120	3	7.7	16.7 $\pm$ 6.4 ₁	1.8 $\pm$ 0.6	2.64 $\pm$ 0.5	16.3 $\pm$ 10.8	57.3 $\pm$ 28.6	62.6 $\pm$ 7.4	10.7 $\pm$ 1.3	4.0 $\pm$ 0.1	15.3 $\pm$ 2.3	8.5 $\pm$ 1.5	3.0 $\pm$ 1.0		
Proximal ileum	30	5	6.9	10.1 $\pm$ 1.3 ₂	0.9 $\pm$ 0.2	15.7 $\pm$ 4.7 ₁	22.1 $\pm$ 7.4	7.9 $\pm$ 2.3 ₃	40.3 $\pm$ 10.3 ₃	19.9 $\pm$ 6.9	4.7 $\pm$ 0.9	14.3 $\pm$ 5.8	11.6 $\pm$ 1.1	3.1 $\pm$ 1.9		
	60	3	6.8	17.9 $\pm$ 5.4 ₁	0.9 $\pm$ 0.4	26.0 $\pm$ 6.5 ₃	59.1 $\pm$ 21.5	28.0 $\pm$ 14.0	33.4 $\pm$ 5.4 ₃	34.5 $\pm$ 6.2 ₃	4.2 $\pm$ 2.0	9.8 $\pm$ 2.6	13.7 $\pm$ 1.8	2.7 $\pm$ 1.6		
	90	3	7.3	27.1 $\pm$ 2.8	1.9 $\pm$ 0.9	9.7 $\pm$ 2.1 ₃	37.2 $\pm$ 18.8	46.6 $\pm$ 19.9	47.5 $\pm$ 0.8	24.4 $\pm$ 3.4 ₁	3.9 $\pm$ 0.3	12.6 $\pm$ 1.8	5.7 $\pm$ 1.0	4.6 $\pm$ 1.9		
	120	2	7.7	18.1 $\pm$ 5.0	0.4 $\pm$ 0.2 ₂	4.4 $\pm$ 2.8	8.3 $\pm$ 2.3 ₃	31.4 $\pm$ 31.4	66.0	8.0	6.0	14.0	8.0	2.0		

The subscripts indicate values which are significantly different from normal as follows: 1. $P < 0.05$ 2. $P < 0.02$ 3. $P < 0.01$ 4. $P < 0.001$

pH The pH in the intestine of normal subjects remained between 6.0 and 7.0, being slightly lower in the proximal intestine, between 6 and 6.6, and increasing to between 6.4 and 7.0 at more distal levels. After both vagotomy and pyloroplasty and vagotomy and gastrojejunostomy an increase in pH was noted at all intestinal levels, with the exception of the proximal ileum after vagotomy and pyloroplasty, where the pH values were lower than in the normals, being between 6.1 and 6.8.

Polyethylene glycol The concentration of polyethylene glycol in each sample was expressed as a percentage of the concentration in the test meal. Dilution of the meal was found to occur in the upper part of the small intestine of normal subjects; in the lower part polyethylene glycol became more concentrated, reaching a maximum level of 89% in the proximal ileum. After vagotomy and a drainage procedure, polyethylene glycol was found to be more diluted in most of the samples at all intestinal levels when compared with the normal subjects. These differences were statistically significant in the

distal jejunum and proximal ileum after vagotomy and pyloroplasty, and in the duodenum, distal jejunum, and proximal ileum after vagotomy and gastrojejunostomy (Table III).

Percentage of fat absorbed In normal subjects fat was mainly absorbed in the duodenum and jejunum and when the meal reached the proximal ileum most of the fat had already been absorbed. After vagotomy and pyloroplasty, no change in the absorption of fat was found in the upper part of the small intestine but a significant reduction compared with normal was noted in the second half hour of the test in the distal jejunum and during the first and last half hours in the proximal ileum. After vagotomy and gastrojejunostomy, a significant reduction in fat absorption was observed in the third half hour in the duodenum, the second half hour in the distal jejunum, and throughout the whole test in the proximal ileum.

Concentration of polyethylene glycol and fat in the test meal remaining in the stomach Some discussion has arisen about the value of polyethylene glycol as

a marker for test meals containing lipids since it has been shown that to some extent polyethylene glycol is separated from the fat in the residue of the meal in the stomach. To test the reliability of the marker, 13 control tests were performed in patients after vagotomy and pyloroplasty, the sampling being done from the stomach alone. The mean ratio of fat to polyethylene glycol in the test meal given to the patients was 16 : 1. In the samples taken from the stomach in patients after vagotomy and gastrojejunostomy a slight change was noted in the mean ratio of fat to polyethylene glycol in the first hour after giving the test meal, 14.36 after half an hour and 13.48 after one hour. Despite this small change in the overall ratio, a wide variation was found in ratios from patient to patient. After an hour and a half, the mean ratio of fat to polyethylene glycol had further altered, being 12.9, and by two hours, although most of the fat had left the stomach, the remainder had a ratio of 29.1 : 1 to polyethylene glycol. The effect of this alteration in the ratio of fat to polyethylene glycol in the meal leaving the stomach was assessed. These new mean ratios obtained from the gastric tests were used to calculate the absorption of fat and were compared with the results obtained using the 16 : 1 ratio of the test meal. As can be seen from Table IV the mean results after using this correction are not significantly different from the mean results obtained in the normal manner.

EFFECTS OF THE DRAINAGE PROCEDURE When comparing the results after vagotomy and pyloroplasty with those after vagotomy and gastrojejunostomy, two statistically significant changes were found. In both of these instances the patients after vagotomy and gastrojejunostomy showed a diminution compared with those after vagotomy and pyloroplasty. In the first, there was less free fatty acid in the distal jejunum after an hour, and in the second the absorption of fat was diminished in the duodenum after 90 minutes. However, when the results after vagotomy were compared with those in

FIG. 1. Comparison of the number of significant differences from normal subjects on analysis of intestinal contents after ingestion of a test meal containing fat in patients after vagotomy and a drainage procedure showing a greater number of such differences after gastrojejunostomy than after pyloroplasty.

the normal subjects it was found that, when considering bile acid concentration, lipase concentration, total fat, and the absorption of fat, there were more differences from normal in the patients after vagotomy and gastrojejunostomy than in the patients after vagotomy and pyloroplasty (Fig. 1).

CHANGES IN COMPOSITION OF INTESTINAL CONTENT AND FORMATION OF MICELLES The most obvious changes in intestinal content after vagotomy and a drainage procedure were the diminution in bile acid concentration within the first half hour of the test meal and the low concentration of pancreatic lipase. These were accompanied by a tendency for more fat to be present, especially in the lower segments of the intestine. These quantitative changes were associated with a remarkable difference in the specimens obtained from patients. In the normal subjects the samples separated spontaneously into

TABLE IV
COMPARISON OF MEAN VALUES FOR ABSORPTION OF FAT AT FOUR INTESTINAL LEVELS AFTER THE INGESTION OF A TEST MEAL CONTAINING FAT IN PATIENTS AFTER VAGOTOMY AND PYLOROPLASTY SHOWING THE SIMILARITY OF THE RESULTS USING TWO RATIOS FOR CALCULATION

Time after Meal (min.)	Duodenum		Proximal Jejunum		Distal Jejunum		Proximal Ileum	
	Test Meal Ratio $\pm$ S.E.	Corrected Ratio $\pm$ S.E.	Test Meal Ratio $\pm$ S.E.	Corrected Ratio $\pm$ S.E.	Test Meal Ratio $\pm$ S.E.	Corrected Ratio $\pm$ S.E.	Test Meal Ratio $\pm$ S.E.	Corrected Ratio $\pm$ S.E.
30	6.4 $\pm$ 5.2	8.6 $\pm$ 5.0	16.6 $\pm$ 8.7	19.4 $\pm$ 9.8]	24.3 $\pm$ 16.6	28.3 $\pm$ 17.2	9.0 $\pm$ 9.0	11.2 $\pm$ 9.7
60	26.1 $\pm$ 9.3	36.0 $\pm$ 7.8	54.3 $\pm$ 9.1	60.4 $\pm$ 8.2	34.5 $\pm$ 19.4	39.9 $\pm$ 21.1	43.3 $\pm$ 15.1	48.6 $\pm$ 16.6
90	43.0 $\pm$ 9.1	57.8 $\pm$ 5.2	64.2 $\pm$ 11.2	70.7 $\pm$ 9.2	73.1 $\pm$ 8.0	78.5 $\pm$ 5.94	9.7 $\pm$ 25.1	53.7 $\pm$ 26.7
120	52.9 $\pm$ 11.4	42.1 $\pm$ 10.1	75.9 $\pm$ 10.2	68.1 $\pm$ 14.0	66.6 $\pm$ 29.1	61.4 $\pm$ 32.9	52.6 $\pm$ 27.2	48.3 $\pm$ 25.5

TABLE V

AMOUNT OF BILE ACID AND MONOGLYCERIDE AT THE FOUR INTESTINAL LEVELS AFTER INGESTION OF THE TEST MEAL CONTAINING FAT TOGETHER WITH THE AMOUNT OF MONOGLYCERIDE SOLUBLE BY BILE ACID AS ESTIMATED FROM HOFMANN (1963)

	Duodenum			Proximal Jejunum			Distal Jejunum			Proximal Ileum		
	Bile Acid (mM.)	Mono-glyceride (mM.)	Estimated Solubility (mM.)	Bile Acid (mM.)	Mono-glyceride (mM.)	Estimated Solubility (mM.)	Bile Acid (mM.)	Mono-glyceride (mM.)	Estimated Solubility (mM.)	Bile Acid (mM.)	Mono-glyceride (mM.)	Estimated Solubility (mM.)
Normal subjects	6.2	11.1	9.0	5.2	7.4	6.5	6.6	4.0	10.0	3.0	0.5	3.8
Vagotomy and pyloroplasty	2.4	7.4	2.5	2.2	7.7	2.0	1.8	4.8	2.0	1.6	4.8	0.5
Vagotomy and gastro-jejunostomy	2.4	7.7	2.5	1.4	4.3	0	1.8	13.0	2.0	1.8	8.8	2.0

TABLE VI

COMPARISON OF THE MEAN VALUES FOR FRACTIONATION OF THE TOTAL FAT FROM THE OILY AND 'MICELLAR' PHASES OBTAINED BY CENTRIFUGATION OF SPECIMENS OF UPPER JEJUNAL CONTENT AFTER A TEST MEAL CONTAINING FAT IN PATIENTS AFTER VAGOTOMY AND PYLOROPLASTY AND IN NORMAL SUBJECTS

Percentage of Total Fat in Each Phase	Normal (8)		Difference A/B (P)	Vagotomy (8)		Difference A/B (P)
	A	B		A	B	
	Oily Phase $\pm$ S.E.	Clear (Micellar) Phase $\pm$ S.E.		Oily Phase $\pm$ S.E.	Turbid Phase (? Micellar) $\pm$ S.E.	
Cholesterol ester	0.3 $\pm$ 0.2	1.6 $\pm$ 0.5	<0.05	0.6 $\pm$ 0.2	0.1 $\pm$ 0.03	n.s.
Triglyceride	20.9 $\pm$ 3.5	5.2 $\pm$ 0.9	<0.001	17.1 $\pm$ 3.4	12.0 $\pm$ 3.8	n.s.
Cholesterol	10.5 $\pm$ 0.8	5.4 $\pm$ 0.6	<0.001	10.6 $\pm$ 3.4	6.6 $\pm$ 0.9	n.s.
Diglyceride	15.4 $\pm$ 1.9	8.2 $\pm$ 1.3	<0.01	13.3 $\pm$ 2.8	8.1 $\pm$ 1.5	n.s.
Monoglyceride	7.3 $\pm$ 1.8	21.1 $\pm$ 2.5	<0.001	14.8 $\pm$ 2.7	20.0 $\pm$ 5.2	n.s.
Free fatty acid	44.5 $\pm$ 5.8	58.6 $\pm$ 3.9	n.s.	43.8 $\pm$ 8.1	52.8 $\pm$ 7.6	n.s.

an upper yellowish layer containing fat and a lower clear layer which was coloured with bile. After vagotomy this spontaneous separation also occurred but, with few exceptions, the lower layer was turbid.

The concentration of bile acids, the calculated quantities of taurine and glycine conjugates, and the amount of monoglyceride which could be rendered soluble by these concentrations are shown in Table V. It can be seen that during the first half hour of digestion in the normal subjects almost all the monoglycerides could become soluble in the intestinal content. When the results after vagotomy are examined the amount of bile acids would render soluble less than half of the monoglycerides. Similar results were obtained for the later periods of digestion.

Centrifugation results After two and a half hours' centrifugation at 2,500 *g* the samples from normal subjects were definitely separated into a thin oily layer on the top and a clear, watery lower layer, designated the oily and micellar phases respectively.

In samples obtained from patients after vagotomy, no clear micellar phase was defined. Beneath the oily layer a turbid emulsion remained. Analysis of the fat in the layers (Table VI) showed that after vagotomy the concentrations of hydrolytic products

FIG. 2. Mean values for fractionation of total fat in oily and 'micellar' phases of upper jejunal content after ingestion of a fatty meal in normal subjects and in patients after vagotomy and pyloroplasty.

F = Free fatty acids 3 = Triglycerides
1 = Monoglycerides Ch = Cholesterol
2 = Diglycerides CH E = Cholesterol esters

TABLE VII

MEAN VALUES FOR BILE ACIDS, LIPASE, AND FRACTIONATION OF TOTAL FAT IN SPECIMENS OF GASTRIC CONTENTS OBTAINED WITHIN TWO HOURS OF INGESTION OF A TEST MEAL CONTAINING FAT SHOWING A GREATER DEGREE OF HYDROLYSIS OF FAT IN PATIENTS AFTER VAGOTOMY THAN IN NORMAL SUBJECTS

	No. of Specimens	Bile (mg./ml.)	Lipase (units)	Cholesterol Ester	Triglyceride	Cholesterol	Diglyceride	Mono-glyceride	Free Fatty Acids
Normal	3	0.4 ± 0.2	0.3 ± 0.3	0.3 ± 0.1	63.4 ± 1.2	8.9 ± 0.4	7.9 ± 0.4	3.5 ± 0.00	12.3 ± 0.7
Vagotomy and pyloroplasty	7	0.4 ± 0.06	3.3 ± 1.3	0.6 ± 0.3	33.2 ± 5.4 ¹	8.8 ± 2.7	12.4 ± 5.6	7.0 ± 1.6	37.9 ± 5.7 ¹
Vagotomy and gastrojejunostomy	4	1.7 ± 0.2 ²	38.0 ± 5.1 ²	0.1 ± 0.0	16.3 ± 1.7 ²	10.8 ± 1.4	12.5 ± 0.7 ¹	18.7 ± 1.9 ²	41.4 ± 3.8 ¹

¹Significantly different from normal

²Significantly different from normal and from vagotomy and pyloroplasty

of triglycerides were not significantly different between the oily and turbid layers whereas in the normal subjects a highly significant difference was found between the oily phase and the micellar phase (Fig. 2). Some alteration in the micellar formation had occurred, since the turbid layer in samples obtained after vagotomy had a higher concentration of fat than in the clear micellar phase in normals (mean values 2.5 and 4.6 mg./ml. respectively).

FRACTIONATION OF TOTAL FAT The results are discussed separately for the intestine and the stomach.

Intestine Results showing the mean figures for each intestinal level are laid out in Tables I-III. In normal subjects rapid hydrolysis occurred within the first 30 minutes at all intestinal levels, and by the end of two hours only 10 to 20% of the fat remained as triglycerides, free fatty acids amounting to 45 to 65%. After vagotomy and pyloroplasty, rapid hydrolysis was also noted at all levels with only occasional statistically significant differences between the amounts of the various products of hydrolysis, mainly in the proximal ileum. A similar pattern of hydrolysis of the triglyceride was seen in patients after vagotomy and gastrojejunostomy and the few statistical differences from normal were found mainly in the proximal ileum.

Stomach Gastric content was fractionated following ingestion of the test meal in one normal subject, in one patient after vagotomy and gastrojejunostomy, and in two patients after vagotomy and pyloroplasty (Table VII). In the normal subject, between 11 and 13.6% of free fatty acids were released. By contrast, the patients after vagotomy and pyloroplasty showed up to 55% of free fatty acid released within two hours. In the normal subject the pH readings were between 2 and 4, whereas in the patient after vagotomy and pyloroplasty in one case the pHs ranged from 5.7 to 6.6

and in the other from 3.6 to 5.0. (In all of these specimens a small amount of bile refluxed into the stomach.) In the patient after vagotomy and gastrojejunostomy a high percentage of free fatty acids (about 40%) was also noted. In this case marked reflux of bile and pancreatic lipase could account for the hydrolysis.

DISCUSSION

Estimations of the concentration of bile acids in the intestinal content of normal subjects following the ingestion of the test meal have shown that the highest level was reached within the first 30 minutes followed by a decrease to a low, relatively constant value maintained up to two hours. Most of the test meal was digested and absorbed after this decrease had taken place. The bile acid content during most of this period of absorption was between 1 and 3 mg. per ml. even at the lower level of the intestine. These results agree with those of Sjövall (1959). The concentration of bile was altered after vagotomy in that the peak in bile concentration was reached 60 or 90 minutes after the test meal was given, depending on the drainage procedure. Two possible factors might explain this low concentration: first, a slower contraction of the gall bladder, or, secondly, poor mixing of bile with the test meal. It seems unlikely that there was any significant delay in emptying of the gall bladder, since the response of the gall bladder to fat entering the duodenum is little altered by vagotomy (Glanville and Duthie, 1964; Rudick and Hutchison, 1964), despite some reports of dilatation of the resting gall bladder in patients after vagotomy (Rudick and Hutchison, 1964). When gastrojejunostomy is the drainage procedure it would be easy to postulate that mixing of the food with the bile was altered due to the bypassing of the duodenal loop. This is not so readily explained in the case of pyloroplasty.

The activity of pancreatic lipase during the

digestion of the test meal was found to be reduced in patients after vagotomy regardless of which drainage procedure was used. In addition, the peak level of activity of the enzyme was delayed compared with that in normal subjects. The precise role of the vagus nerve in control of pancreatic secretion is not yet clear but White, McAlexander, and Magee (1962) have shown an effect of vagotomy on the gastro-pancreatic reflex. According to them, distension of the stomach, which in the intact subject results in an increase in the output of pancreatic juice, does not have this effect in patients who have undergone vagotomy. The reduction in pancreatic secretion following vagotomy did not seem to be due to a reduction in acid secretion of the stomach, as Magee, Fragola, and White (1963) demonstrated that gastric distension with an alkaline solution in dogs increased pancreatic secretion, despite the fact that the fluid was not sufficiently acid to release secretion from the duodenum. Again the question of incomplete mixing of pancreatic secretion with the test meal would be similar to that discussed under the concentration of bile.

The low activity of lipase and the low concentration of bile acids, together with the delay in reaching the peak values in patients after vagotomy, did not seem to be due to dilution of the test meal as measured by the non-absorbable marker polyethylene glycol. The amount of dilution in the duodenum of patients after vagotomy during the first half hour of the experiment was similar to that in normal subjects. Further distally, the test meal became slightly more dilute during the first hour in the jejunum in patients after vagotomy and gastrojejunostomy but this difference was not statistically significant and would hardly account for the changes observed in concentrations of bile and pancreatic lipase.

An increased amount of total fat in the intestinal content in patients after vagotomy was notable in the more distal small bowel. This finding might be due to a slight hypermotility of the bowel combined with a more rapid emptying of the stomach, especially after gastrojejunostomy, or due to less fat being absorbed from the intestine. Under the conditions of the present experiment no direct evidence was available to assess the effect of these factors.

Despite this increased amount of fat in the distal small bowel after vagotomy and despite the reduced amount of lipase and of bile acids, the hydrolysis of fat reached levels similar to those in the normal subject. A similar result was obtained by Lundh (1958) using the same technique in patients after partial gastrectomy. Part of the explanation of our results may lie in the greater degree of hydrolysis which occurred while the meal was still in the stomach

of patients after vagotomy. This intragastric hydrolysis was shown to be due to reflux of pancreatic lipase and bile in patients with vagotomy and gastrojejunostomy. After vagotomy and pyloroplasty the increased hydrolysis in the stomach might be accounted for by the rise in pH, allowing the more complete action of gastric lipase shown by Schöndheyder and Volqvartz (1946) to have an optimum pH in the region of pH 6.

In this study polyethylene glycol has been used as a marker of the test meal in order to assess the amount of fat absorbed. This use has been criticized following the observation that fat separates from the water-soluble marker polyethylene glycol in the stomach (Wiggins and Dawson, 1961). When this separation was taken into account in the calculation of the site and the degree of absorption of fat, Borgström, Dahlquist, and Lundh (1962) found no significant change from previous results obtained without such a correction. These experiments were done on normal subjects and are in agreement with our gastric tests done on patients after vagotomy and pyloroplasty. In these tests the samples were collected from the stomach by the same procedure as was used in the small intestine. No significant difference was found in the calculated absorption of fat when a correction was made for the alteration in the ratio of fat to polyethylene glycol. However, a wide variation in the ratios of fat to polyethylene glycol was observed even though the mean figures were little different from those of the test meal itself. This fluctuation in the ratio could well be due to the position of the sampling holes of the polythene tube either being in a phase which was predominantly fat or in a phase which was predominantly water soluble and contained the polyethylene glycol. It would seem that this type of separation would be less likely to occur in the narrower confines of the small intestine where the contents are more frequently agitated by segmentation movements. Although individual variation will have occurred with this method of assessment of fat absorption, the overall picture may be revealed. Our present results in the normal subjects are similar to those obtained by Borgström *et al.* (1962).

A decrease in the absorption of fat could be due to (1) intestinal hypermotility, (2) an alteration in the mucosal mechanism for absorption, (3) a change in the composition of the products of digestion of fat within the intestinal lumen, alone or in combination.

1 The occurrence of diarrhoea in patients after vagotomy seems to indicate that in some cases intestinal motility is altered after total abdominal vagotomy.

2 Some anatomical changes after vagotomy have been reported in the upper jejunum of dogs, namely,

loss of the tips of villi and diminished intracellular levels of enzyme after vagotomy and pyloroplasty (Ballinger, Iida, and Aponte, 1963). This might alter the mucosal reception of fat. In addition, it has been observed that bile acids may play a part in the mucosal re-synthesis of free fatty acids (Saunders and Dawson, 1963), so that the decrease in concentration of bile acids observed in the patients after vagotomy might have had an effect on the mucosal transfer of free fatty acids.

3 The slight alteration in absorption of fat in patients after vagotomy seems to be mainly connected with the alterations in the intestinal content. In the first hour after ingestion of the meal the intestinal contents in the normal subjects contained a high level of bile acids and lipase. During this time the major part of the test meal would be discharged from the stomach and mixed with bile and pancreatic juice. It is generally accepted that the fat in a meal forms an emulsion with bile acids, and hydrolysis of the triglycerides in the fat meal proceeds rapidly. Micelles are formed with the bile acid solution and the monoglycerides and free fatty acids which have been released (Hofmann and Borgström, 1964). In patients after vagotomy, conditions were found to be considerably altered. Much less bile acid was available to emulsify the fat. This low level of bile acid, together with a lowered lipase content, would lead one to expect some delay in digestion. However, only a few differences were noted in the hydrolysis of the fat. The decrease in the bile acid concentration did lead to some difference on solubility of the products of hydrolysis.

The capacity of the bile acids in the intestine after vagotomy to make monoglycerides soluble was much smaller than the amount of monoglyceride present; for example, in the distal jejunum and proximal ileum at one hour in patients after vagotomy and gastrojejunostomy, the amounts of monoglyceride present were 14 mM and 25 mM respectively whereas the bile acids would have only been able to render soluble 1.6 mM and 2.0 mM of monoglycerides respectively. Thus, although there was enough bile acid to reach the critical concentration above which micelles could be formed, a large excess of monoglyceride was present. In addition to the deficiency of bile acids and lipase, the pH of the intestinal contents tended to be higher in the patients after vagotomy. This did not reach extremes but several of the intestinal samples in the vagotomized patients were above pH 7. Since the maximum rate of micellar formation is between a pH of 5.5 and 7, some delay in forming micelles could have occurred after vagotomy. While this might explain a delay in micellar formation, it should not have materially altered the importance of the micellar phase in

absorption of fat, according to Hofmann and Borgström (1962), who suggested that once a critical micellar concentration of bile acids is reached the bile acids have a 'transport function' and can be used again to render soluble more monoglycerides.

When an attempt was made to define micellar and oily phases of intestinal content by centrifugation, the analysis in normal subjects gave results confirming the findings of Hofmann and Borgström (1964) but it was found impossible to isolate a true micellar phase in specimens obtained after vagotomy. This change from the normal formation of micelles might provide some basis for the change in the absorption of fat. The larger concentration of fat in the turbid layer compared with the clear micellar layer in normals may indicate that some lipid is suspended or emulsified rather than in micellar solution. More rigorous centrifugation for a longer period might further separate the components of this layer.

A definite incidence of steatorrhoea has been noted by many workers in about one third of patients after vagotomy, for example, Cox, Bond, Podmore, and Rose (1964) noted an incidence of 43% in their study. Most of these alterations were minor, being just above the upper limit of normal for faecal fat. In the present study we have found only a few significant differences in the absorption of fat along the intestine. However, we have shown a definite alteration in the formation of the micellar phase of the intestinal content. This, combined with the other factors, increased motility and possible alteration of the mucosa, would seem to provide sufficient explanation for the alteration in fat absorption which has been observed. The fact that changes are more obvious when the duodenum is bypassed by the gastrojejunostomy stoma is what one might expect from basic physiological principles and again would underline the superiority of pyloroplasty as a drainage procedure when considering absorptive and nutritional disorders.

SUMMARY

After ingestion of a homogenized test meal containing fat, samples of intestinal content were obtained by intestinal intubation at different levels of the alimentary tract in 24 tests in normal subjects, in 24 tests in patients after vagotomy and pyloroplasty, and in 28 patients after vagotomy and gastrojejunostomy for chronic duodenal ulceration. The samples were analysed for pH, polyethylene glycol (a marker substance), bile acids, lipase, and total fat and its hydrolytic products. Some specimens were separated into micellar and oily phases by centrifugation.

After vagotomy the concentration of bile acids

and the lipase activity differed somewhat from normal and some diminution in the absorption of fat was observed. This might be due to an upset in the formation of micelles by the lowered concentration of bile. More changes were found after vagotomy and gastrojejunostomy than when pyloroplasty was the drainage procedure.

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