Secretory response of the human pancreas to continuous intravenous infusion of secretin

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EDITORIAL SYNOPSIS Measurement of the maximum secretory response of the pancreas is shown to be a valuable index of pancreatic function and the test is free from side effects.

Secretin has been prepared in a pure form with an activity of 17,500 u./mg. by Jorpes and Mutt (1964), and using this preparation, Baron, Perrier, Janowitz, and Dreiling (1963) and Hansky, Tiscornia, Dreiling, and Janowitz (1964) demonstrated a maximum pancreatic response in dogs for both volume and bicarbonate with continuous intravenous secretin infusion in doses varying from 4 to 16 units per minute. The present study was undertaken to measure the maximum secretory response of the human pancreas in normal subjects and in patients suspected of pancreatic disease and to compare these results with those of the standard secretin-pancreozymin tests described by Burton, Evans, Harper, Howat, Oleesky, Scott, and Varley (1960).

MATERIAL

NORMAL SUBJECTS Seven subjects, men and women aged 16 to 65 years of age, formed the control group. All had normal glucose tolerance tests, serum amylase levels, and faecal fat output, and were free of clinical and radiological evidence of pancreatic disease.

PATIENTS WITH BILIARY TRACT DISEASE Two patients (M.B. and M.L.) were studied following cholecystectomy, the pancreas appearing normal at laparotomy.

PATIENTS WITH PANCREATIC DISEASE Of four patients with chronic pancreatitis, two had steatorrhoea (H.E. and L.M.), one (C.A.) had pancreatic lithiasis, and all four had either latent or frank diabetes mellitus. In two (H.E. and L.M.) there was biopsy confirmation of chronic pancreatitis. One patient (M.H.) with an abnormal glucose tolerance test was suspected of having chronic relapsing pancreatitis on account of recurrent episodes of abdominal pain. One patient (D.C.) was studied three weeks after the onset of acute pancreatitis.

PATIENTS WITH MISCELLANEOUS DISORDERS A group of

six patients with miscellaneous disorders is shown in Figure 4a and b. In all these patients, studies were arranged in the belief that pancreatic exocrine disease might be present

METHODS

All subjects were intubated after a 12-hour fast. A 14F Rehfus tube was positioned fluoroscopically to drain the descending and transverse portions of the duodenal loop and a 14 to 16 nasogastric tube was positioned to drain the body of the stomach. Both tubes were taped to the cheek to prevent forward movement. It was assumed that the position of the tubes had not altered significantly during the infusion since no change was demonstrated in the four patients whom it was convenient and possible to check. Throughout the test, subjects reclined in bed with head and shoulders comfortably raised on pillows. All patients lay towards the left side to facilitate pooling of gastric contents in the body of the stomach. Duodenal and gastric aspirates were collected separately in small flasks immersed in iced water. Aspiration was carried out using a Gomco thermotic drainage pump. The duodenal fluid was collected in 10-minute periods, the volume measured, and each specimen kept in iced water until analysed within a few hours of collection. The total volume of the duodenal Rehfus tube and connexion tubing to the flask was 9.5 ml.

The bicarbonate, bilirubin, amylase, and total protein concentrations were measured using methods adapted to the Technicon AutoAnalyzer (Northam and Banwell, 1966). The measurement of the bicarbonate content of duodenal fluid was based on the standard AutoAnalyzer method for plasma but using a more concentrated bicarbonate-carbonate buffer reagent to give a working range from 0 to 140 mEq. bicarbonate/litre. To obtain an estimate of the bilirubin concentration, the duodenal fluid was diluted in the AutoAnalyzer with a bicarbonate-carbonate buffer at pH 8.5 and the percentage transmission at 480 m μ compared with that of bilirubin standards prepared from Dade bilirubin control

serum. The amylase activity was measured using a modification of an automated amylolytic method (Scheidt and Gochman, 1964).

Vitrum secretin was used throughout this study. Material from the same batch was used for any one individual study but different batches were used at different times during this work. Secretin was dissolved in normal saline and infused at rates varying from 1 to 18 u./min. by a scalp vein needle into a hand vein using a Palmer constant infusion apparatus. Each infusion rate was maintained for 30 minutes. An interval of 10 minutes elapsed between the cessation of one dosage rate and the start of the next, the rate of infusion being increased stepwise. In eight subjects, a standard secretin-pancreozymin test (Burton *et al.*, 1960) was performed immediately before the constant infusion of secretin.

RESULTS

BASAL COLLECTIONS IN NORMAL SUBJECTS The volume and bicarbonate output of the basal 10-minute collections showed considerable variation from subject to subject (volume range 4 to 23 ml.: bicarbonate concentration 5 to 33 mEq./l.) These

figures have not been analysed further. Spontaneous variation of the basal output has also been reported in dogs (Baron *et al.*, 1963) and in man (Burton *et al.*, 1960; Dreiling and Janowitz, 1962; Sarles, Bauer, and Prezlin, 1965).

CONTINUOUS INTRAVENOUS INFUSION IN NORMAL SUBJECTS Figure 1 illustrates the typical volume and bicarbonate response in a normal subject (M.P.) to stepwise increases in the rate of secretin infusion. The amylase and bilirubin outputs are also shown.

In general, the volume and bicarbonate response in the first 10 minutes of each 30-minute infusion period was variable, the highest output being reached in the second and third 10-minute periods. The mean value of the second and third 10-minute collections was taken to represent the maximum response at each infusion rate. Figures 2 and 3 and Table I demonstrate the response to increasing secretin doses in the seven normal subjects. The maximum response was reached at secretin infusion rates of 4 to 6 u./min., although in two subjects (M.K. and M.P.) a

TABLE I
'NORMAL' SUBJECTS

Patient	Diagnosis	Body Weight (kg.)	Secretin Dose (units/min.)	Response							Mean Response (Average of Samples 2 and 3)				Maximum Bicarbonate Concentration (mEq./l.)
				Volume (ml./min.): 10-Min. Samples			Bicarbonate (μEq./min.): 10-Min. Samples				Volume		Bicarbonate		
											ml./min.	μl./kg./min.	μEq./min.	μEq./kg./min.	
				1	2	3	1	2	3						
W.B.	Colonic diverticulitis	71.9	2	4.0	4.5	4.5	356	472	531	4.5	62	501	6.96	118	
			4	3.7	5.7	6.2	366	621	632	5.9	82	626	8.70	102	
			6	8.1	5.6	4.8	738	543	470	5.2	72	506	7.03	98	
M.K.	Oesophagitis	66.1	1	1.0	1.2	0.8	15	23	17	1.0	15	20	0.30	21	
			2	1.0	2.0	3.2	17	166	358	2.6	39	262	3.96	112	
			4	2.5	5.5	5.0	298	705	505	5.2	79	605	9.15	128	
			6	3.4	5.4	5.2	412	719	697	5.3	80	708	10.71	134	
H.W.	Proctitis	67.9	1	3.6	3.6	3.8	360	417	463	3.7	54	440	6.47	122	
			2	2.5	4.0	4.0	302	496	512	4.0	59	504	7.40	128	
			4	4.5	5.2	5.0	490	598	570	5.1	75	584	8.60	115	
			6	2.8	5.0	—	352	543	—	5.0	74	543	7.99	126	
P.W.	Epilepsy	51.3	2	1.1	1.5	3.0	97	147	246	2.2	43	197	3.84	88	
			4	3.0	2.5	3.5	246	200	231	3.0	58	215	4.20	112	
			6	2.5	4.0	3.5	282	484	406	3.7	72	446	8.70	121	
			15	4.2	3.3	4.0	268	280	452	3.6	70	366	7.14	113	
P.K.	Glandular tuberculosis	49.5	1	0.3	1.0	1.6	5	69	134	1.3	26	101	2.04	84	
			2	0.6	1.5	1.3	53	157	139	1.4	28	148	2.99	107	
			4	0.3	2.5	2.5	18	238	310	2.5	50	274	5.53	124	
			6	2.4	3.4	2.9	276	384	351	3.1	63	367	7.41	121	
M.P.	Proctitis	70.0	8	3.4	3.0	3.1	404	345	362	3.0	61	353	7.13	117	
			2	1.2	3.0	3.4	44	309	388	3.2	46	348	4.98	114	
			4	3.5	3.8	3.8	350	421	426	3.8	54	423	6.04	113	
			6	4.7	5.6	4.8	475	498	504	5.2	74	501	7.16	105	
			10	4.5	5.0	5.0	491	510	510	5.0	71	510	7.28	102	
F.W.	Psychoneurosis	50.4	2	1.5	1.9	1.9	108	228	248	1.9	38	238	4.73	127	
			4	1.9	3.3	3.3	250	366	346	3.3	65	356	7.07	111	
			6	1.5	3.3	4.0	156	366	437	3.6	71	401	7.95	111	
			8	2.7	3.7	4.1	253	398	387	3.9	77	393	7.80	106

FIG. 1. The characteristic response to progressive increase in the rate of secretin infusion in a normal subject (M.P.).

FIG. 2. The volume response to progressive increase in the rate of secretin infusion in seven normal subjects.

FIG. 3. The bicarbonate response to progressive increase in the rate of secretin infusion in seven normal subjects.

maximum response was not clearly attained and it may have been submaximal. The maximum bicarbonate concentration ranged from 118 to 134 mEq./l., and in five subjects was reached before a maximum secretory response for volume and bicarbonate output had been attained. There was a tendency for the bicarbonate concentration to fall with supra-maximum doses and when infusion was prolonged to more than 100 minutes.

Bilirubin concentration in the duodenal fluid was low throughout most infusions.

The amylase output in the duodenal fluid remained relatively constant with increasing rates of secretin infusion.

Relationship between maximum secretory response and body size The relationship between body weight and the maximum volume and bicarbonate response to secretin infusion in the seven normal subjects is shown in Figure 4a and b. The regression of response on body weight (Table II) was found to be highly significant for the maximum volume response ($P < 0.001$) and significant for the maximum bicarbonate response ($P = 0.02$). Similarly, there was a significant regression of response on surface area (calculated from Dubois tables).

GASTROINTESTINAL DISORDERS The maximum volume and bicarbonate response in various gastrointestinal disorders is shown in Figure 4a and b and Table III.

Biliary tract disease The volume response for both patients (M.L. and M.B.) was higher than for the normal subjects, though bicarbonate output was within the normal range. Burton and co-workers (1960) had noted a significant increase in the mean volume of duodenal contents in similar patients using the secretin pancreozymin test.

Chronic pancreatitis All patients had abnormally low maximum volume and bicarbonate responses. In

TABLE II

REGRESSION OF MAXIMUM VOLUME RESPONSE (Y_1) AND MAXIMUM BICARBONATE RESPONSE (Y_2) UPON BODY WEIGHT (X) IN SEVEN NORMAL SUBJECTS

Regression Equation $Y = bX + a$	Test of Significance of Regression			Normal Range	
	S.E. (b)	$t = \frac{b}{S.E.(b)}$	P at $n = 5$	X kg.	Y
Y_1 Maximum volume response (ml./min.)	$Y_1 = 0.098 X - 1.379$	0.0123	7.97	< 0.001	50 3.52 61 4.60 75 5.97
Y_2 Maximum bicarbonate response (μEq./min.)	$Y_2 = 10.12 X - 97.25$	2.915	3.47	0.02	50 409 61 520 75 663
				Normal Range	
				S.D. of a Single Observation of Y about Regression Line at Given Values of X	95% Confidence Limits for a Single Observation of Y at Given Values of X ($n = 5, t = 2.57$)
				0.351 ml./min.	± 0.90 ml./min.
				0.325 ml./min.	± 0.83 ml./min.
				0.367 ml./min.	± 0.94 ml./min.
				91.28 μEq./min.	± 235 μEq./min.
				84.33 μEq./min.	± 217 μEq./min.
				95.46 μEq./min.	± 245 μEq./min.

FIG. 4a. The maximum volume.

FIG. 4b. The maximum bicarbonate response of normal subjects and patients with gastrointestinal disorders related to body weight.

- Normal subjects.
- Chronic pancreatitis.
- Unproved chronic pancreatitis.
- Adult coeliac disease.
- After cholecystectomy.
- Diabetes mellitus.
- + Post acute pancreatitis.
- × Idiopathic steatorrhoea.
- ⊗ Diarrhoea, hyperchlorhydria.

three (L.M., H.E., and L.S.) the maximum bicarbonate concentration attained was low (45, 35, and 20 mEq./l. respectively): in C.A. the bicarbonate concentration (96 mEq./l.) approached the normal level ($123 \pm \text{S.D. } 6.8 \text{ mEq./l.}$).

Suspected chronic pancreatitis The patient (M.H.) had maximum volume and bicarbonate output within the normal range.

Post-acute pancreatitis The patient (D.C.) had an increased total volume output but the bicarbonate level was within the normal range.

MISCELLANEOUS DISORDERS The two patients (B.G. and C.G.) with adult coeliac disease who were studied before treatment both had low maximum volume and bicarbonate responses. One patient (R.M.) with diabetes mellitus had abnormally low responses. Moderate impairment of pancreatic function has been recorded previously by Pollard, Miller, and Brewer (1943) and by Chey, Shay, and Shuman (1963) in primary diabetes mellitus.

Two patients, one with idiopathic steatorrhoea (D.T.) and the other (J.T.) with diarrhoea and increased gastric acid output (basal acid output 29.4 mEq./hr. and maximum acid output of 48.0 mEq./hr.), had volume responses that greatly exceeded the normal range. J. T. also showed a markedly increased bicarbonate output and that of D.T. was at the upper limit of normal.

COMPARISON OF THE RESPONSE TO THE SECRETIN-PANCREOZYMIN TEST (BURTON TEST) AND TO MAXIMUM SECRETIN INFUSION Eight patients had both Burton tests and constant secretin infusions performed at maximum doses. Two were normal subjects: six had miscellaneous gastrointestinal disorders.

The Burton test gave an abnormal volume response for the two patients (L.M. and H.E.) with chronic pancreatitis, but normal results were obtained on the two normal subjects (W.B. and M.W.), on one patient after cholecystectomy (M.L.), and on

TABLE III

MAXIMUM VOLUME AND BICARBONATE RESPONSE IN GASTROINTESTINAL DISORDERS

Patient	Diagnosis	Body Weight (kg.)	Secretin Dose (units/min.)	Response						Mean Response (Average of Samples 2 and 3)				Maximum Bicarbonate Concentration (mEq./l.)				
				Volume (ml./min.): 10-Min. Samples			Bicarbonate (μEq./min.): 10-Min. Samples			Volume		Bicarbonate						
										ml./min.		μl./kg./min.			μEq./min.		μEq./kg./min.	
				1	2	3	1	2	3									
M.B.	After cholecystectomy	61.2	2	2.0	2.9	3.3	210	345	398	3.1	51	371	6.06	121				
			4	3.0	3.8	2.9	381	459	362	3.3	54	410	6.70	127				
			8	2.6	3.5	3.3	304	409	300	3.4	55	354	5.78	117				
			12	4.1	5.2	4.0	442	546	400	4.6	75	473	7.73	108				
			15	4.7	5.6	—	447	480	—	5.6	91	480	7.84	95				
M.L.	After cholecystectomy	48.6	4 ¹	3.8	3.7	3.9	296	385	378	3.8	78	381	7.84	104				
			6 ¹	3.4	4.5	4.5	391	477	441	4.5	92	459	9.44	115				
			8 ¹	4.6	4.5	4.5	463	436	405	4.5	92	420	8.64	103				
L.M.	Chronic pancreatitis	48.6	2	0.1	0.1	0.1	1	1	1	0.1	2	1	0.02	13				
			4	0.1	0.5	0.3	1	21	9	0.4	8	15	0.31	39				
			8	0.1	0.3	0.3	1	7	9	0.3	6	8	0.16	31				
			2 ¹	1.6	2.3	2.5	62	82	88	2.4	49	85	1.75	35				
H.E.	Chronic pancreatitis	56.7	2	0.3	0.3	0	0	4	0	0.1	2	2	0.03	12				
			6	0.2	0.2	0.6	2	2	9	0.4	7	5	0.09	16				
			6 ¹	2.5	1.5	1.5	77	51	51	1.5	26	51	0.90	34				
L.S.	Chronic pancreatitis	73.3	1	0	0.8	0.6	0	13	2	0.7	10	7	0.10	16				
			2	1.2	1.4	0.6	0	0	10	1.0	14	5	0.07	17				
			3	0.5	0.9	0.3	3	5	5	0.6	8	5	0.07	14				
			4	1.3	0.3	0.9	26	2	13	0.6	8	7	0.10	20				
C.A.	Chronic pancreatitis	94.5	1	1.0	3.7	2.1	37	241	168	2.9	31	204	2.16	80				
			2	1.9	2.2	1.8	144	178	151	2.0	21	164	1.73	84				
			4	1.3	3.3	4.2	95	304	404	3.7	39	354	3.74	96				
			8	4.5	3.7	3.8	418	322	335	3.7	39	328	3.47	93				
M.H.	Unproved chronic pancreatitis	48.1	2	0.2	0.5	0.3	4	4	12	0.4	8	8	0.17	13				
			4	0.4	0.3	0.5	10	12	12	0.4	8	12	0.25	35				
			6	0.3	3.4	2.8	16	312	257	3.1	64	284	5.91	92				
			8	2.1	2.5	2.4	212	252	238	2.4	52	245	5.10	101				
			12	3.4	2.8	2.6	221	235	244	2.7	56	239	4.97	94				
D.C.	Post-acute pancreatitis	58.5	2	1.4	1.1	1.5	144	110	166	1.3	22	138	2.36	111				
			6	3.1	5.0	3.6	363	505	364	4.3	73	434	7.42	117				
			8	2.6	5.7	5.8	278	616	621	5.7	97	618	10.56	108				
			6 ¹	5.0	6.8	6.5	540	666	617	6.6	112	641	10.96	108				
B.G.	Adult coeliac disease	59.3	2	2.3	1.9	0.6	2	13	11	1.2	20	12	0.20	19				
			6	1.0	1.6	1.6	53	136	144	1.6	27	140	2.36	90				
			8	1.3	3.2	3.0	60	240	290	3.1	52	265	4.46	97				
			6 ¹	6.0	4.2	5.0	342	328	385	4.6	78	356	6.00	78				
C.G.	Adult coeliac disease	55.8	2	0.4	0.6	0.9	18	28	79	0.7	12	53	0.95	86				
			4	0.7	0.7	1.9	72	72	186	1.3	23	129	2.31	98				
			8	1.9	1.9	2.0	216	206	154	1.9	34	180	3.23	111				
			2 ¹	2.5	3.2	4.4	—	224	277	3.8	68	250	4.48	69				
R.M.	Diabetes mellitus	79.6	2	0.5	2.0	2.1	11	84	189	2.0	25	136	1.71	90				
			4	3.6	3.1	2.3	291	202	205	2.7	34	203	2.55	89				
			6	3.2	3.0	3.0	313	306	306	3.0	38	306	3.84	102				
			8	4.2	2.6	3.3	420	222	346	2.9	36	284	3.56	105				
D.T.	Idiopathic steatorrhoea	41.8	2	2.0	2.4	2.0	110	230	202	2.2	52	216	5.16	101				
			4	3.4	3.8	6.0	357	338	606	4.9	117	472	11.30	105				
			6	5.2	6.0	6.5	527	570	605	6.2	148	587	14.00	101				
J.T.	Diarrhoea, hyperchlorhydria	51.7	2	1.7	3.5	3.6	37	170	184	3.5	68	177	3.42	52				
			4	1.4	2.8	2.1	62	90	128	2.4	46	109	2.11	61				
			8	2.1	2.7	4.0	65	223	448	3.3	64	335	6.48	112				
			12	3.5	5.2	7.0	404	589	834	6.1	118	711	13.76	116				
			15	6.0	8.7	—	635	956	—	8.7	168	956	18.50	110				

¹Infusion of Cecekin (cholecystokinin-pancreozymin) with secretin.

TABLE IV
RESULTS OF SECRETIN TESTS

Patient	Diagnosis	Body Weight (kg.)	Response to Secretin-pancreozymin Test										Maximum Response to Continuous Secretin Infusion		
			Post-secretin Period								Total Output		Volume (μl./kg./min.)	Bicarbonate (μEq./kg./min.)	Maximum Bicarbonate Concentration (mEq./l.)
			30-minute Output			Peak 10-minute Output			Maximum Bicarbonate Concentration (mEq./l.)	Volume (ml./kg.)	Bicarbonate (mEq./kg.)				
			Volume (ml./30 min.)	Bicarbonate (mEq./30 min.)	Volume (μl./kg./min.)	Bicarbonate (μEq./kg./min.)	Volume (μl./kg./min.)	Bicarbonate (μEq./kg./min.)							
W.B.	Normal	71.9	126	10.0	58	4.63	82	7.37	98	3.1	0.28	82	8.70	118	
H.W.	Normal	67.9	106	10.5	52	5.17	56	6.85	122	3.6	0.37	75	8.60	128	
L.M.	Chronic pancreatitis	48.9	8	0.1	5	0.04	6	0.12	22	0.4	0.01	1	0.31	39	
H.E.	Chronic pancreatitis	56.7	45	0.9	26	0.52	35	0.88	25	1.6	0.03	7	0.09	16	
M.L.	Post-cholecystectomy	48.6	110	10.1	75	6.90	92	9.00	118	4.1	0.40	92	9.44	115	
M.B.	Post-cholecystectomy	61.2	63	5.7	34	3.10	49	5.04	110	2.8	0.28	91	7.84	127	
D.C.	Post-acute pancreatitis	58.5	140	11.6	80	6.61	89	7.60	105	5.6	0.42	112	10.96	117	
D.T.	Idiopathic steatorrhoea	41.8	117	10.0	93	7.95	100	10.14	101	5.6	0.47	148	14.00	105	
	Lower limit of normal (mean - 2 S.D.) given by Burton <i>et al.</i> (1960)		78	6.2	—	—	—	—	—	2.2	0.18	—	—	—	

the patients with idiopathic steatorrhoea (D.T.) and post-acute pancreatitis (D.C.). Both the volume and bicarbonate responses after secretin were, however, low in case M.B. (after cholecystectomy).

The post-secretin injection phase of the Burton test was analysed in terms of the peak volume and bicarbonate output for any 10-minute period and the total 30-minute volume and bicarbonate output after secretin. They are compared with the maximum volume and bicarbonate output after maximum secretin infusion (Table IV). In general, lower maximum bicarbonate concentrations were attained using the Burton test. The peak 10-minute and total 30-minute volume and bicarbonate outputs were generally lower than the output during the maximum secretin infusion (Figures 5a and b). Moreover, the peak 10-minute response showed a closer correlation with the maximum secretin response than the 30-minute response.

DISCUSSION

This study has shown that a maximum secretory response of the pancreas may be produced by constant intravenous infusion of secretin at 4 to 6

u./min. A similar 'maximum' response of the gastric mucosa to subcutaneous histamine injection (Kay, 1953) and constant intravenous histamine infusion (Lawrie, Smith, and Forrest, 1964) has already been established. Although this maximum gastric response did not represent the peak secretory capacity of the mucosa (Payne and Kay, 1962) this measurement correlated closely with the parietal cell mass of the stomach (Card and Marks, 1960). There is some evidence that the maximum secretory response of the pancreas bears a similar relationship to the total secretory cell mass of the gland. Recently, Hansky, Tiscornia, Dreiling, and Janowitz (1963) demonstrated in dogs a correlation between the maximum pancreatic secretory response and the weight of the pancreas which offered support for this suggestion. Our own observations in man suggest that there is a relationship between the maximum pancreatic response and the body weight of normal subjects comparable to the observations made by Marks (1961) on the relationship of body weight to maximum gastric secretion. There is much biological evidence to support such a relationship (Bertalanffy, 1960). That Hansky and his colleagues (1963) were unable to demonstrate a correlation between maxi-

FIG. 5. A comparison of (a) the volume response and (b) the bicarbonate response obtained by the Burton test and maximum secretin infusion.

maximum secretory response and body weight in dogs may be attributable to the small differences in weight of the animals which were studied.

Comparison between results obtained by the Burton test and the maximum infusion of secretin show that the latter procedure gave the greatest volume and bicarbonate response. The coefficients of variation for volume and maximum bicarbonate concentration (Table V) were similar to those reported by authors using standard secretin procedures (Dreiling and Janowitz, 1962; Sun, 1963; and Bank, Marks, Moshal, Efron, and Silber, 1963). However, contrary to the experience of Burton *et al.* (1960) and Dreiling and Janowitz (1962) the coefficient of variation for maximum volume and bicarbonate output was greatly reduced when the output was related to body weight (Table V).

The values for maximum volume and bicarbonate output in this study were similar to the values obtained by Hartley, Gambill, and Summerskill (1965) using a single injection of secretin administered intravenously over a period of 2 to 3 minutes. The coefficients of variation of their responses were, however, much greater (peak volume output 48%, peak bicarbonate output/kg. body weight 24%) than when a constant infusion of secretin was used.

The results obtained on patients with various gastrointestinal diseases demonstrate the application of the maximum infusion procedure, which promises to be a valuable method for the investigation of pancreatic dysfunction. The technique is free from side effects and should take no longer to perform than a standard secretin test.

SUMMARY

The secretory response of the human pancreas to continuous intravenous infusion of secretin was measured in normal subjects and in patients suspected of having pancreatic disease.

The maximum volume and bicarbonate output was related to body weight.

TABLE V

ANALYSIS OF MAXIMUM VOLUME AND BICARBONATE RESPONSE AND MAXIMUM BICARBONATE CONCENTRATION IN SEVEN NORMAL SUBJECTS

	Mean	S.D. (n = 6)	95% Confidence Limits of a Single Observation about the Mean (n = 6 t = 2.45)		Coefficient of Variation
Maximum volume response Y_1					
(a) ml./min.	4.60	1.03	2.1	7.1	22.3%
(b) $\mu\text{l. / kg. / min.}$	74.71	6.21	59.5	89.9	8.3%
Maximum bicarbonate response Y_2					
(a) $\mu\text{Eq. / min.}$	520.3	125.0	214	826	24.0%
(b) $\mu\text{Eq. / kg. / min.}$	8.48	1.15	5.7	11.3	13.6%
Maximum bicarbonate concentration mEq./l.	123.7	6.8	107	140	5.5%

A comparison with a standard secretin test procedure showed that maximum infusion of secretin may be a useful method for investigating pancreatic dysfunction.

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