

# The Effects of Gastrin, Gastric Inhibitory Polypeptide, Secretin, and the Octapeptide of Cholecystokinin upon Immunoreactive Somatostatin Release by the Perfused Canine Pancreas

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**ABSTRACT** The effects of gastrin, gastric inhibitory polypeptide, secretin, and the octapeptide of pancreozymin-cholecystokinin on immunoreactive somatostatin release were studied in the isolated perfused dog pancreas. Gastrin at a concentration of 65 ng/ml and the octapeptide of pancreozymin-cholecystokinin at a concentration of 25 ng/ml produced a prompt, but transient statistically significant, twofold rise in mean somatostatin concentration. Secretin at a concentration of 0.3 U/ml and gastric inhibitory polypeptide concentration of 58 ng/ml produced a prompt two- to threefold rise in mean somatostatin release, which persisted throughout the perfusion period. With all four polypeptides the pattern of the somatostatin response resembled that of insulin. It appears that pancreatic somatostatin release is stimulated by gastrointestinal hormones that influence the secretion of insulin and glucagon.

## INTRODUCTION

The demonstration of somatostatin-containing D cells (1, 2) within the islets of Langerhans has raised the possibility that their physiological role or roles, like that of their neighboring cells, may be related to nutrient homeostasis (3). If this were true, the secretory

activity of the D cell might then be affected by nutrients and hormones that influence the A and B cells. Indeed, it has already been reported that arginine (4), glucagon (5), glucose (6–8), leucine (8), an amino-acid mixture (8), and pancreozymin-cholecystokinin (8), all stimulators of insulin secretion, also enhance the release of somatostatin.

The present study was designed to investigate further the effects of gastrointestinal hormones upon pancreatic somatostatin release.

## METHODS

The preparation used was the isolated perfused dog pancreas (9), as previously modified (5). The isolated pancreas with the attached segment of duodenum was perfused with a synthetic medium (9) without recirculation. Flow rate was constant at 19–21 ml/min, and pressure was maintained between 25–50 mm Hg throughout the experiment. In all perfusions, glucose concentration was 100 mg/dl. In the gastrin experiments, a 1 mM mixture of 10 amino acids (10) was added to the perfusate to simulate the hyperaminoacidemia of a protein meal. The pancreatic effluent was collected continuously from a cannula in the portal vein and divided into 1-min aliquots in chilled tubes containing an EDTA-Benzamidinium mixture (0.003M/0.03M). These were stored at  $-20^{\circ}\text{C}$  until assay. Assay of immunoreactive somatostatin was performed by the method of Arimura et al. (11) using Arimura antiserum 101. Insulin and glucagon assays were performed as previously described (12, 13). None of the hormones perfused interfered in any of the three assays.

Each hormone was perfused for two or three 8–10-min periods per experiment in three or four experiments. Only one hormone was perfused in each experiment. Hormone-free

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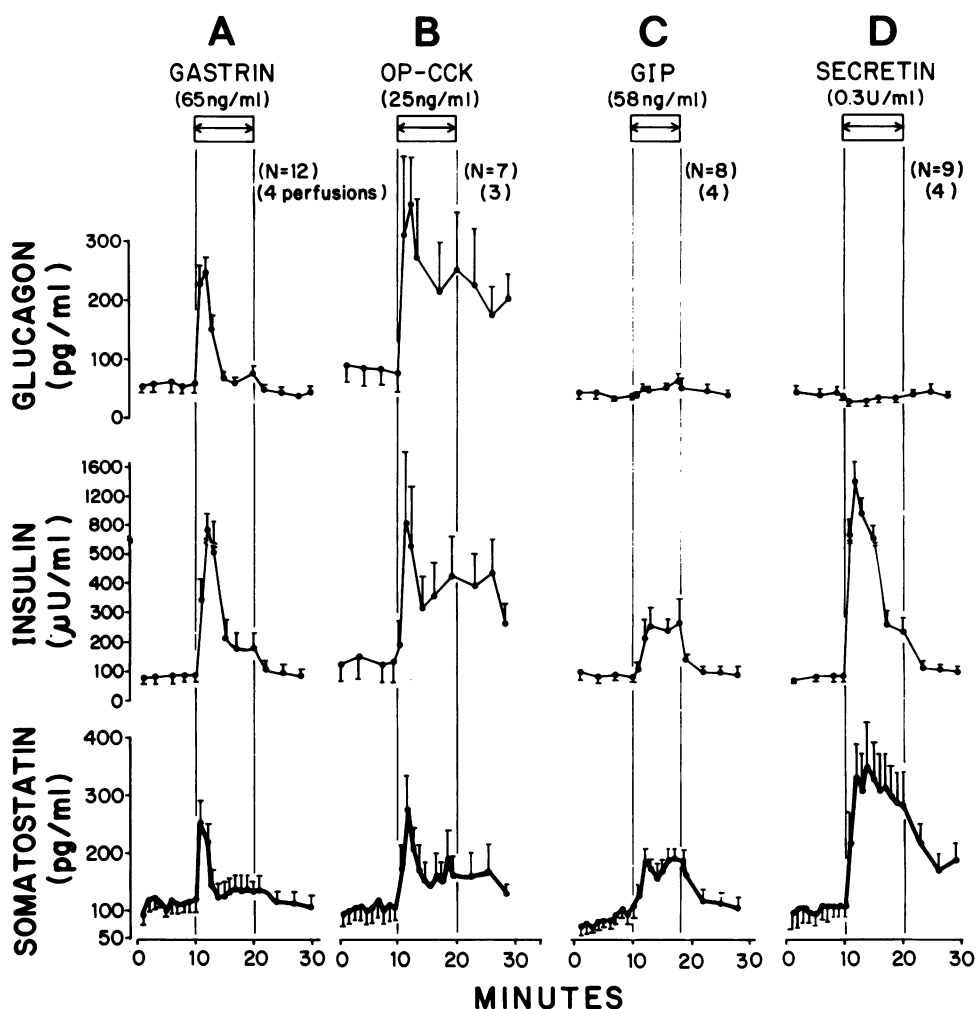


FIGURE 1 The effects of (A) gastrin, (B) the octapeptide of cholecystokinin (OP-CCK), (C) GIP, and (D) secretin on immunoreactive somatostatin, insulin, and glucagon release from the isolated perfused dog pancreas (mean  $\pm$  SEM). All hormones were perfused for a period of 10 min, except GIP which was perfused for 8 min. N = number of challenges with a polypeptide, and the figure in parentheses indicates the number of experiments, i.e., the number of pancreases perfused.

buffer was perfused for 30 min between each challenge with a polypeptide. 17-amino acid hog gastrin, generously supplied by Drs. Morton Grossman and John Walsh, porcine gastric inhibitory polypeptide (GIP),<sup>1</sup> lot EGIII, by Dr. John Brown, pure porcine secretin, lot 17561, by Professor Viktor Mutt, and the octapeptide of cholecystokinin, lot UTA-860-H/TJ-5, by E. R. Squibb and Sons, Inc., Princeton, N. J. Secretin was solubilized in normal saline and bovine serum albumin and other polypeptides in distilled water in 0.2% bovine serum albumin.

The results were analyzed statistically using the Wilcoxon signed rank test for paired data, and the Mann-Whitney test for analysis of individual experiments. Data is expressed as the mean  $\pm$  SEM.

<sup>1</sup> Abbreviation used in this paper: GIP, gastric inhibitory polypeptide.

## RESULTS

*Effect of gastrin.* Gastrin was perfused at a concentration of 65 ng/ml on 12 occasions in four pancreases. On each occasion, this resulted in a simultaneous rise of immunoreactive somatostatin, insulin, and glucagon, all three of which reached a peak within 2 min (Fig. 1A). Mean ( $\pm$ SEM) somatostatin levels rose from the base-line level of  $117 \pm 18$  pg/ml to a peak of  $252 \pm 41$  pg/ml at 1 min ( $P < 0.01$ ) and receded rapidly thereafter. A slight increase above base line persisted during the latter part of gastrin perfusion, but this did not differ significantly from the pre-perfusion values. The patterns of glucagon and insulin response were similar to that of somatostatin.

*Effects of the octapeptide of pancreatico-cholecystokinin.* Although incompletely purified pancreatico-cholecystokinin has been shown to stimulate somatostatin release (8), the effects of the synthetic octapeptide, free of other gut hormones such as GIP, had not been studied. The octapeptide in a concentration of 25 ng/ml was perfused on seven occasions in three pancreases. Mean somatostatin rose from the base-line value of  $106 \pm 21$  pg/ml to a peak of  $276 \pm 62$  pg/ml at 2 min ( $P < 0.02$ ), the biphasic release pattern again resembling that of insulin and glucagon release (Fig. 1B). The second phase of somatostatin release was not consistently elevated, however. The mean of the values after the 3rd min in each experiment was significantly above the respective base-line value in five of the seven challenges ( $P < 0.01$ ), but the mean increase in somatostatin for the entire group was not significant during this period. This is in contrast to the more sustained response previously reported with perfusion of partially purified full-sequence pancreatico-cholecystokinin, which is said to contain about 2% GIP (8).

*Effects of GIP.* GIP at a concentration of 58 ng/ml was perfused on eight occasions in four pancreases. On each occasion the somatostatin level rose promptly. The mean value increased from  $104 \pm 15$  pg/ml to a peak of  $181 \pm 22$  pg/ml at 2 min ( $P < 0.01$ ) and remained significantly elevated throughout the period of perfusion reaching another peak of  $186 \pm 13$  pg/ml at 7 min ( $P < 0.01$ ) (Fig. 1C). Again, the pattern of release of somatostatin was remarkably similar to that of insulin. A small but nonsignificant rise in glucagon release was also observed.

*Effects of secretin.* Secretin at a concentration of 0.3 U/ml was perfused on nine occasions in four pancreases. On each occasion a prompt rise in somatostatin concentration occurred. The mean level rose from  $106 \pm 20$  pg/ml to a peak of  $347 \pm 74$  pg/ml at 4 min ( $P < 0.01$ ) (Fig. 1D) and remained above  $281 \pm 61$  pg/ml throughout the perfusion. Again, the pattern resembled that of the insulin response. Slight suppression of glucagon release occurred (NS).

## DISCUSSION

These studies reveal that somatostatin release by the canine pancreas is stimulated during infusion with pharmacologic concentrations of gastrin, GIP, secretin, and the octapeptide of pancreatico-cholecystokinin. It was previously reported (8) that 33-amino acid pancreatico-cholecystokinin increases somatostatin release. Thus, the D cell appears to be a possible target of at least four of the alimentary hormones that influence the B and A cells (14–21). With each hormone the pattern of the somatostatin response was remarkably similar to that of insulin. Although these

studies do not permit assessment of the contribution of somatostatin by the duodenal remnant, measurements of tissue concentration of somatostatin in the dogs suggest that the pancreas contains approximately 10 times as much somatostatin as the duodenum (22).

The physiologic significance of the response of somatostatin release during perfusion of gastrointestinal hormones remains to be established. It may be relevant that, in pharmacological amounts, somatostatin inhibits the release of gastrin (23), secretin (24), and GIP (25), and perhaps of pancreatico-cholecystokinin (26), and may also interfere with their effects on gall bladder contraction (27) and on pancreatic (24,27) and gastric (23) exocrine function. The doses used were at least 20 times the maximum estimated rate of pancreatic release from the pancreas (28). If such inhibitory effects upon digestive function also occur at physiologic concentrations of somatostatin, as has recently been suggested (28), a physiologic feedback system may be considered in which somatostatin secretion, stimulated by nutrients and gastrointestinal hormones, reduces the release of the gut hormones and, in this way and (or) by direct action, controls the rate of the digestive functions that they stimulate. If so, this might permit the D cell, by varying somatostatin release, to influence the rate at which ingested nutrients enter the circulation (3). The responses of pancreatic somatostatin secretion to all nutrients and gut hormones thus far tested, together with the diverse effects of somatostatin upon the gastrointestinal tract and on insulin and glucagon secretion (29, 30), make a role of the D cell in regulation of nutrient homeostasis a plausible possibility.

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