Increased Plasma Glucagon-Like Immunoreactivity in Dogs with Ileojejunal Transposition

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OHNEDA, A., TSUCHIYA, T., NAITO, H., SASAKI, I., OHNEDA, M. and KAWAMURA, T. Increased Plasma Glucagon-Like Immunoreactivity in Dogs with Ileojejunal Transposition. Tohoku J. Exp. Med., 1990, 162 (1), 95–108 — To elucidate hormonal and metabolic changes in intestinal adaptation, an experimental study was performed in dogs subjected to ileojejunal transposition. Fasting levels of blood glucose, plasma insulin and gastric inhibitory polypeptide (GIP) did not change significantly throughout 12 weeks. Plasma glucagon measured with an antiserum specific to the C-terminal portion of glucagon slightly increased and plasma total glucagon measured with a non-specific antiserum gradually increased. Glucose tolerance deteriorated at the 4th week in the transposed group. The response of plasma insulin and GIP to glucose in the transposed group did not differ from that of the sham operated group. Plasma glucagon increased significantly during glucose loading at the 12th week. The response of plasma total glucagon to glucose was most prominent, reaching a peak of 3,755 ± 742 pmol/liter. The value was significantly increased, compared with that of the sham group or normal group (p < 0.01). Insulin-induced hypoglycemia enhanced a larger increment of plasma total glucagon in the transposed group than in the sham group (p < 0.05). At the 12th week plasma total amino acids were decreased and several amino acids were reduced. It is concluded that ileojejunal transposition elicited an exaggerated response of plasma total glucagon to glucose and several metabolic derangements and that the transposition offers an excellent model for hyperenteroglucagonemia.

Experimental and clinical studies have demonstrated that following partial resection of the small bowel the residual intestine shows adaptive changes, which include mucosal hypertrophy (Flint 1912; Clotworthy et al. 1952; Loran and Althausen 1958; Bloom and Polak 1982), an increase in absorptive function (Dowling and Booth 1966, 1967; Tilson and Wright 1971; Weser and Hernandez

Received August 21, 1990; revision accepted for publication August 30, 1990.
1971; Bury 1972). The mechanism for these adaptive changes is not fully understood. In the previous studies concerning the intestinal adaptation, most investigators have used small animals (Booth et al. 1959; Dowling and Booth 1967; Weser and Hernandez 1971; Gregor et al. 1980), in which the changes in plasma hormones could not be investigated precisely. Therefore, in order to elucidate the changes in plasma glucagon-like immunoreactivity (GLI) and metabolic derangements in a course of intestinal adaptation, the present study was carried out in dogs subjected to ileojejunal transposition.

**Methods**

In the present study, 10 healthy mongrel dogs weighing 13 to 18 kg were used. After an overnight fast, 6 dogs were laparotomized under pentobarbital anesthesia and ileojejunal transposition (IJT) was carried out, as shown in Fig. 1. The jejunum was divided 20 cm distal to the ligament of Treitz and an ileal part corresponding to a quarter of the small intestine was transposed isoperistaltically to the jejunum (IJT group). In the other 4 dogs, the jejunum and ileum were transected at the same sites as mentioned above and were resutured (sham group).

A glucose tolerance test (GTT) was carried out in a conscious state before and 4, 8 and 12 weeks after the operation in the IJT group and at the 12th week in the sham group. After an overnight fast, a 20% solution of glucose was administered through a stomach tube in a dose of 2 g/kg of body weight. Blood samples were obtained from the crural vein before and 15, 30, 45, 60, 90 and 120 min after glucose load. Blood glucose was determined by the glucose oxidase method (Teller 1956). Blood samples for hormone assay were drawn in amounts of 4 ml and poured into a glass tube containing 1,000 KIU of aprotinin (Trasylol®; Bayer Co., Leverkusen, West Germany) and 10 mg EDTA. The blood samples were refrigerated until the completion of the experiment. Plasma was separated by centrifugation at 4°C and stored at -20°C until the assay began. Immunoreactive insulin (IRI) in plasma was measured by the two-antibody system (Morgan and Lazarow 1963). Plasma glucagon was determined with an antiserum (G 21) specific to the C-terminal portion of glucagon and designated as immunoreactive glucagon (IRG) (Ohneda et al. 1975) and with a non-specific antiserum (G 25) designated as total IRG (Ohneda et al. 1979).

![Fig. 1. Experimental models. In ileojejunal transposition, a distal quarter of the small intestine (B'-C, I) was isoperistaltically transposed to the jejunum (A-A') 20 cm distal to the ligament of Treitz (TL).](image-url)
gastric inhibitory polypeptide (GIP) was determined according to the method described previously (Ohneda et al. 1983), using an antiserum R 65, donated by Dr. Moody (Novo Institute, Bagsvaerd, Denmark).

In order to investigate the response to glucagon, 12 weeks after the operation a glucagon test was carried out. After an overnight fast, 20 μg/kg of porcine glucagon was administered intravenously as a bolus to the conscious dogs and blood samples were drawn before and 5, 10, 15, 30, 45, 60, 90 and 120 min following the glucagon injection. Blood glucose and plasma IRI were determined, as mentioned above.

Furthermore, to study the response of glucagon to hypoglycemia, an insulin test was performed. After an overnight fast, pork insulin (Actrapid® Novo Industri A/S, Bagsvaerd, Denmark) was injected intravenously in a dosage of 0.1 U/kg of body weight and blood samples were collected before and 15, 30, 45, 60, 90 and 120 min after the insulin administration. Blood glucose and plasma IRG and total IRG were determined.

Liver function, serum protein fraction, serum lipids and blood urea nitrogen were determined 12 weeks after the operation with Autoanalyser (Model TBS 805; Toshiba Co., Tokyo) using kits. Furthermore blood samples were obtained before and 12 weeks after the operation in the transposed group and at the 12th week in the sham group and the serum amino acid fraction was measured with an automatic amino acid analyser (Hitachi 835; Hitachi Ltd., Tokyo).

In order to investigate the heterogeneity of circulating glucagon in the IJT group, plasma obtained during the glucose load was applied to a column with Sephadex G 50 (1 x 60 cm). The column was filled with 0.01 M phosphate buffer with 0.12 M saline containing 0.2% bovine albumin. Gel filtration was carried out at a constant rate of 12 ml/hr using a pump, as reported elsewhere (Ohneda 1987a). In chromatography, the column was calibrated with blue dextran and labelled glicentin, insulin and glucagon. Total IRG in the eluate was determined with the antiserum G 25.

Data were expressed in terms of mean ± S.E. Statistical analyses for the comparison of the changes from the base-line value and multiple comparison were performed by analysis of variance. Statistical analyses for the maximal changes between experimental groups were carried out using analysis of variance. Comparison of the mean values between experimental groups was performed using Student's t-test, where appropriate. For comparison, data of 5 normal dogs, weighing 16 to 18 kg, are quoted from the report of the same author (Ohneda et al. 1983).

**Results**

**Body weight**

After the operation, the body weight of each animal was reduced transiently but regained thereafter. There was no significant difference in the change of body weight between the IJT and the sham groups during the experimental period.

**Fasting levels of blood glucose and plasma hormones**

The fasting level of blood glucose was 4.3±0.18 mmol/liter before the operation in the IJT group and did not show any discernible change over the 12 weeks, in comparison with those in the sham group (4.6±0.37 mmol/liter) and in the normal group (4.9±0.11 mmol/liter). The fasting plasma IRI was 28±5.3 pmol/liter before the operation in the IJT group and ranged from 46.7±14.7 to 85.3±34.7 pmol/liter over 12 weeks, but the changes in fasting plasma IRI were not significantly different. The fasting plasma IRI was 32.0±14.0 pmol/liter in
the sham group at the 12th week, while it was 73.3 ± 10.7 pmol/liter in the normal group. The fasting levels of plasma IRI were not significantly different in these experimental groups. The fasting plasma GIP was 30.8 ± 10.6 pmol/liter before the operation in the IJT group and increased to 60.8 ± 23.8 pmol/liter at the 8th week, although not significantly. The fasting levels of plasma GIP in the sham group and normal group were 24.0 ± 17.0 and 52.2 ± 6.0 pmol/liter, respectively. There was no significant difference in the fasting plasma GIP between these experimental groups. The fasting plasma IRG was 19.4 ± 10.4 pmol/liter before the operation in the IJT group and increased to 30.6 ± 10.4 pmol/liter 8 weeks after the operation ($p < 0.05$). The fasting level of plasma IRG was 25.1 ± 4.6 pmol/liter in the sham group at the 12th week, whereas it was 10.3 ± 5.4 pmol/liter in the normal group. A significant difference was observed in fasting plasma IRG between these experimental groups ($p < 0.05$). The fasting level of plasma total

Fig. 2. Changes in blood glucose, plasma insulin, GIP, glucagon and total glucagon during oral glucose load in a group of 6 dogs before the operation of ileojejunal transposition. For comparison, the results of a group of 5 normal dogs are depicted as the shadows. Data points are means ± s.e. In Figs. 2 to 5 the following abbreviations are used: BG, blood glucose; IRI, insulin; GIP, gastric inhibitory polypeptide; IRG, glucagon; total IRG, total glucagon.
IRG was $117 \pm 59$ pmol/liter before the operation in the IJT group and increased gradually following the operation, reaching $634 \pm 514$ at the 8th week and $270 \pm 139$ pmol/liter at the 12th week, although the difference did not reach statistical significance. The fasting plasma total IRG in the sham group was $214 \pm 43$ pmol/liter at the 12th week, whereas it was $130 \pm 41$ pmol/liter in the normal control group. There was no significant difference in fasting plasma total IRG between these experimental groups.

Changes in glucose tolerance and plasma hormones during GTT

Glucose tolerance deteriorated transiently in the course of the period after the operation in the IJT group, as shown in Figs. 2 to 5. The blood glucose level at 120 min in GTT was $4.5 \pm 0.44$ mmol/liter before the operation (Fig. 2) and increased to $7.1 \pm 1.21$ mmol/liter at the 4th week ($p < 0.05$) in the IJT group (Fig. 3). However, the blood glucose level at 120 min during GTT at the 12th week did

![Graph](image)

Fig. 3. Changes in blood glucose, plasma insulin, GIP, glucagon and total glucagon during oral glucose load 4 weeks after the operation in the IJT group. Data points are means ± s.e.
not differ from that of the sham operated group (Fig. 5) or that of the normal group.

Plasma IRI increased from the basal level of $26.7 \pm 6.0$ pmol/liter to a peak of $155.3 \pm 29.3$ pmol/liter 30 min after glucose load in the IJT group before the operation ($p < 0.05$). These responses of plasma IRI to glucose in the IJT group did not differ from that before the operation throughout the experimental period. Furthermore, the response of plasma IRI to glucose load in the IJT group did not differ during the experimental period from those of the sham group and the normal group, as shown in Figs. 2 and 5.

Plasma GIP increased during GTT before the operation in the IJT group ($p < 0.05$) and the response of plasma GIP was similar to that of the group of unoperated normal dogs (Fig. 2). Although the response of plasma GIP to glucose load was slightly decreased at the 4th week in the IJT group, the peak response of plasma GIP to glucose was not significantly different between these

![Graph showing changes in blood glucose, plasma insulin, GIP, glucagon and total glucagon during glucose load 8 weeks after the operation in the JIT group. Data points are means ± S.E.](image)
Plasma IRG was 23.1±4.3 pmol/liter at fasting and did not change after glucose load in the IJT group before the operation (Fig. 2). Plasma IRG increased slightly after glucose load at the 4th and 8th week (Figs. 3 and 4). Plasma IRG level reached a peak of 55.7±14.9 pmol/liter following glucose load performed 12 weeks after the operation ($p<0.05$, Fig. 5). In contrast, plasma IRG was 24.0±4.0 pmol/liter at fasting and did not change during GTT in the sham group (Fig. 5).

The changes in the response of plasma total IRG was the most prominent. Plasma total IRG increased from the basal level of 153±87 pmol/liter to a peak of 613±166 pmol/liter at 45 min ($p<0.01$) during GTT before the operation in the IJT group (Fig. 2). These changes in plasma total IRG before the operation

![Graph showing changes in blood glucose, plasma insulin, GIP, glucagon, and total glucagon during oral glucose load 12 weeks after the operation in the IJT group. Data points are means±S.E. The shadows or dot lines show the changes in a group of 4 dogs with sham operation.](image)

Fig. 5. Changes in blood glucose, plasma insulin, GIP, glucagon and total glucagon during oral glucose load 12 weeks after the operation in the IJT group. Data points are means±S.E. The shadows or dot lines show the changes in a group of 4 dogs with sham operation.
did not differ from the normal group. The response of plasma total IRG became exaggerated during the course of the experiment. At the 8th week plasma total IRG reached a level of 2,400±755 pmol/liter at 60 min (p<0.05, Fig. 4). Such a remarkable response of plasma total IRG was maintained at the 12th weeks (p < 0.05, Fig. 5). In contrast, plasma total IRG was 196±30.6 pmol/liter at fasting and reached a peak of 923±76 pmol/liter 60 min after glucose load in the sham group (p <0.05, Fig. 5). The response of plasma total IRG in the sham group did not differ significantly from that in the normal group.

**Glucagon test**

In order to see the responses of blood glucose and plasma IRI to exogenous glucagon, a glucagon test was performed at the 12th week in both the IJT and sham groups. In the IJT group, blood glucose rose from the initial level of 4.9±0.09 mmol/liter to a peak of 8.8±0.78 mmol/liter 15 min after the glucagon injection, returning to the initial level at 90 min (p <0.01). Plasma IRI increased from the basal level of 8±1.3 pmol/liter to a peak of 341.3±96.7 pmol/liter after the glucagon injection (p <0.05). In the sham group, blood glucose rose from the initial level of 4.1±0.23 mmol/liter to a peak of 7.5±0.7 mmol/liter (p <0.01). Plasma IRI increased in response to glucagon to a peak of 273±76 pmol/liter at 10 min (p <0.05). There was no statistical difference in the peak of blood glucose or plasma IRI between the IJT and sham groups.

**Insulin test**

In a previous report, an increased release of gut GLI was observed in response to hypoglycemia (Ohneda et al. 1989). To see whether the responses of pancreatic and gut GLI to hypoglycemia are altered in intestinal adaptation, an insulin test was performed at the 12th week in the IJT and sham groups. In the IJT group blood glucose decreased from the basal level of 4.8±0.2 mmol/liter to a nadir of 1.9±0.1 mmol/liter 45 min after the insulin injection, returning to the level of 3.5±0.3 mmol/liter at 120 min (p <0.01). Plasma IRG was 58.9±14.0 pmol/liter at fasting and reached a peak of 89.1±22.6 pmol/liter at 30 min. Plasma total IRG increased from a basal level of 364±20 pmol/liter to a peak of 645±98 pmol/liter at 45 min (p <0.05). In the sham group, blood glucose decreased from the basal level of 5.6±0.7 mmol/liter to a nadir of 2.9±0.7 mmol/liter 15 min after the insulin injection (p <0.01). Plasma IRG increased from the baseline of 11.4±4.8 pmol/liter to a peak of 57.1±18.9 pmol/liter at 30 min and remained elevated (p <0.05). Plasma total IRG was 161±103 pmol/liter at fasting and reached a level of 311±150 pmol/liter at 30 min (p <0.05). There was no difference in blood glucose or plasma IRG between the IJT and sham group. In contrast, the maximal increment in plasma total IRG was larger in the IJT group than in the sham group (p <0.05).
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**Fig. 6.** Elution profile of chromatography of total IRG of plasma obtained 60 min after glucose load in a dog with IJT. Arrows indicate calibration sites.

**Table 1.** Liver function, serum protein, serum lipids and urea nitrogen in IJT and sham groups

<table>
<thead>
<tr>
<th>Measurements</th>
<th>IJT (n=5)</th>
<th>Sham (n=4)</th>
</tr>
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<tbody>
<tr>
<td>A. Liver function</td>
<td></td>
<td></td>
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<tr>
<td>Bil (mg/100 ml)</td>
<td>0.22±0.02</td>
<td>0.25±0.03</td>
</tr>
<tr>
<td>GOT (IU/liter)</td>
<td>18.6 ± 1.9</td>
<td>38.5 ± 4.3</td>
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<tr>
<td>GPT (IU/liter)</td>
<td>34.4 ± 4.1</td>
<td>74.5 ± 20.2</td>
</tr>
<tr>
<td>Al P (IU/liter)</td>
<td>7.4 ± 2.3</td>
<td>14.8 ± 5.2</td>
</tr>
<tr>
<td>G GT P (IU/liter)</td>
<td>1.6 ± 0.7</td>
<td>1.8 ± 0.5</td>
</tr>
<tr>
<td>LAP (IU/liter)</td>
<td>7.4 ± 2.3</td>
<td>14.5 ± 5.4</td>
</tr>
<tr>
<td>B. Serum protein</td>
<td></td>
<td></td>
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<tr>
<td>Total (g/100 ml)</td>
<td>7.6 ± 0.2</td>
<td>6.1 ± 0.6</td>
</tr>
<tr>
<td>A/G</td>
<td>0.87 ± 0.08</td>
<td>0.95 ± 0.23</td>
</tr>
<tr>
<td>Al (%)</td>
<td>46.2 ± 2.4</td>
<td>47.4 ± 6.8</td>
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<tr>
<td>Gl alpha_1 (%)</td>
<td>6.9 ± 0.7</td>
<td>6.6 ± 1.5</td>
</tr>
<tr>
<td>Gl alpha_2 (%)</td>
<td>9.3 ± 1.0</td>
<td>4.5 ± 0.3</td>
</tr>
<tr>
<td>Gl beta (%)</td>
<td>21.4 ± 5.1</td>
<td>29.9 ± 5.6</td>
</tr>
<tr>
<td>Gl gamma (%)</td>
<td>10.2 ± 2.6</td>
<td>11.6 ± 0.5</td>
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<tr>
<td>C. Serum lipids</td>
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<td></td>
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<tr>
<td>TG (mg/100 ml)</td>
<td>28.2 ± 3.7</td>
<td>32.8 ± 5.7</td>
</tr>
<tr>
<td>TC (mmol/liter)</td>
<td>2.2 ± 0.16</td>
<td>3.08 ± 0.47</td>
</tr>
<tr>
<td>D. Blood urea nitrogen (mmol/liter)</td>
<td>4.4 ± 0.33</td>
<td>3.0 ± 0.84</td>
</tr>
</tbody>
</table>

Values are means±s.e.
Column chromatography of plasma total IRG during GTT

Fig. 6 shows an elution profile of chromatography of total IRG of plasma obtained 60 min after glucose load at the 12th week in a dog of the IJT group. A main peak is observed at the glicentin marker. In addition, two small peaks are seen at blue dextran and between the insulin marker and the glucagon marker.

Liver function, renal function, serum protein and lipids

At the 12th week, liver function, renal function, serum protein and lipids were investigated in both the IJT and sham groups. As shown in Table 1, no abnormalities were observed in liver function, renal function and serum protein and lipids in the IJT group, compared with the sham group.

Plasma amino acids

To see the influence of intestinal adaptation on plasma amino acids levels, amino acid analysis was carried out on plasma samples obtained before the operation and at the 12th week in the IJT and sham groups. As shown in Fig. 7, total amino acids before the operation in the IJT group $1,314 \pm 242 \mu$mol/liter and did not differ from those in the sham group ($1,245 \pm 64 \mu$mol/liter). However, in the IJT group total amino acids were significantly reduced to $1,167 \pm 87 \mu$mol/liter at the 12th week, compared with those before the operation ($p < 0.05$). Individual amino acid fraction is presented in Fig. 7. A marked reduction in serine, proline, glycine, alanine, tyrosine and arginine was observed in the IJT group ($p < 0.05$ or less), compared with those before the operation in the IJT group.
DISCUSSION

In the present study, to investigate the mechanism of intestinal adaptation, ileojejunal transposition was performed in dogs, instead of intestinal resection. It has been demonstrated that ileojejunal transposition, reported by Dowling and Booth (1967), induces intestinal adaptation (Altmann and Leblond 1970; Grönqvist et al. 1975). In the animals subjected to ileojejunal transposition, there is no loss of the intestine and various adaptive changes would be expected in the transposed ileum, similar to those seen in the ileum of animals with resection of the proximal intestine.

One of the most prominent findings observed in the present study was a change in plasma total IRG. The fasting levels of plasma total IRG increased slightly during the course of the experiment. However, the response of plasma total IRG to oral glucose load was much more remarkable. The increased response of plasma total IRG to glucose continued through 12 weeks, when the peak level of plasma total IRG reached 3,700 pmol/liter. These results are consistent with those reported previously as intestinal adaptation in animal models or human subjects (Altman and Leblond 1970; Bloom and Polak 1982).

In the present animal model, an exaggerated response of plasma total IRG was observed during oral glucose load. Furthermore, in insulin-induced hypoglycemia, which stimulates the release of glicentin (Ohneda et al. 1987, 1989), the plasma response of total IRG in the IJT group slightly increased compared with the sham group. This result, therefore, suggests that the release of gut GLI is enormously enhanced in particular by the intraluminal administration of nutrients. These results would indicate the slight increase in fasting plasma total IRG during the course of the experiment.

Chromatographic study using Sephadex G 50 suggests that plasma total IRG released from the gut in response to oral glucose load consists mainly of glicentin. Furthermore, a previous morphological and chemical investigation suggests that the elevated plasma total IRG was derived from the gut (Ohneda 1987b; Sasaki et al. 1987).

The ileum transposed animal model, in which an elevation of plasma glicentin was observed, offers an excellent model to study the biological action of glicentin. As far as glucose metabolism is concerned, glucose tolerance deteriorated transiently and became normalized 12 weeks after ileojejunal transposition. This suggests that glicentin does not affect seriously glucose tolerance, in contrast to glucagonoma syndrome, in which diabetic glucose tolerance was frequently reported (Bhathena et al. 1981).

Plasma total amino acids were markedly decreased in the IJT group. The analysis of plasma amino acid revealed a decrease especially in alanine, glycine, serine and arginine. These results resemble the changes in plasma amino acids observed in glucagonoma syndrome (Mallinson et al. 1974), indicating that
glicentin per se, or related-peptides of glicentin, elicits an increase in gluconeogenesis and reduction of plasma amino acids.

On the other hand, the response of plasma insulin and blood glucose to exogenous glucagon administration did not differ in the IJT group from that in the sham group. The finding was not consistent with the result reported by McGavran et al. (1966), who stated that response of blood glucose and plasma insulin to exogenous glucagon is reduced in glucagonoma syndrome.

In a preliminary study hypertrophy of the gut was observed in the ileum transposed dogs (Sasaki et al. 1987). Concerning the establishment of intestinal adaptation, Loran and Althausen (1958) stated that loss of the intestine releases a factor promoting compensatory hypertrophy of the gut. In the present study, the animals underwent ileum transposition and did not lose any parts of the intestine. Nevertheless intestinal adaptation took place in our animals. Therefore, compensatory mechanism does not work in the changes of the gut observed in the present experiment. In addition, the present study does not support the role of the alteration in the intraluminal conditions, such as pH, pressure and bacterial flora (Grönqvist et al. 1975) in the development of intestinal adaptation.

To the contrary, the changes in the intraluminal nutrients seem much more important in intestinal adaptation. In IJT animals the ileum transposed to the jejunum would be exposed to a large amount of nutrients, this resulting in mucosal hypertrophy, suggested by the experiments with intraileal sugar infusion (Weser et al. 1985, 1986). In the first stage after ileal transposition, secretion of glicentin is exaggerated at the transposed ileum in response to intraluminal passage of a large amount of nutrients. The increase in glicentin secretion might induce cellular hypertrophy of the mucosal layer of the intestine through its trophic action, as suggested by the results reported previously (Gleeson et al. 1971; Bloom and Polak 1982). The hypertrophy of the intestinal mucosa would increase the number or the function of glicentin secreting L cells and results in hypersecretion of glicentin in response to nutrients. Thus an increased secretion of glicentin would make a vicious circle inducing hypertrophy of the intestinal mucosa.

In this process, a role of neurotensin should be considered, because neurotensin is contained much more in the ileum (Polak et al. 1977). Neurotensin might be secreted from the transposed ileum in response to intraluminal passage of nutrients. However, human subjects with intestinal adaptation did not reveal any remarkable rise in plasma neurotensin (Bloom and Polak 1982). Therefore, it seems unlikely that neurotensin plays a role in the course of intestinal adaptation, as glicentin does.

In parallel with L cell hyperplasia, changes in GIP secreting K cells should be considered in the process of intestinal adaptation. As shown in the present study, however, no exaggerated response of plasma GIP was observed at all. Therefore, it seems likely that trophic action of glicentin to the gastrointestinal tract might occur in selective manner and that an elevation of plasma glicentin
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may be one of the mechanisms for mucosal growth.

At present, the physiological roles of glicentin are not known. There was only one case with enteroglucagonoma, which suggests the biological action of glicentin, disturbance of bowel movement and hypertrophy of intestinal mucosa (Gleeson et al. 1971). The present experiment, coupled with the previous study (Ohneda 1987b; Sasaki et al. 1987), indicates clearly that the elevated plasma level of GLI (glicentin) relates to transient glucose intolerance, reduction of plasma amino acids and morphological changes in the intestine. Thus the IJT animal preparation is an appropriate model for hyperenteroglucagonemia and might be an excellent tool for the investigation of glicentin physiology.

References

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