Enhancing the Anti-Dumping Effect of Roux Gastrojejunostomy with Intestinal Pacing

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We wondered whether Roux gastrojejunostomy alone or with intestinal pacing would slow gastric emptying and ameliorate the dumping syndrome after truncal vagotomy and subtotal distal gastrectomy. In five conscious dogs with vagotomy and distal gastrectomy, the Roux loop alone slowed gastric emptying of 100 ml 5% glucose instillates, but not of 100 ml 25% glucose instillates, while pacing the loop backwards slowed emptying of both. Pacing also decreased the postcibal hemoconcentration and hyperglycemia found after the 25% instillates. However, pacing did not alter the postprandial hyper-GIP-emia (gastric inhibitory peptide) and hyperinsulinemia found in Roux gastrectomy dogs, suggesting that pacing worked by slowing emptying of glucose rather than by releasing enteric hormones. Although pacing did not stimulate jejunal action potentials (contractions), the greater the number of action potentials occurring during pacing, the more the slowing ($r = .738$, $p < .001$). We concluded that the combination of Roux gastrojejunostomy and pacing ameliorated postgastrectomy dumping in dogs. The tests provide a basis for treating humans with postgastrectomy dumping.

THE DUMPING SYNDROME is a well recognized complication of vagotomy, gastric resection and gastric drainage procedures. These operations impair the regulation of gastric emptying; gastric chyme empties unduly rapidly into the small intestine after the procedures.[1,2] If the chyme is hypertonic, enterosorption of water occurs, resulting in hemoconcentration and an increase in pulse rate. The patient may complain of sweating with flushing or pallor, epigastric fullness, nausea, borborygmi and diarrhea. Cardiovascular disturbances, such as tachycardia and palpitations, are also common.

Medical regimens for controlling this distressing condition are far from satisfactory, and surgical approaches, such as jejunal interposition and reversal, conversion of Billroth I to Billroth II gastrectomy, and pyloric reconstruction, have variable results.[3,4] Up to 50% of patients have persistent symptoms after reconstructive surgery.

Retrograde electrical pacing of the small bowel may have a role in the treatment of postgastrectomy dumping. Pacing the duodenum backwards slows gastric emptying of isotonic solutions in healthy dogs.[5] Moreover, retrograde duodenal pacing slows gastric emptying of hypertonic instillates in dogs with Billroth I gastrectomy and therefore ameliorates dumping in them.[6] However, pacing does not return the rate of gastric emptying in Billroth I dogs to that found in healthy dogs, so it does not abolish dumping completely.

We wondered whether Roux-en-Y gastrojejunostomy alone or with retrograde pacing of the Roux loop would return gastric emptying to that found in health, and so abolish completely the postgastrectomy dumping syndrome. We found that, while the Roux loop prevented rapid gastric emptying of 5% glucose solutions after gastrectomy, it did not do so when 25% glucose solutions were given. Pacing was also required to restore emptying of 25% glucose solutions to the control.

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Materials and Methods

Animal Preparation

Postgastrectomy dogs. In five healthy female dogs weighing 15 to 18 kg, bilateral truncal vagotomy and two-thirds distal gastrectomy with Roux-en-Y gastrojejunal reconstruction were performed. To construct the Roux loop, the jejunum was divided 15 cm distal to the ligament of Treitz, the distal cut end was closed, and an end-to-side gastrojejunal anastomosis performed just distal to the site of closure (Fig. 1). Jejunal continuity was then restored by anastomosing the proximal cut end of the jejunum to the side of the mid jejunum 40 cm from the gastrojejunal anastomosis. Five monopolar sil-

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ver-silver chloride recording electrodes were implanted on the serosal surface of the Roux loop at 5 cm intervals beginning 10 cm distal to the gastrojejunal anastomosis. Bipolar pacing electrodes attached to an implantable pacing unit were sewn to the Roux loop 5 cm proximal to the end-to-side jejunojejunal anastomosis and 35 cm distal to the gastrojejunostomy. Insulated wires from the recording electrodes led to a radiotube socket mounted in a stainless steel cannula. The cannula was positioned in the left abdominal wall and sewn in place with wire sutures. The implantable pacing unit to which the leads from the pacing electrodes were attached was placed in a subcutaneous pocket on the right side of the abdomen. After surgery, the dogs were maintained on a diet of 2 cans of dog food per day. Tests were begun after a 2-week recovery period.

Control dogs. Five unoperated healthy female dogs of similar weight were used as controls.

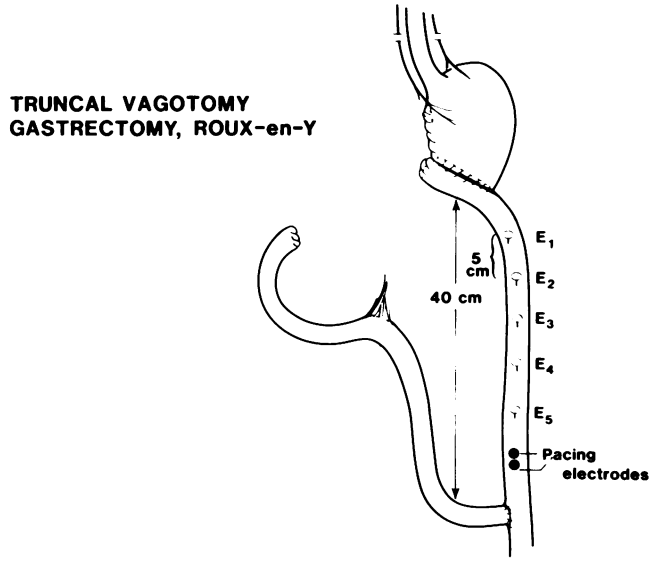

FIG. 1. Canine experimental preparation. E = Recording electrode.

Conduct of Tests

Postgastrectomy dogs. Sixteen gastric emptying tests were performed on each dog on different days. In eight tests, the emptying of a 100 ml gastric instillate of 5% glucose was studied, while in the remaining eight tests 25% glucose was used. With each instillate, four tests with retrograde pacing of the Roux loop alternated with 4 tests without pacing.

After a 24-hr fast, the conscious dog was placed in a Pavlov sling, and leads from the monopolar recording electrodes were attached to channels of an AC coupled chart recorder (Brush 360 Gould instruments, time constant 1 sec). The abdominal cannula was used as the indifferent electrode. A polyethylene catheter was placed transcutaneously into either the superior or the inferior vena cava to allow blood sampling.

The electrical activity of the Roux loop was recorded for at least 30 min before the gastric instillate was given. Ten minutes before giving the instillate, 1 ml of blood was withdrawn for determination of hematocrit, serum glucose, serum immunoreactive gastric inhibitory polypeptide (IR-GIP), and serum immunoreactive insulin. The hormones were measured only in the tests where 25% glucose was used. The pulse in beats/min was also recorded. These parameters were again measured immediately prior to giving the instillate.

An oral-gastric tube was inserted and 100 ml of the 5% glucose or 25% glucose solution marked with ^{14}C-polyethylene glycol (PEG, 4000, New England Nuclear, Boston, MA) was instilled. The tube was then withdrawn. One-ml blood samples for hematocrit, serum glucose, IR-GIP and IR-insulin were withdrawn at 5-min intervals for a period of 20 min and then at 10-min intervals for an additional period of 40 min. Pulse was also recorded at these intervals. Twenty minutes after the instillate was given, the oral-gastric tube was reinserted and the gastric contents were aspirated. The stomach was then washed with 100 ml water and the wash was recovered.

In experiments where retrograde pacing was employed, the frequency of the pacesetter potentials (PP) in the Roux loop was first determined. The frequency was usually 13 cycles/min to 14 cycles/min, which, because of transection of the jejunum, was a frequency slower than 19 cycles/min to 20 cycles/min characteristic of the intact canine proximal jejunum.[7,8] The pacing unit was extrinsically activated 10 to 15 min before the instillate was given and the pulse generator was adjusted to provide stimuli of strength, duration, and frequency great enough to ensure capture of the jejunal pacesetter potentials. The strength was usually about 8 ma, the duration 50 msec, and the frequency 14 to 15 pulses/min. Propagation of pacesetter potentials from the site of stimulation in an orad direction along the entire loop was observed and maintained for at least 10 min before giving the instillate. Pacing was continued during the 20-min period in which the instillate was in the stomach, and terminated after the gastric wash.

Control dogs. Identical studies without pacing were performed four times in each of the five unoperated control dogs using the 5% glucose instillate and four times using the 25% glucose instillate.

Analysis of Data

Gastric emptying. The volume of gastric instillate emptied (V_E) was determined in ml using the following formulae:

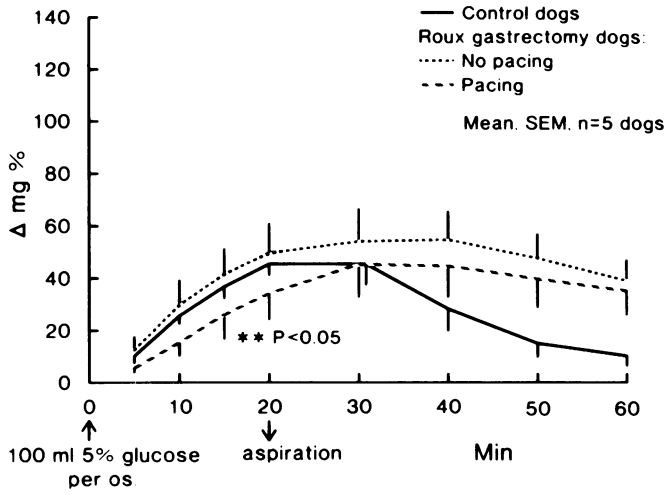

FIG. 2. Effect of Roux gastrectomy and pacing on serum glucose after 100 ml 5% glucose gastric instillate. Basal values: control 96 ± 4, Roux alone 87 ± 2, Roux pacing 83 ± 3. **Differs from control and no pacing curves.

$$V_E = 100 - V_R$$

and

$$V_R = V_A \frac{C_A}{C_I} + V_W \frac{C_W}{C_I}$$

where V_R is the volume (ml) of the original instillate remaining in the stomach after 20 min, V_A is the volume (ml) of the gastric aspirate, V_W is the volume (ml) of the gastric wash, and C_I, C_A and C_W are the concentrations of ^{14}C-PEG in the instillate, aspirate, and wash, respectively. The concentration of ^{14}C-PEG was assessed by scintillation counting using a Beckman apparatus Model LS-3150 T.

Jejunogastric reflux. To assess whether retrograde pacing of the Roux loop caused jejunogastric reflux, the concentration of ^{14}C-PEG in the gastric aspirate at the end of the 20 min was measured and expressed as a percentage of the concentration of ^{14}C-PEG in the original instillate. If reflux occurred, a decrease in the percentage would be expected.

Blood tests. The concentration of glucose in the serum was determined using a Beckman Glucose Analyzer II, and the concentrations of immunoreactive GIP and insulin were determined using radioimmunoassay.[9,10]

Electrical recordings. The percentage of pacesetter potentials associated with action potentials (action potentials trigger contractions) was calculated for the 20-min period in which the instillate was in the stomach. A comparison was made between the percentage during periods of pacing and the percentage during periods without pacing. The occurrence of phase III of the interdigestive myoelectrical complex during the 20-min test period was also noted. The incidence of action potentials was correlated with the rate of gastric emptying.

Statistical tests. The Student's t-test for unpaired data was employed when comparing data from postgastrectomy dogs and controls. The Student's t-test for paired data was used when comparing data within postgastrectomy dogs.

TABLE 1. *Effect of Vagotomy, Distal Gastrectomy and Roux Gastrojejunostomy Alone or with Pacing on Canine Gastric Emptying*

Type of 100 ml Instillate	Mean ± SEM ml Emptied in 20 min*		
	Unoperated Control Dogs	Roux Gastrectomy Dogs	
		No Pacing	Pacing
5% glucose	84 ± 5	70 ± 10	53 ± 10†‡
25% glucose	34 ± 3§	54 ± 10*§	35 ± 9‡

* Of 5 dogs (n = 5). Four tests were done in each dog.
† Differs from control, $p < 0.05$.
‡ Differs from no pacing, $p < 0.05$.
§ Differs from value above, $p < 0.01$.

Results

Effect of Roux Gastrojejunostomy Alone

Five per cent glucose instillates. Roux gastrojejunostomy alone prevented rapid gastric emptying of 5% glucose instillates in dogs after truncal vagotomy and two-thirds distal gastrectomy, and so obviated most of the sequelae of rapid emptying.

Gastric emptying, hematocrit, pulse: The Roux dogs emptied a mean ± SEM of 70 ± 10 ml of the instillate in 20 min, a value similar to the 84 ± 5 ml emptied by unoperated control dogs (Table 1, $p > 0.05$). Moreover, postcibal increases in hematocrit and pulse did not occur in the Roux dogs, just as they did not in the control dogs.

Serum glucose: In control dogs, serum glucose increased rapidly after instillation of the 5% glucose, reached a peak at 30 min after instillation, and then declined promptly toward the basal level (Fig. 2). In Roux dogs, the initial increase and the 30-min value were similar, but the prompt decline after 30 min was not found. Nonetheless, the postgastrectomy curve did not differ overall from the control curve ($p > 0.05$).

Twenty-five per cent glucose instillates. In contrast to the tests with the 5% glucose instillates, Roux gastrojejunostomy did not prevent rapid gastric emptying of 25% glucose instillates after vagotomy and gastrectomy. It also failed to prevent postinstillate hemoconcentration, hyperglycemia, hyper-GIP-emia, or alterations in serum insulin.

Gastric emptying, hematocrit, pulse: The Roux dogs emptied a mean of 54 ± 10 ml in 20 min, a volume greater than that emptied by the controls (34 ± 3 ml,

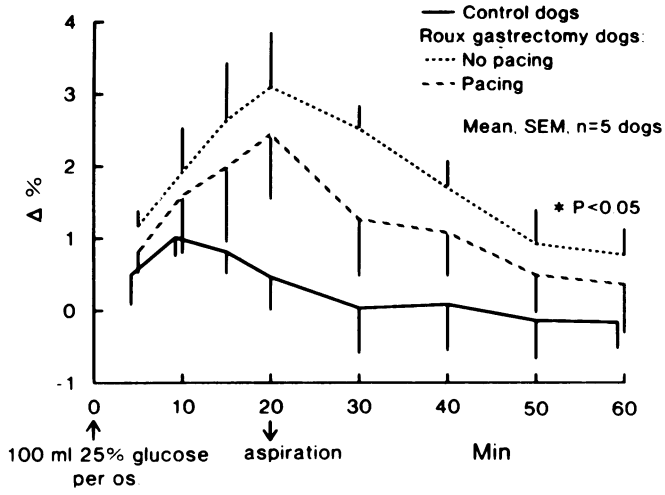

FIG. 3. Effect of Roux gastrectomy and pacing on hematocrit after 100 ml 25% glucose gastric instillate. Basal values: control 36 ± 1, Roux alone 28 ± 3, Roux pacing 28 ± 3. *Differs from control curve.

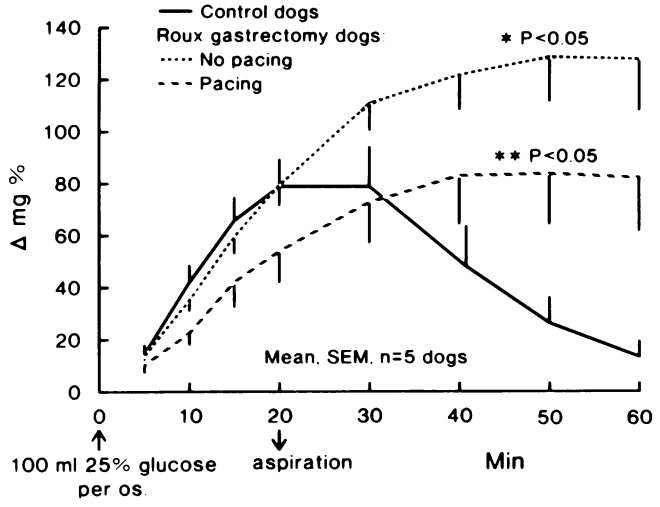

FIG. 5. Effect of Roux gastrectomy and pacing on serum glucose after 100 ml 25% glucose gastric instillate. Basal values: control 96 ± 3, Roux alone 90 ± 3, Roux pacing 88 ± 8. *Differs from control curve. **Differs from control and no pacing curve.

$p < 0.05$, Table 1). Moreover, a greater postcibal increase in hematocrit occurred in Roux dogs than in control dogs ($p < 0.05$, Fig. 3). A larger increase in postcibal pulse also appeared to occur in Roux dogs compared to control dogs, although the two curves did not differ when the t-test was applied ($p > 0.05$, Fig. 4).

Serum glucose: In control dogs, an initial prompt postinstillate increase in serum glucose was followed by a peak at 30 min and then a rapid decline, just as with 5% glucose instillates (Fig. 5). However, the peak was greater with the 25% instillates. In the Roux dogs, the initial increase after giving the instillates was similar to that of the controls, but after the residuum of the instillate was aspirated at 20 min, serum glucose levels continued to rise. They remained markedly elevated for the duration of the test ($p < 0.05$).

Serum hormones: In the controls, serum IR-GIP increased promptly after giving the instillates, peaked at 20 min, and then declined toward the basal levels (Fig. 6). Although the initial rate of increase in the Roux dogs was similar, the overall pattern was different ($p < 0.01$), the levels remaining elevated after the residuum of the glucose instillate was aspirated from the stomach at 20 min.

Serum insulin also increased promptly in the control dogs, just as GIP did (Fig. 7). However, insulin reached a peak at 30 min after the instillates, whereas GIP peaked

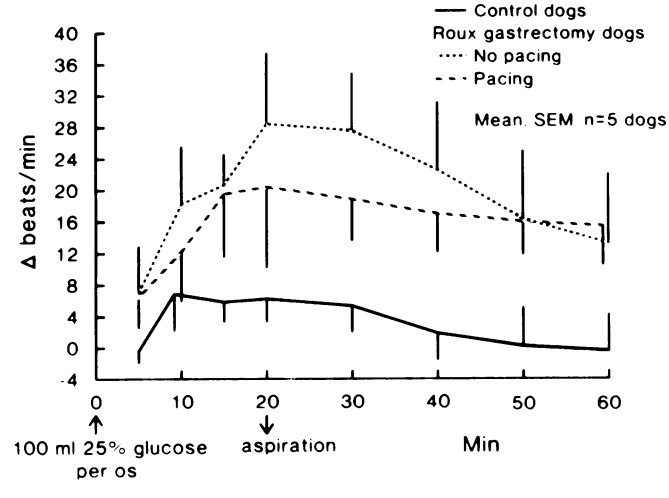

FIG. 4. Effect of Roux gastrectomy and pacing on pulse after 100 ml 25% glucose gastric instillate. Basal values: control 71 ± 5, Roux alone 61 ± 6, Roux pacing 64 ± 8. Curves do not differ, $p > 0.05$.

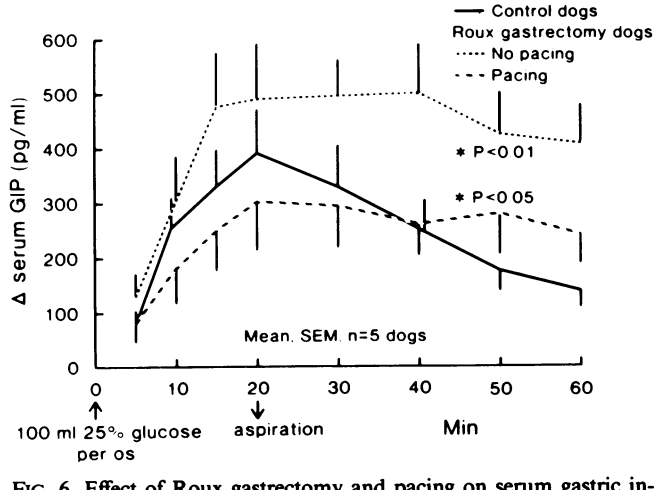

FIG. 6. Effect of Roux gastrectomy and pacing on serum gastric inhibitory polypeptide after 100 ml 25% glucose gastric instillate. Basal values: control 236 ± 25, Roux alone 243 ± 31, Roux pacing 236 ± 27. *Differs from control curve.

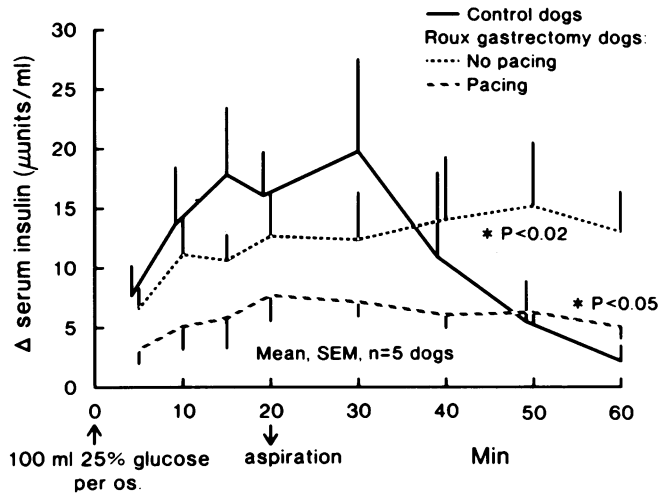

FIG. 7. Effect of Roux gastrectomy and pacing on serum insulin after 100 ml 25% glucose gastric instillate. Basal values: control 3 ± 1, Roux alone 2 ± 1, Roux pacing 2 ± 1. *Differs from control curve.

at 20 min. Insulin then declined promptly toward basal levels. In the Roux dogs, the increase during the initial 30 min was similar to that of the controls, but the overall pattern was different ($p < 0.02$). Just as with serum GIP, the concentration of insulin in the serum of the Roux dogs remained elevated after aspirating the residual instillate at 20 min.

Effect of Roux Gastrojejunostomy with Pacing

Five per cent glucose instillates. Pacing the Roux loop backwards slowed the rate of gastric emptying of 5% glucose compared to the unpaced loop, and resulted in less postcibal hyperglycemia.

Gastric emptying: With pacing the Roux dogs emptied a mean of 53 ± 10 ml in 20 min, a volume less than the 70 ± 10 ml found in Roux dogs without pacing ($p < 0.05$) and less than the 84 ± 5 ml found in controls ($p < 0.05$, Table 1). The concentration of ^{14}C-PEG in the gastric aspirate with retrograde pacing was 71 ± 4% of that of the original instillate and without pacing 66 ± 7% ($p > 0.05$). Thus, pacing slowed emptying without increasing dilution of the gastric marker.

Hematocrit and pulse: As in "no pacing" and control studies, pacing had little effect on pulse and hematocrit when the 5% instillate was used.

Serum glucose: With retrograde pacing, the postcibal increase in serum glucose after giving the 5% instillate was slightly less than in control ($p < 0.05$) and "no pacing" tests ($p < 0.05$, Fig. 2), but the levels remained elevated after aspiration of the instillate, just as in tests on the Roux dogs without pacing.

Twenty-five per cent glucose instillates. Pacing the Roux loop backwards restored the rate of gastric emptying of hypertonic glucose solutions to that of unoperated control dogs, prevented hemoconcentration, and ameliorated postcibal hyperglycemia.

Gastric emptying: Pacing the loop slowed gastric emptying to a mean of 35 ± 9 ml, a volume almost identical to the volume emptied by the control dogs (34 ± 3 ml, $p > 0.05$, Table 1). The concentration of ^{14}C-PEG in the gastric aspirate was 56 ± 4% of that in the original instillate with retrograde pacing and 53 ± 6% in "no pacing" studies ($p > 0.05$). Thus, pacing slowed emptying of 25% glucose instillates without increasing dilution of gastric marker, just as was the case when 5% instillates were given. However, more dilution of marker occurred with the 25% instillates (56%) than with the 5% instillates (71%, $p < 0.05$). Moreover, 50% of the gastric aspirates were bile stained in the Roux gastrectomy dogs when the 25% instillate was used, whereas only 16% of aspirates were bile stained with the 5% instillate ($p = 0.002$). Similarly, in control dogs, 65% of the aspirates were bile stained with the 25% instillate, whereas 33% were bile stained with the 5% instillate ($p = 0.05$).

Hematocrit and pulse: Retrograde pacing also prevented the postcibal increase in hematocrit that occurred in Roux dogs without pacing. The changes in hematocrit and pulse observed after giving the 25% instillate in paced Roux dogs did not differ from controls ($p > 0.05$, Figs. 3 and 4).

Serum glucose: Pacing the Roux loop slowed the initial rate of increase in serum glucose compared to Roux gastrectomy alone ($p < 0.05$, Fig. 5). Also, the overall increase in serum glucose was less than in the "no pacing" studies ($p < 0.05$). However, the serum glucose did not decline after 30 min in the Roux dogs with pacing, so that the curve with pacing still differed from that of the control dogs ($p < 0.05$).

Serum hormones: Pacing the Roux loop after gastrectomy did not greatly alter the postcibal pattern of serum IR-GIP or serum IR-insulin compared to Roux gastrectomy alone (Figs. 6 and 7). Pacing appeared to minimize the increase in the serum concentrations of the two hormones, but analysis of the curves showed no clear-cut change from Roux gastrectomy alone ($p > 0.05$). The concentrations of the hormones in the serum remained elevated in the paced Roux dogs after aspiration of the remaining instillate at 20 min, just as in the unpaced Roux dogs, so that the linear trends of the curves in the paced Roux dogs still differed from those of the unoperated control dogs ($p \leq 0.05$).

Electrical Activity

Frequency of pacesetter potentials. Recordings from all the electrodes appeared similar. Therefore, only those from Electrode 1, 10 cm distal to the gastrojejunal anas-

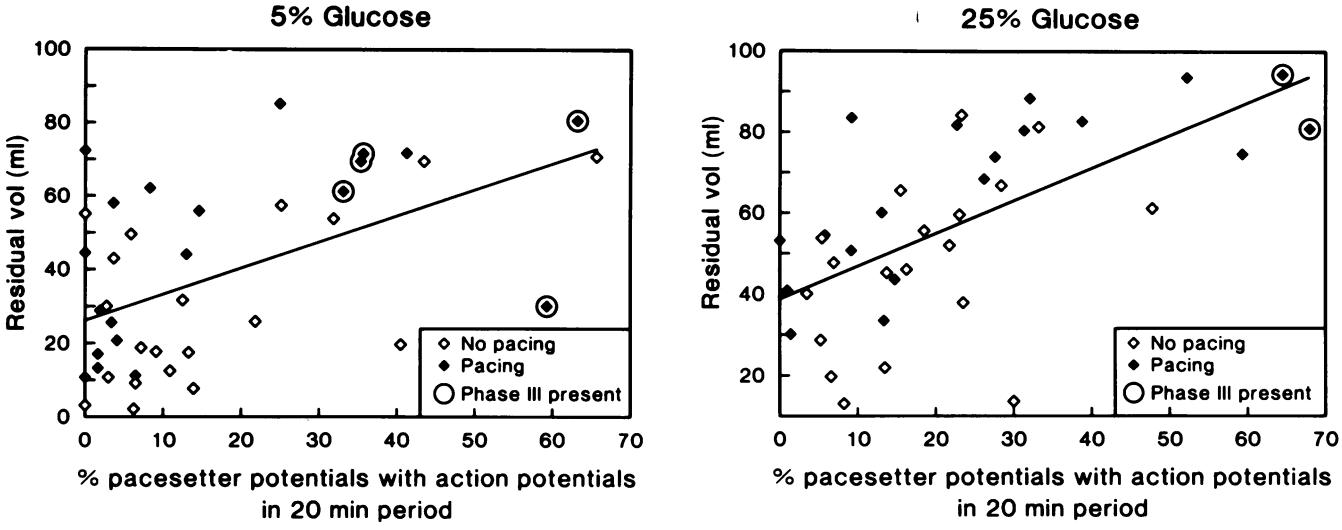

FIG. 8. Residual volume of gastric instillate against per cent of pacesetter potentials with action potentials. Left: 100 ml 5% glucose instillate ($r = 0.531$, $p < 0.001$). Right: 100 ml 25% glucose instillate ($r = 0.628$, $p < 0.001$).

tomosis, were analyzed in detail. In the postgastrectomy dogs without pacing of the Roux loop, the frequency of the pacesetter potentials before giving the 5% instillate was 13.5 ± 0.5 cycles/min and before the 25% instillate was 13.4 ± 0.4 cycles/min. After giving either instillate, there was no consistent change in the frequency ($p > 0.05$), nor did aspiration cause any change.

With retrograde pacing, the frequency of the pacesetter potentials increased from 13.3 ± 0.4 cycles/min to 14.6 ± 0.3 cycles/min when the 5% instillates were used ($p < 0.001$) and from 13.3 ± 0.3 cycles/min to 14.9 ± 0.3 cycles/min when the 25% instillates were used ($p < 0.001$). When pacing was discontinued, the frequency returned to prepacing rates with the 5% instillates, but remained slightly faster at 13.9 ± 0.2 cycles/min with the 25% instillates ($p < 0.05$).

Action potentials. Correlation with emptying: The relationship between the percentage of pacesetter potentials with action potentials during the 20-min period in which the instillates were in the stomach and the rate of gastric emptying was analyzed. We found that the greater the percentage of pacesetter potentials with action potentials, the slower the rate of gastric emptying (Fig. 8). This was true for both 5% glucose instillates ($r = 0.531$, $p < 0.001$) and 25% glucose instillates ($r = 0.628$, $p < 0.001$). When the intense bursts of action potentials of Phase III of the interdigestive myoelectric complex occurred in the Roux loop during the 20-min test period with pacing, gastric emptying was usually especially slow. Phase III occurred more often with the 5% instillate (five times) than with the 25% instillate (two times).

Influence of pacing: Retrograde pacing had no effect on the percentage of pacesetter potentials with action potentials during the 20-min period when the instillates were in the stomach. The percentages when the 5% glucose instillate and the 25% glucose instillate were in the stomach without pacing were 16 ± 4% and 19 ± 3%, respectively, and these values did not differ from the corresponding percentages during pacing (18 ± 5% and 26 ± 5%, $p > 0.05$).

Discussion

This study has demonstrated that retrograde pacing of a canine Roux loop after gastrectomy and Roux-en-Y gastrojejunostomy can effectively retard the rate of gastric emptying of a 25% glucose instillate. This results in a reduction in postcibal hemoconcentration and hyperglycemia. These findings suggest that Roux-en-Y gastrojejunostomy and retrograde intestinal pacing with implanted pacing units may have a role in the treatment of the postgastrectomy dumping syndrome in clinical practice. Patients with dumping could slow emptying and prevent dumping by pacing in the postprandial period, after which they could turn the pacer off to let gastric residue and debris empty from the stomach. The slowing of gastric emptying at will by pacing would have an advantage over the permanent, uncontrolled slowing produced by operations such as reversed jejunal interposition.

Others have shown that postgastrectomy Roux-en-Y reconstruction alone is of some benefit in ameliorating the dumping syndrome,[3,4] and the findings from this study confirm that. With an isotonic instillate (5% dextrose), gastric emptying was no faster in Roux gastrectomy dogs than in dogs with intact stomachs. As chyme in the human stomach is usually isotonic, the rate of gastric emptying of most meals after Roux-en-Y recon-

struction should be similar to that in an unoperated healthy stomach, and so dumping should be minimal.

However, as this study has illustrated in dogs, gastric emptying of hypertonic solutions (25% dextrose) is more rapid after Roux gastrectomy than in the unoperated stomach. Even though hypertonic instillates emptied more slowly than isotonic instillates in postgastrectomy dogs, hypertonic solutions emptied more rapidly after gastrectomy than in health. Presumably, in patients with Roux gastrectomy, when the gastric chyme is hypertonic, rapid gastric emptying and the features of dumping will occur. Pacing the Roux loop might return the rate of gastric emptying of hypertonic solutions to normal in such patients and prevent features of dumping.

In a previous study on the effect of retrograde pacing on canine gastric emptying from our laboratory,[6] no gross changes in the concentration of ^{14}C-PEG gastric marker occurred between the pacing and no pacing studies, suggesting that pacing did not cause jejunogastric reflux. This was also found to be the case in the present study with both test meals. It was noted, however, that some dilution of the aspirate did occur, and this was more marked when the 25% instillate was used. Bile staining of the aspirate was also more common with the 25% meal in both postgastrectomy dogs and in healthy dogs, suggesting that the hypertonic meal encouraged reflux of bile back into the stomach, irrespective of whether pacing was used, and even when the antro-pyloric barrier to reflux was intact.

The serum glucose levels in the Roux gastrectomy dogs remained elevated after aspiration of the instillate, whereas, the levels in controls reverted toward the baseline. In the Roux gastrectomy dogs, a much larger volume of the 25% glucose solution was presented to the jejunum during the 20 min the instillates were in the stomach, accounting in part for the postcibal hyperglycemia. In addition, pooling of the instillate in the proximal gut may also have occurred in the postgastrectomy dog, as shown by Mayer, et al.[11] When the residuum of the instillate was aspirated from the gastric remnant, the volume which was "dumped" into the Roux loop and pooled there continued to be absorbed, resulting in prolonged elevation of serum glucose.

It is more difficult to explain why the glucose levels remained elevated after aspiration of the instillates in the paced dogs. The same amount of instillate was emptied in Roux gastrectomy dogs with pacing as in control dogs. It may be that in the Roux gastrectomy dogs, pacing caused even more pooling of the instillate in the Roux loop than occurred after gastrectomy alone. We know from previous work that pooling of intraluminal content occurs with retrograde pacing.[12] This most likely diminished the area of small bowel available for absorption, therefore retarding the rate of absorption. Perhaps when pacing was terminated in these tests, the instillate then passed distally into a larger area of bowel and continued to be absorbed, hence the persistent late elevation in the serum glucose compared with controls.

We wondered further whether these changes in serum glucose seen with pacing might also be explained in part by pacing-induced augmented release of GIP. Gastric inhibitory polypeptide is located in the K cells of the duodenal and jejunal mucosa and is released when glucose, fat, peptones, and amino acids are absorbed across the mucosa. Once released, GIP, in turn, augments insulin release from the pancreas. Hyperglycemia is essential for IR-GIP to be insulinotropic when glucose and fat are ingested.[13] In our control tests, serum GIP levels increased in response to the 25% instillate. This, together with the postcibal hyperglycemia, resulted in an increase in insulin output which, in turn, caused a lowering of the serum glucose levels. When the residuum of the instillate was aspirated from the stomach, there was likely little or no glucose left in the small bowel. The serum levels of glucose fell due to insulin-induced catabolism. Because there was no more sugar to be absorbed, both GIP and insulin levels subsequently fell also.

In Roux gastrectomy dogs without pacing, there was an even larger increase in serum GIP in response to the instillate than in the controls, because a larger glucose load was "dumped" into the Roux loop. When the residuum of the instillate was aspirated from the gastric remnant at 20 min, the glucose which was in the Roux loop continued to stimulate GIP output, and, as absorption was continuing, the sustained hyperglycemia and the sustained GIP output continued to stimulate insulin release. This explains why serum glucose, GIP, and insulin remained elevated throughout the second half of the study period.

With retrograde pacing, the amount of glucose "dumped" into the Roux loop was less. This produced a lower rate of glucose absorption and an apparent lower mean rate of GIP and insulin release. However, because of greater variability in the GIP and insulin data, the GIP and insulin responses in the pacing tests did not differ from those in the "no pacing" tests. Again, after aspiration of the residual gastric instillate, absorption of glucose pooled in the proximal small bowel continued, causing a sustained output of GIP and insulin until the end of the test period. Thus, the tests show that the reduction in hyperglycemia with pacing was not likely due to pacing-induced release of GIP and insulin. The amount of GIP and insulin released with pacing was not greater than that released without pacing. Rather, the diminished hyperglycemia with pacing occurred because gastric emptying of glucose was slowed.

The percentage of pacesetter potentials with associated action potentials was inversely proportional to the

amount of instillate of either test meal emptied from the stomach whether or not retrograde pacing of the Roux loop was employed. Also, when Phase III of the IDMEC occurred in the loop during the 20-min test period, gastric emptying was especially slow. Interdigestive electrical patterns were seen more often with the 5% than with the 25% instillate, probably because the hypertonicity of the latter inhibited the interdigestive cycles. With vagotomy, the interdigestive pattern may not always be interrupted after a meal.[14,15]

Previous studies from this institution[16] have shown that in dogs with an isolated, but myoelectrically continuous jejunal segment, transit of glucose and saline through the segment was longest during Phase I and shortest during phase III of the interdigestive cycle. One might have expected that in this study the increase in action potentials (contractions) during phase III would have encouraged more rapid gastric emptying. However, Weisbrodt et al.[17] showed that, when duodenal contractions were numerous and antral contractions infrequent, canine gastric emptying was slow. They explained this on the basis that duodenal contractions offered resistance to gastric outflow. These findings are in keeping with ours. In the present study, the rate of gastric emptying decreased as the incidence of action potentials, hence the amount of resistance offered by the Roux loop, increased.

The instillation of either 5% or 25% glucose into the gastric remnant had no effect on the frequency of pacesetter potentials in the Roux loop, nor did aspiration of the stomach at the end of 20 min. As expected, retrograde pacing increased the frequency and reversed the direction of propagation of the pacesetter potentials. However, pacing did not increase the number of action potentials, so that it must have produced its effect on gastric emptying by increasing frequency and/or reversing the direction of propagation of the pacesetter potentials. Nonetheless, Phase III, which seemed to have a maximal slowing effect on gastric emptying, was propagated in an aborad direction whether or not retrograde pacing of an intestinal loop was employed. This was also observed by Sarr, et al.[18] Thus, the magnitude of contractile activity in the Roux loop and the direction of contractile propagation both influence the rate of gastric emptying.

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DISCUSSION

DR. EDWARD M. COPELAND, III (Gainesville, Florida): If you have electrodes on the Roux-Y limbs, in a paced and not-paced setting, you could potentially answer one of Dr. Vogel's questions about vagotomy and its effect on electrical activity. I would like to ask you what those electrical tracings were in your Roux-Y limbs.

E. R. WOODWARD, M.D. (Gainesville, Florida): The authors present additional information on the electrophysiology of smooth muscle. Our knowledge on this subject has lagged far behind that of the myocardium and even that of skeletal muscle. The important contributions of this group continue to close the gap.

Solid phase emptying is usually delayed in the vagotomized patient with a Roux-en-Y reconstruction. We have used this method for the