

Alimentary tract and pancreas

Effects of nutrient liquids on human gastroduodenal motor activity

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SUMMARY The effects of intragastric infusion of 10% Intralipid and 10% dextrose on the intraluminal pressures in the antrum, pylorus and duodenal bulb have been examined. Ten studies with each infusate have been performed in 10 normal subjects and the results compared with those obtained previously in 22 studies during intragastric infusion of isotonic saline. During saline infusion, contractile activity varied. In six studies fasting motor activity persisted; in the remainder, variable activity, without recognisable pattern was recorded. With saline, the gastroduodenal region usually functioned as a unit and the pylorus was the least autonomous part. Neither a sustained rise of basal pressure nor rhythmic, independent contractions were recorded from the pylorus. The contractile activity of the gastroduodenal region with Intralipid and dextrose was more uniform than with saline. Fasting motor activity was always abolished. The gastroduodenal region ceased to contract as a unit and the pylorus acquired autonomous activity. Rhythmic, independent contractions of the pylorus were recorded in nine of 10 studies during Intralipid infusion and six of 10 studies with dextrose. In addition, a sustained rise in pyloric basal pressure was recorded in eight of 10 studies with Intralipid and three of 10 studies with dextrose. Pyloric motility indices were significantly greater with fat than with dextrose. The observed differences in gastroduodenal motility are consistent with a role for the pylorus in the control of emptying of liquid from the stomach.

Disagreement persists concerning the motility of the pylorus and gastroduodenal region. In dogs¹ and man^{2,3} a raised basal pressure which was increased by intraduodenal infusion of fat or acid, has been recorded from the pylorus by some workers. Using the same techniques, however, others have failed to reproduce these results.⁴⁻⁸ Berger,⁹ using a photoelectric device to register closure of the pylorus, showed that the normal human pylorus was usually open and contracted only when a contraction passed through the gastroduodenal region. Thus the pylorus does not appear to have an independent action and the whole gastroduodenal region acts as a unit.

In a recent study¹⁰ we have used a different technique to obtain recordings of intraluminal pressure simultaneously from the antrum, pylorus, and duodenal bulb of normal subjects during intragastric infusion of isotonic saline. Under these

conditions the pylorus did not have an independent action. The studies with saline represent the effects of distension of the gastroduodenal region by an inert liquid. We have now used the same technique to examine the effects of distension with two nutrient liquids, 10% Intralipid and 10% dextrose. The effects of saline, fat and dextrose on gastroduodenal motility have been compared.

Methods

SUBJECTS

All subjects were healthy volunteers. In the previous study with saline infusion¹⁰ 22 recordings were obtained from 15 subjects. In the present study, pressure recordings were obtained in 10 subjects with intragastric infusion of 10% Intralipid and 10 subjects with intragastric infusion of 10% dextrose.

MEASUREMENT OF INTRALUMINAL PRESSURE

The details of the technique have been described previously.¹⁰ The method uses the change in trans-

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mucosal potential difference that occurs at the pylorus⁵ to help position a set of three perfused open ended pressure recording tubes within the pylorus. Figure 1 explains the principle of the method. The position of the tubes may be monitored throughout the recording by continuous potential difference measurement and intraluminal pressures may be recorded continuously from the antrum, pylorus, and duodenal bulb.

After a four hour fast, the set of pressure recording tubes was passed through the subject's nose and his duodenum intubated. Throughout the study the subject lay on his right side. Intra-gastric infusion of either 10% Intralipid or 10% dextrose and the pressure recordings were begun simultaneously. The infusates were infused at the same rate (1 litre per hour) as the saline during our previous study.¹⁰ The set of tubes was withdrawn slowly until correctly positioned according to potential difference measurements and then anchored to the nose with adhesive tape. Its position was monitored by potential difference measurements and adjusted whenever necessary during the pressure recording. Recordings were obtained for as long as possible.

With this technique, good quality, continuous recordings may be obtained from the pylorus. Slight movements of the tubes within the pylorus are indicated by drifts in the potential difference readings. These movements can usually be corrected by minor adjustments to the position of the tubes without affecting the pressure recordings. Once the correct position is lost it cannot usually be regained because the tubes are rapidly ejected from the duodenum. The large variation in the length of recordings is indicative of the difficulties inherent in the method.

To help interpret the pressure recordings, a

simultaneous radiological and manometric study was performed. Fifty percent barium sulphate in Intralipid was infused into one subject. While pressure recordings were obtained, the movements of the gastroduodenal region were observed fluoroscopically and recorded on videotape. To limit the dose of radiation to the subject, screening was performed for three minutes only.

ANALYSIS OF THE RECORDINGS

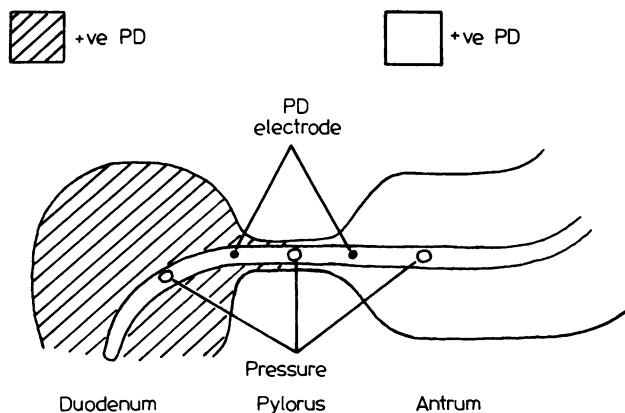
All recordings, obtained while the tube was positioned correctly were analysed. The incidence of contractions per minute was calculated and the amplitude of each pressure wave was measured to the nearest centimetre of water. The total area under the pressure waves on each recording was measured by counting the number of millimetre squares and a motility index was calculated and expressed as mm² per minute.

The results of the original study with saline and the present studies with Intralipid and dextrose, have been compared statistically using Wilcoxon's rank sum test, Student's *t* test and χ^2 or Fisher's exact test.

Results

The quality and duration of recordings obtained with the three different infusates were similar. In the previous study with isotonic saline, recordings were obtained for five to 45 minutes (mean 17 minutes). During 10% Intralipid and 10% dextrose, recordings were obtained for five to 48 minutes (mean 24 minutes) and 11 to 49 minutes (mean 26 minutes), respectively. In the study with saline 265 antral, 213 pyloric and 833 duodenal pressure waves were recorded in a total recording time of 382 minutes. During Intralipid infusion 12 antral, 345 pyloric and

Fig. 1 Diagram showing the correct position of pressure recording tube and arrangement of pressure openings and potential difference electrodes. If two potential difference electrodes are positioned so that one records positive potential difference and other records negative potential difference, the pressure opening between them will lie within the pylorus. Other pressure openings will lie in antrum and duodenal bulb.



207 duodenal waves were recorded in a total of 240 minutes and with dextrose, 95 antral, 247 pyloric and 287 duodenal waves were recorded in 269 minutes. Artefacts, due to movements of the subject, coughing, sneezing or talking, occupied 0.4, 0.5, and 0.3 percent of the recordings during saline, fat and dextrose, respectively.

INTERPRETATION OF THE PRESSURE RECORDINGS
The vast majority of pressure waves recorded by perfused open ended tubes are simple spikes, superimposed on the low amplitude (3–6 cm water), high frequency (15–20 per minute) waves produced by ventilation. The spike-like phasic pressure waves are produced only by contractions that close the gut wall onto the tubes and occlude the pressure openings.^{10 11} Weak contractions, that do not occlude the lumen of the gut, are not recorded by open ended tubes.

The basal pressure is the end-expiratory pressure and with the equipment used, its amplitude is determined by the difference in height between the fluid level in the stomach and the transducer. Usually, it is stable and is not raised before the arrival of a phasic pressure wave. A sustained rise in basal pressure is produced by a tonic contraction that occludes an opening in the tube.

PATTERN OF CONTRACTILE ACTIVITY

During the previous study with saline,¹⁰ a variety of contractile activity was recorded. In five of 22 recordings all three phases of the fasting migratory motor complex were identified. Burst activity, characteristic of phase III of the migratory motor complex was recorded in a sixth. In the remaining recordings no pattern could be identified; contractile activity ranged from absence to frequent but irregularly occurring contractions of variable amplitude.

In contrast, during fat infusion no activity characteristic of the fasting migratory motor complex was recorded. In nine of 10 recordings, after an interval without any activity, frequent, rhythmic contractions of the pylorus appeared five to 17 minutes after the start of the infusion (Fig. 2). The activity persisted for most of the remainder of the recordings (five to 38 minutes) in eight cases and only briefly (1 minute 22 seconds) in one.

Hypertonic dextrose, like fat, abolished fasting motor activity. In five of 10 recordings dextrose initially abolished gastroduodenal contractions but, in the remainder, contractions persisted. In six of 10 recordings, frequent, rhythmic contractions of the pylorus appeared five to 24 minutes after the beginning of the dextrose infusion (Fig. 3). This activity was intermittent, with episodes lasting two

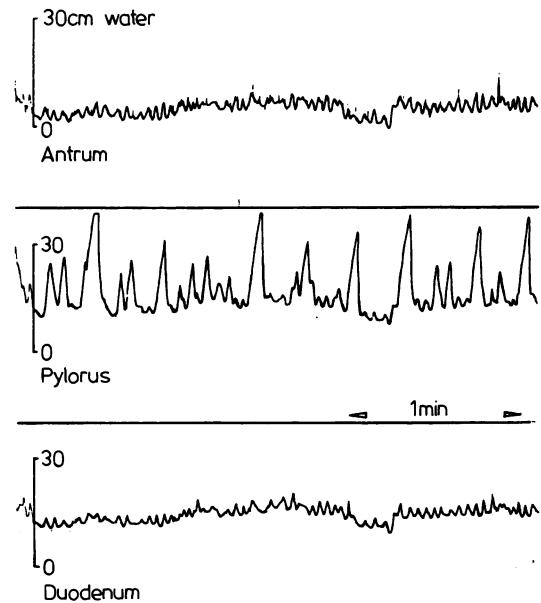


Fig. 2 Pressure recording during intragastric infusion of 10% Intralipid showing frequent, rhythmic contractions of the pylorus.

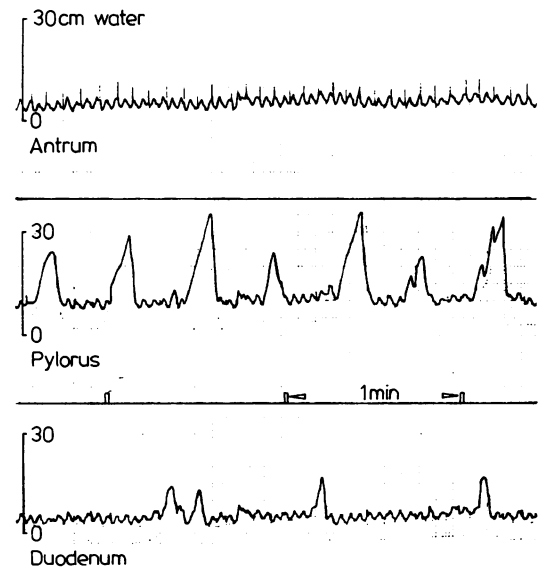


Fig. 3 Pressure recording during intragastric infusion of 10% dextrose showing frequent, rhythmic contractions of pylorus.

to 21 minutes. In two subjects, frequent, regular antral contractions appeared, in one, duodenal contractions only and in the remaining subject, no contractions at all were recorded.

SYNCHRONISATION OF GASTRODUODENAL CONTRACTIONS

In the study with saline infusion, two types of activity could be recognised: independent contractions of the individual parts of the gastroduodenal region (Figs. 4 and 5) and concerted contractions of the whole region (Fig. 6). The two types of activity were equally common.

Simultaneous radiological and manometric recordings with 50% barium sulphate suspension revealed the events that produced these different types of activity.¹⁰ Contractions arising in the proximal stomach progressed distally. When powerful contractions (>10 cm water) reached the terminal antrum, the terminal antrum, pylorus and duodenum contracted together. This concerted contraction was recorded as pressure waves in all three parts of the gastroduodenal region. Weak (<10 cm water) progressive contractions faded as they reached the terminal antrum and were recorded as independent antral pressure waves.

In contrast with saline, concerted contractions of the whole gastroduodenal region were never

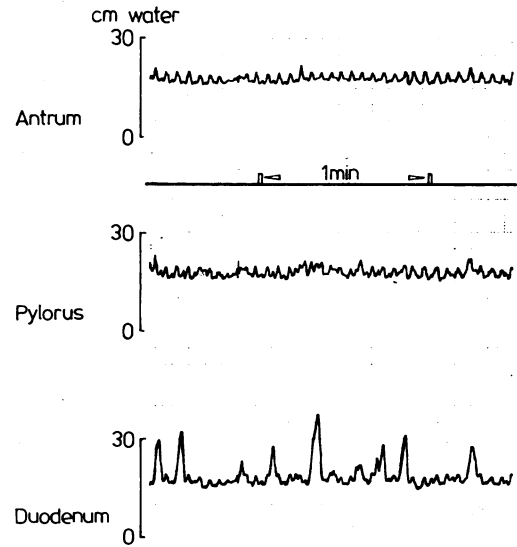


Fig. 5 Pressure recording during intragastric infusion of isotonic saline showing independent duodenal contractions.

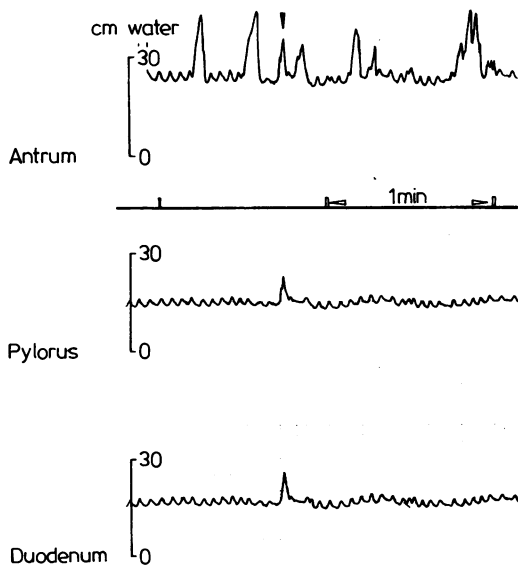


Fig. 4 Pressure recording during intragastric infusion of isotonic saline showing independent contractions of antrum. Arrow indicates artefact caused by sighing.

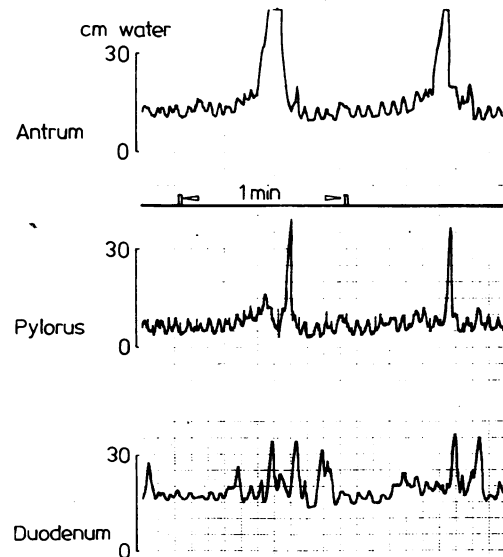


Fig. 6 Pressure recording during intragastric infusion of isotonic saline showing two concerted contractions of whole gastroduodenal region.

recorded during fat or dextrose infusion. In nine of 10 recordings with fat and six of 10 recordings with dextrose, rhythmic, independent pyloric contractions were recorded (see Figs. 2 and 3). With saline, rhythmic, independent contractions of the antrum and duodenal bulb were common but were never recorded from the pylorus; independent pyloric contractions were always sporadic.

When barium sulphate suspension in Intralipid was infused, simultaneous radiological and manometric recordings were obtained during a period of rhythmic independent pyloric contractions. The antrum and duodenum appeared inert and distended with contrast and despite rhythmic contractions of the pylorus, neither were seen to contract.

Analysis of the recordings obtained with saline indicated that contractions of adjacent parts of the gastroduodenal region were related if the more distal part contracted within 11 seconds of its proximal neighbour. The pylorus lies between the antrum and duodenum, therefore, its contractions may be related to both antral and duodenal contractions.

If contractions were separated by more than 11 seconds, they were unrelated or independent.¹⁰ A similar analysis, applied to the recordings obtained with Intralipid and dextrose, produced results similar to those of saline. Therefore, the same classification of pressure waves was applied to all recordings.

During saline infusion, the pylorus was the least autonomous part of the gastroduodenal region. Sixty-four per cent of pyloric waves were related to the antrum and 80% were related to the duodenum. Thus, if an antral contraction resulted in a pyloric

contraction, a concerted contraction of the whole gastroduodenal region usually occurred. In contrast, during fat and dextrose infusion, the pylorus was the most autonomous part. With Intralipid, only 1% of pyloric waves was related to an antral contraction and 16% to a duodenal contraction. With dextrose, only 6% of pyloric waves were related to an antral contraction and 39% to a duodenal contraction. These differences between saline and fat or dextrose are very highly significant ($p < 0.0005$, χ^2 test).

The alterations in gastroduodenal synchronisation produced by the different infusates are reflected in changes in the incidences of contraction. Compared with saline, fat produced a significant reduction in the incidence of antral ($p < 0.01$) and duodenal ($p < 0.05$) contractions and a significant increase in the incidence of pyloric contractions ($p < 0.02$, Wilcoxon's rank sum test). Compared with saline, dextrose significantly reduced the incidence of antral contractions ($p = 0.02$). When fat and dextrose were compared, there were no significant differences in the incidence of contractions.

BASAL PRESSURES AT THE PYLORUS

A sustained rise in basal pressure was not recorded from the pylorus during isotonic saline infusion. In contrast, a raised basal pressure at the pylorus was recorded in eight of 10 recordings during Intralipid infusion (Fig. 7) and three of 10 recordings during dextrose infusion (Fig. 8). These differences between saline and fat ($p < 0.00001$) and saline and dextrose ($p = 0.048$, Fisher's exact test) are significant. Regular phasic contractions were often superimposed on the rises in basal pressure (Figs. 9 and 10). The maximum rise of basal pressure in each recording ranged from 5–26 cm water with fat and

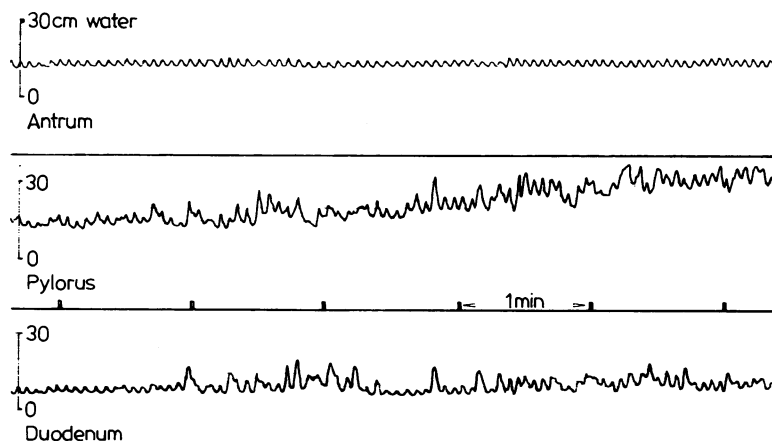


Fig. 7 Pressure recording during intragastric infusion of 10% Intralipid showing rise in pyloric basal pressure.

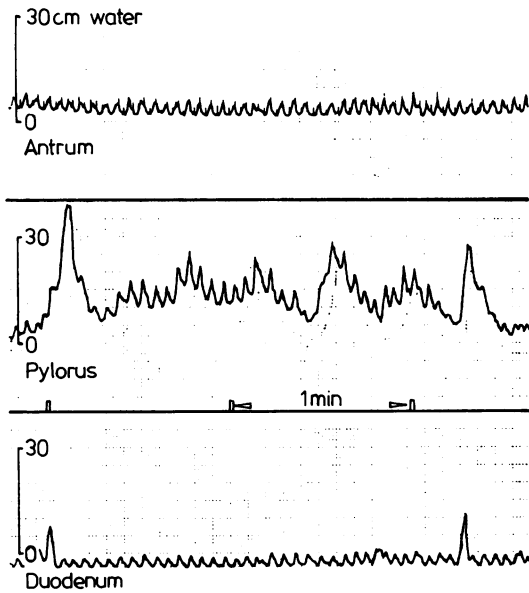


Fig. 8 Pressure recording during intragastric infusion of 10% dextrose showing intermittent rise of pyloric basal pressure.

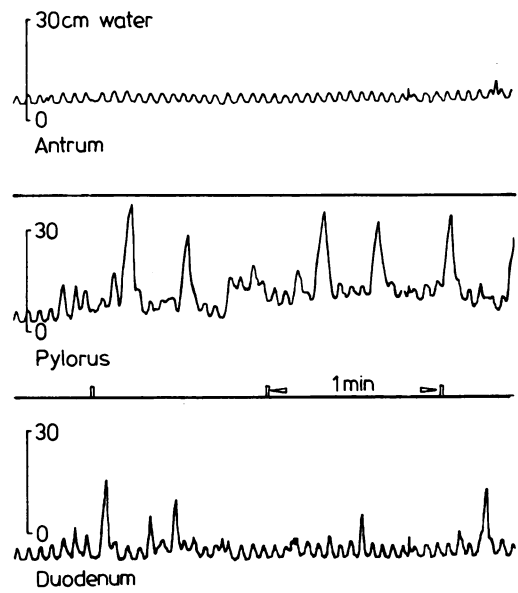


Fig. 10 Pressure recording during intragastric infusion of 10% dextrose showing regular, phasic contractions superimposed on rise of pyloric basal pressure.

7-15 cm water with dextrose. The rises of pyloric basal pressure were intermittent and were sustained for 44 seconds to 23 minutes 10 seconds with fat and 1 minute 8 seconds to 6 minutes 48 seconds with dextrose.

AMPLITUDE OF THE PRESSURE WAVES

The amplitude of the pressure waves with each infusate are listed in the Table. With saline infusion, related contractions were significantly stronger than

unrelated contractions in all parts of the region but, during fat and dextrose infusion, the differences in amplitude between related and unrelated pressure waves were not significant. The exception to this generalisation occurred with dextrose infusion, when related duodenal waves were significantly stronger than unrelated waves ($p < 0.001$, Student's *t* test after logarithmic transformation).

Comparison of motility indices during fat and dextrose infusion revealed significantly more pyloric

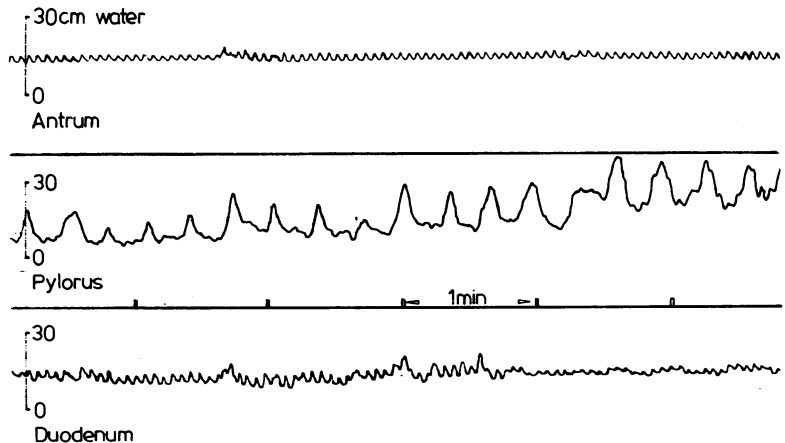


Fig. 9 Pressure recording during intragastric infusion of 10% Intralipid showing regular, phasic contractions superimposed on rising pyloric basal pressure.

Table Mean (standard deviation) amplitudes in centimetre water of gastroduodenal phasic pressure waves

	Saline	Intralipid	Dextrose
Antrum			
Related	32.9 (16.92) N=122	16.7 (5.03) N=3	10.9 (4.59) N=14
Unrelated	17.2 (11.32) N=143	15.8 (6.65) N=9	19.3 (10.49) N=81
Pylorus			
Related to antrum	26.0 (11.80) N=136	19.8 (5.62) N=3	18.2 (7.36) N=14
Unrelated to antrum	17.7 (8.80) N=77	19.0 (8.46) N=342	19.0 (10.26) N=233
Pylorus			
Related to duodenum	25.1 (11.64) N=168	19.5 (9.26) N=56	18.2 (10.69) N=96
Unrelated to duodenum	15.9 (6.06) N=45	19.4 (10.98) N=289	19.4 (9.71) N=151
Duodenum			
Related	23.1 (10.16) N=247	15.6 (5.35) N=72	16.8 (8.82) N=119
Unrelated	16.9 (6.86) N=586	14.9 (6.80) N=135	13.5 (5.81) N=168

motility with fat than dextrose ($p < 0.05$, Wilcoxon's rank sum test). Antral duodenal motility indices were not significantly different.

Discussion

Differences in gastroduodenal motility during saline and fat or dextrose infusion may represent the differences between fasting and fed activity. Although the migratory motor complex persisted in some subjects during saline infusion, it was abolished by Intralipid and dextrose. In man and dogs, saline may disrupt fasting motor activity without establishing digestive activity^{12, 13} and nutrient liquids are known to inhibit the migratory motor complex.^{14, 15}

The inhibition of antral and duodenal contractions by nutrient liquids has been observed previously in cats, dogs and man^{1, 9, 16-21} and the inhibitory effects of fat are known to be greater than those of dextrose.^{16, 22} The effects of fat and dextrose on the synchronisation of gastroduodenal contractions have not been described previously. A few studies have examined phasic contractions of the pylorus and reported that the pylorus is inhibited by fat and hypertonic dextrose in the same way as the antrum.^{9, 20, 21, 23} This conflicts with our observations. It is interesting that Kaye and his colleagues⁶ commented that phasic activity was prominent at the gastroduodenal junction after intraduodenal instillation of olive oil.

Perfused, open ended tubes fail to record contractions that do not occlude the openings in the tubes.

Therefore, the pyloric activity recorded with fat and dextrose may not have been truly autonomous and weak antral and duodenal contractions may have remained undetected. Although the combined radiological and manometric study suggests that all antral and duodenal contractions were inhibited, it is not conclusive, as weak contractions in a distended viscus would not necessarily be visible radiologically. Such contractions, however would be functionally unimportant.

The demonstration of rises in pyloric basal pressure during infusion of nutrient liquids supports the work of Fisher and Cohen² and Brink and his colleagues.¹ These workers recorded rises in pyloric basal pressure after intraduodenal instillation of fat or hypertonic glucose but, unlike us, also detected a high pressure zone at the pylorus when saline was instilled. Other workers have failed to duplicate these results and there are two possible explanations for their failure. In our study, the rise in pyloric basal pressure during fat or dextrose infusion was intermittent and occurred after a delay of many minutes. If a pull-through technique is used, the rise in pressure will be missed if the pull-through is performed too soon. We have shown that the amount of tonic activity at the pylorus depends on the nature of the instillate. The quantity instilled may be important also and the stimulus used by other workers may have been inadequate to elicit the response.

It is possible to speculate on the role of the gastroduodenal motility recorded with nutrient liquids. Although emptying of liquids from the stomach is controlled mainly by the tone of the body of the stomach,²⁴ gastroduodenal motility is important also. In man, emptying of hypertonic dextrose is more rapid after proximal gastric vagotomy with pyloroplasty than after proximal gastric vagotomy alone.²⁵⁻²⁷ In dogs, the gastroduodenal region can regulate the emptying of fat and hypertonic glucose from the stomach by providing a variable resistance to outflow.²⁸ Therefore, the gastroduodenal region may retard the emptying of nutrient liquids from the stomach by an active breaking mechanism and not merely by a decrease in propulsive contractions.

The pyloric activity recorded during intragastric infusion of 10% Intralipid and 10% dextrose would be an effective breaking mechanism. The ability of an independently contracting segment of gut to retard the flow of gastrointestinal contents has been established.²⁹ Both phasic and tonic pyloric contractions would retard gastric emptying. The observed differences in gastroduodenal motility with isotonic saline, Intralipid and 10% dextrose and the known differences in rates of emptying of these infusates are consistent with this hypothesis.

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