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The relationship between gastric pH and the emptying of solid, semisolid and liquid meals

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Abstract *The effect of three different meal constituents, solid, semisolid and liquid, on gastric pH, recorded in the proximal and distal stomach, was evaluated in a prospective study of 20 normal volunteers. The solid and liquid were ingested together as one meal and the semisolid as another. Simultaneous recordings of the rate of gastric emptying of the isotopically labelled meal constituents and the gastric pH were made. The rate of gastric emptying was more rapid for the liquid and semisolid constituents ($t_{1/2}$ = 35.6, range 9.8–103.3 min and 47.4, range 33.5–120 min, respectively) than for the solid meal constituent ($t_{1/2}$ = 72.0, range 45.0–103.8 min), $P < 0.01$. Both the combined meal of solid and liquid and the semisolid meal produced a higher pH response in the proximal stomach than in the distal stomach (5.2, range 2.4–6.1 vs 2.9, range 0.8–5.3 and 5.9, range 4.3–6.6 vs 4.3, range 1.1–5.9), $P < 0.01$. There were significant correlations between the rate of gastric emptying of all three meal constituents and the decline phase in the gastric pH recorded at both the proximal and distal probes, $P < 0.01$ (Pearson's correlation). The strongest correlations were found between the rate of gastric emptying and the gastric pH recorded in the proximal stomach. The decline phase of gastric pH followed the emptying of semisolid more closely than the emptying of either solid or liquid.*

Keywords *gastric acid secretion, gastric emptying, gastric motility, gastric pH.*

INTRODUCTION

Prolonged gastric pH monitoring is being increasingly used in the physiological evaluation of gastric function and to investigate the effect of drugs on the gastric secretory state.[1,2] The baseline gastric pH lies between pH 0.3–1.9 and in response to a meal rises to a plateau pH of about 5.5.[3,4] The plateau period is quite short and is followed by a more variable period of decline in pH toward baseline values. The rate of gastric emptying of a meal is directly affected by its consistency and composition. Liquids empty rapidly, semisolid more slowly and solids are the slowest to empty.[5,6,8] The proximal stomach is thought to act as a reservoir for foodstuffs and is capable of receptive and adaptive relaxation after meals. The distal stomach exhibits peristaltic activity and is the site where solid food particles are mixed and digested. By a combination of propulsion, grinding and retropulsion this region regulates the gastric emptying of particles < 0.15 mm in size and resists the passage of solid particles of diameter greater than 0.5 mm.[8,9]

It is therefore probable that meals of different consistency would have different effects on the gastric pH measured in the proximal and distal stomach. We tested this hypothesis in normal volunteers by investigating the relationship between the gastric emptying pattern of three different meal constituents and gastric pH recorded from the proximal and distal stomach by pH probes placed 5 cm and 15 cm below the lower oesophageal sphincter.

METHODS

Informed consent was given by 20 healthy volunteers who were recruited to undergo testing, according to a protocol which was approved by the Creighton University Human Research Committee (IRB #838). All volunteers were healthy, not pregnant, not on medications and had no previous history of gastrointestinal complaints. There were 12 males and 8 females with a median age of 31 years, range 20–49 years.

After an overnight fast the subjects underwent stationary manometry to identify the position of the

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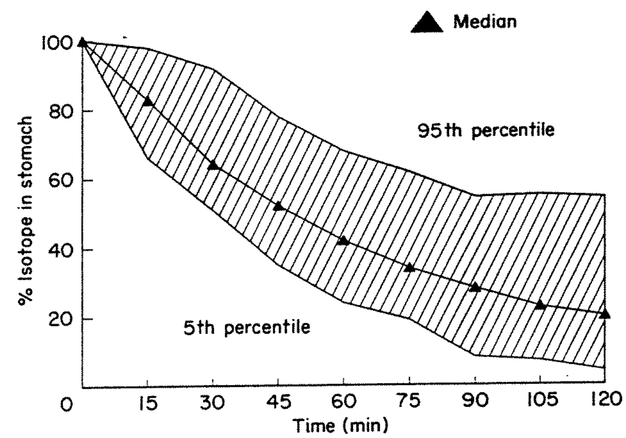

Figure 1 Median rate of gastric emptying for oatmeal with fifth and ninety-fifth percentiles shaded.

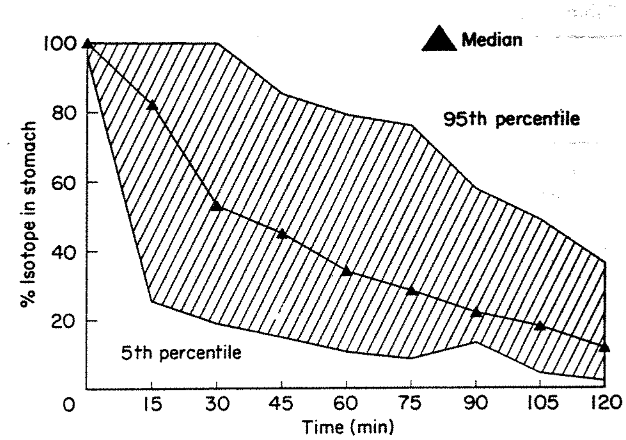

Figure 2 Median rate of gastric emptying for the liquid component of the liquid/solid meal with fifth and ninety-fifth percentiles shaded.

patients, hence their distal probe pH recordings were not included in the analysis of the oatmeal study. In one subject the pH recording was lost as a result of electronic failure leaving 19 patients in whom simultaneous gastric pH and gastric emptying could be compared.

The rate of gastric emptying was not different when males were compared to females for any of the meal constituents, therefore median values for gastric emptying of the whole group were calculated. Gastric emptying studies showed that after the solid/liquid meal the emptying of liquid was the most rapid with a $t_{1/2}$ of 35.6 min (range 9.8–103.3 min). The rate of oatmeal emptying was slower with a $t_{1/2}$ of 47.4 min (range 33.5–120 min) but not statistically significantly different from liquid emptying. Solid emptying was the slowest with a $t_{1/2}$ of 72.0 min (range 45.0–103.8 min) $P < 0.01$ compared to both oatmeal and liquid. The emptying of the solid meal followed a linear pattern ($P < 0.01$ by general regression analysis) whereas the emptying of the oatmeal and liquid followed an exponential first-order pattern ($P < 0.01$ by general regression analysis). The median value, and fifth and ninety-fifth percentiles for emptying of each of the three meal components are shown in Figs 1–3 and indicate that the normal range for liquid emptying is very wide, particularly during the initial 30-min period. The normal range for emptying of the semisolid and solid meals was much narrower.

The gastric pH data for the two meals is summarized in Table 1. The baseline gastric pH recorded at the proximal probe, 5 cm below the LES, and the distal probe, 15 cm below the LES were similar indicating that during the fasting state the pH throughout the stomach was uniform. After the meals the pH in the proximal and distal stomach responded differently. The pH response to meals in the proximal stomach was of a greater

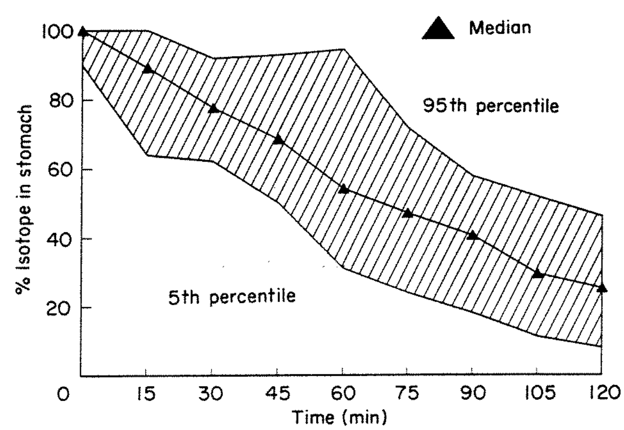

Figure 3 Median rate of gastric emptying for the solid component of the liquid/solid meal with fifth and ninety-fifth percentiles shaded.

magnitude than in the distal stomach. The combined meal resulted in the pH in the proximal stomach rising to a peak pH of 5.2 (range 2.4–6.1) whereas in the distal stomach the peak pH was 2.9 (range 0.8–5.3), $P < 0.01$. The oatmeal produced a peak pH of 5.9 (range 4.3–6.6) in the proximal stomach and 4.3 (range 1.1–5.9), in the distal stomach, $P < 0.01$. The pH response to all of the three meal constituents was prompt, as shown in the time to reach peak pH (Table 1). The time taken to reach peak pH was not significantly different between the proximal and distal probes. The mean duration of pH response was longer in the proximal stomach compared to the distal stomach although this only reached significance for the oatmeal.

For both proximal and distal probes there was a

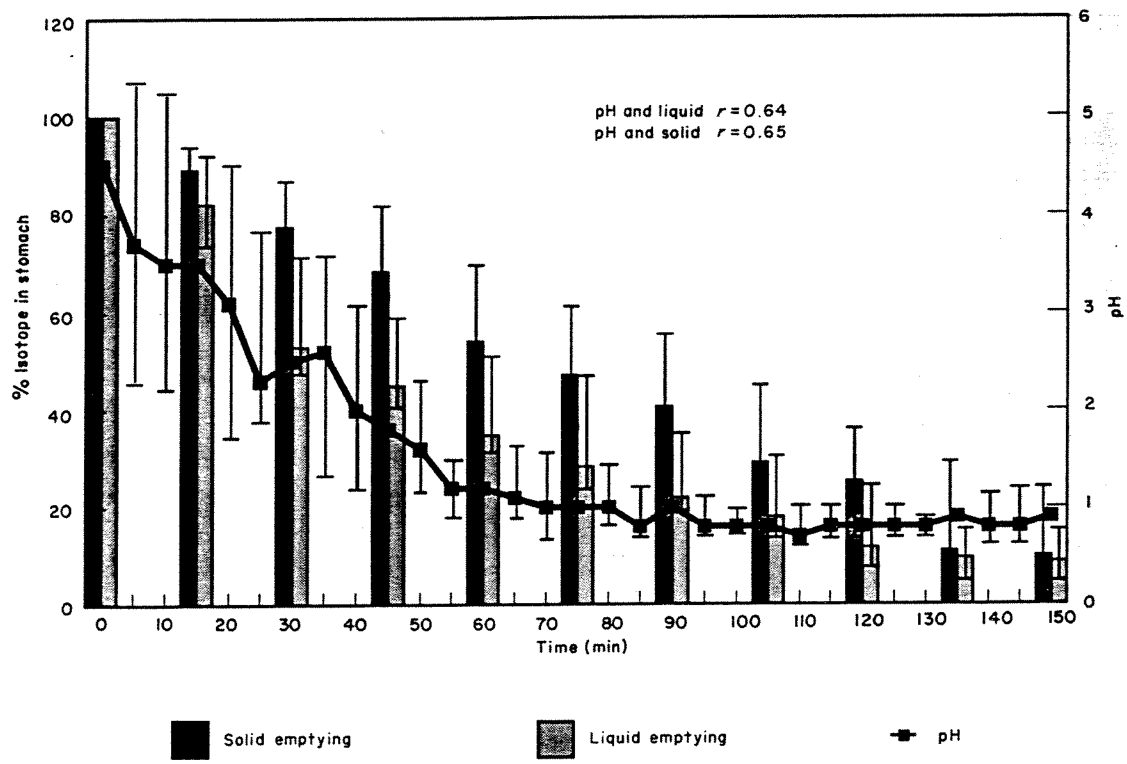

Figure 5 Simultaneous median gastric emptying of solid/liquid meal (bars) and median proximal gastric pH (line) with interquartile ranges.

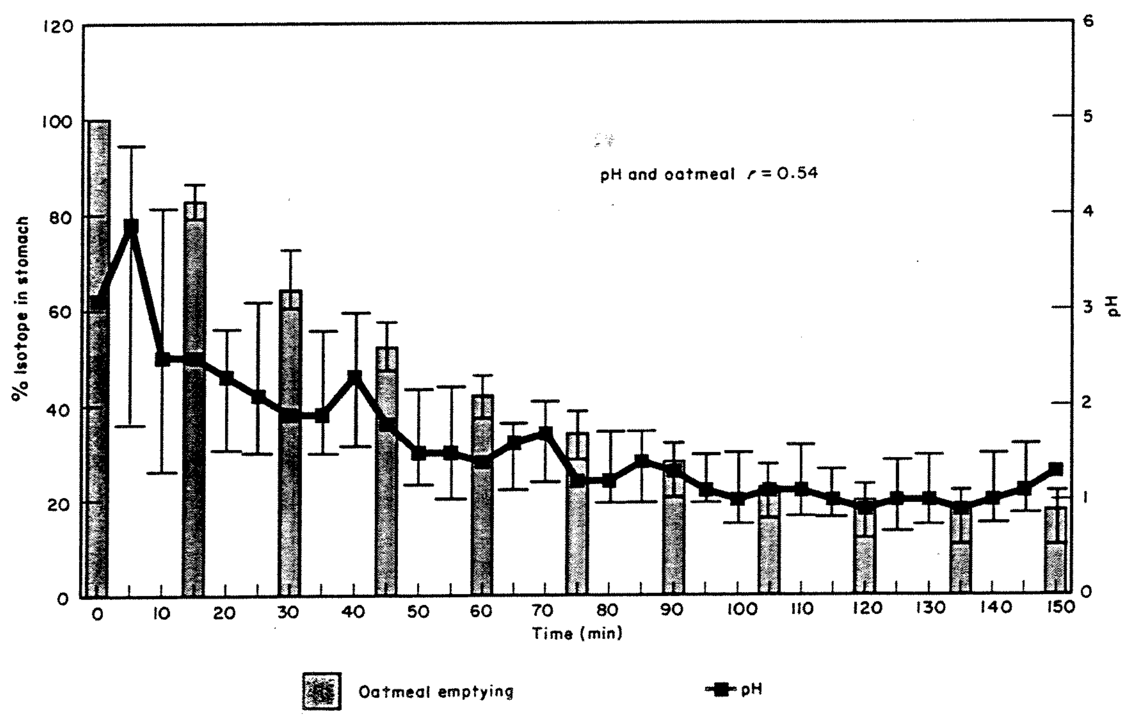

Figure 6 Simultaneous median gastric emptying of oatmeal (bars) and median distal gastric pH (line) with interquartile ranges.

with a $t_{1/2}$ of 72.0 min. The pattern of emptying followed a linear decline.

In conclusion this study supports the concept that the proximal and distal regions of the stomach function differently in response to meals with good correlations seen between the decline phase of post-prandial gastric pH and the gastric emptying of solid, semisolid and liquid meals. The decline phase of gastric pH followed the emptying of semisolid more closely than the emptying of either the solid or liquid constituents.

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