Altered solid and liquid gastric emptying in patients with duodenal ulcer disease

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SUMMARY Alteration in gastric emptying has been implicated in duodenal ulcer disease. The precise abnormalities remain controversial. We have used a radionuclide technique to assess solid and liquid gastric emptying in 14 patients with endoscopically proven duodenal ulcer and 22 healthy controls. Solid gastric emptying values for the patient group fell within the normal range. The median time taken for 50% (T50) of the liquid marker to empty from the stomach was 12 minutes (range 6–23 minutes) which was significantly faster (p<0.005) than controls (median 18 minutes, range 11–35). In 10 of the 14 patients, however, the rate of liquid emptying was within the normal range. There was no significant difference in the T50 for gastric emptying of solids between the groups, but in duodenal ulcer patients food left the stomach significantly earlier than in controls (p<0.05). After this, however, the linear rate at which duodenal ulcer patients emptied solid food from the stomach was a median 0.75%/minutes (range 0.5–1.4 minutes), which was slower (p<0.0005) than controls, median 1.25/minutes (range 0.7–2.3). These results show that the pattern of gastric emptying of digestible solids and liquids in patients with duodenal ulcer disease, as a group, is significantly altered.

The role played by gastric emptying in duodenal ulcer disease is unclear.1 The results of studies which have assessed emptying of meals have been conflicting.2–7 This has probably occurred because of the complexity and variability of the composition of the meals used and also because intubation techniques can interfere with normal physiological function.8 We have used an improved radionuclide technique9 in an attempt to avoid these problems to assess solid and liquid emptying in both healthy controls and patients with duodenal ulcer disease.

Subjects

Twenty two normal healthy volunteers (12 men, 10 women) median age 34 years (range 21–62 years) and 14 patients (13 men, one woman) median age 53.5 years (33–66 years) with duodenal ulcer were studied after giving informed consent for the study. All controls were free of symptoms, had no past history of upper gastrointestinal disease, were non-smokers and were not taking medications. The 14 duodenal ulcer patients all had an endoscopically confirmed duodenal ulcer before the investigation, and none had clinical or endoscopic evidence of pyloric stenosis. Ten smoked between 5–40 cigarettes per day, the remaining four being reformed smokers. No patient received medication for 48 hours before the investigation.

Radionuclide assessment: the gastric emptying test was carried out after an overnight fast. The method has been reported previously.9 While eating a standard solid and liquid meal, the subject sat in front of a scintillation camera, with the camera to the subject’s back. The solid component of the meal was a 100 g ‘hamburger’ of ground beef incorporating 1–2 mCi of 99mTc-sulphur colloid tagged to chicken liver.10 The liquid marker was 0.5–1.0 mCi of 113mIn DTPA mixed in 150 ml of 10% dextrose. The scintillation camera was interfaced to a computer for data collection. The energy window alternated regularly between that of 113mIn (393 keV) and 99mTc (140 keV) using an automatic switching device. Data were collected for 120 minutes. At the end of data acquisition, 100 µCi of 99mTc-DTPA in 150 ml of water was given orally and a one-minute left lateral image of the upper abdo-
men was taken to allow for attenuation correction. The computer data comprised list mode files which were reformatted to produce separate dynamic studies for the solid and liquid components. Corrections were made for $^{133} \text{mIn}$-Compton scatter, attenuation, patient movement and radionuclide decay. Analysis of the data by use of computer drawn regions-of-interest that included the stomach but excluded the intestine enabled calculations to be made of the time for 50% of the liquid tracer to leave the gastric region (Liquid T50). Solid emptying characteristics were assessed by considering the time taken from ingestion until solid began to leave the stomach (lag period), time taken for 50% to leave the stomach (solid T50) and the percentage of the marker remaining at 100 minutes. The rate at which the solid component of the meal emptied as a percentage per minute was also calculated.

**Statistical Analysis**

Data were analysed using the Wilcoxon’s unpaired test.

**Results**

**Solid Emptying**

In all subjects solid emptying was slower than liquid emptying and was characterised by a lag period followed by linear emptying (Fig. 1). There was no significant difference (Table) for the solid T50 between the controls and patient groups. All patients fell within the normal range (Fig. 2). Both the lag period and the linear emptying rate, however, were significantly altered in the patient group (Table).

**Liquid Emptying**

The liquid emptying was non-linear and followed a mono-exponential pattern (Fig. 1). Liquid T50 was significantly faster (Table) in the patient group than the controls. Four of the patients had a liquid T50 faster than the normal range (Fig. 3).

**Discussion**

Our study confirms the findings of others using intubation techniques that duodenal ulcer patients empty liquids more rapidly than normal indi-

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Duodenal ulcer</th>
<th>Significance level</th>
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<tbody>
<tr>
<td>Subjects (no)</td>
<td>22</td>
<td>14</td>
<td>ns</td>
</tr>
<tr>
<td>Solid lag period (min)</td>
<td>35 (9-69)</td>
<td>23-5 (10-32)</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Solid linear rate (%/min)</td>
<td>1-25 (0-7-2-3)</td>
<td>0-75 (0-5-1-4)</td>
<td>p&lt;0.0005</td>
</tr>
<tr>
<td>Solid T50 (min)</td>
<td>76</td>
<td>85</td>
<td>ns</td>
</tr>
<tr>
<td>Solid retention at 100 min (%)</td>
<td>30 (12-65)</td>
<td>42 (16-60)</td>
<td>ns</td>
</tr>
<tr>
<td>Liquid T50 (min)</td>
<td>18</td>
<td>12</td>
<td>p&lt;0.005</td>
</tr>
<tr>
<td></td>
<td>(11-35)</td>
<td>(6-23)</td>
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Data are median values with range in parentheses.
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![Graph](image)

**Fig. 2** Individual solid gastric emptying results expressed as time taken for 50% of meal to clear the gastric region (T50) for controls and patients with duodenal ulcer. The line dividing each group represents the median value.

![Graph](image)

**Fig. 3** Individual liquid gastric emptying results expressed as the time taken for 50% of the liquid meal to clear the gastric region (T50) for controls and patients with duodenal ulcer. The line dividing each group represents the median value.

Individuals\(^3\) \& \(^7\) although the 50% emptying time was outside the normal range in only four patients. A non-invasive radionuclide study, however,\(^1\) failed to show any significant difference between five duodenal ulcer patients and five controls for solid and liquid emptying; this may have been because of the small number of patients studied. The technique used in that study was similar to our own methods except that a different meal was used (cornflakes, sugar and milk, with indigestible paper pieces impregnated with \(^99m\)Tc sulphur colloid as a solid phase marker) and scans were undertaken in the supine position. No corrections were made for attenuation of activity in the gastric region of interest and therefore only gross differences were likely to be found, particularly in liquid emptying.

Most reports of studies using a mixing solid and liquid meal have used intubation techniques. Those studies which have considered solid emptying have reported more rapid emptying\(^1\)\(^3\)\(^4\)\(^13\)\(^14\) or no change from normal.\(^1\)\(^2\)\(^12\) These discrepancies may relate to the different methods used or depend on the pH or caloric content of the meal, since increases in duodenal acidity and large caloric intakes cause less slowing of gastric emptying in duodenal ulcer patients than control subjects.\(^8\)\(^13\)

Howlett \& al\(^2\) found that the T50 for solids was similar in both duodenal ulcer patients and a control group. By use of component analysis, however, they showed that the pattern of emptying was different. We found also that there was no difference from controls in T50 for solids in duodenal ulcer patients although solid emptying started earlier and the rate of emptying was slower in our patient group compared with our control group.

There are several possible explanations for our findings. The age of our patient group was older than that of our controls (53-5 vs 34). An age difference of this magnitude, however, is most unlikely to affect the results of gastric emptying studies.\(^15\)\(^16\) Pylorospasm and pyloric stenosis were unlikely to be significant factors as there was no evidence of either problem in the investigation of the patients and such hold up would have tended to slow gastric emptying of liquids rather than accelerate it. We have not found any significant difference in gastric emptying between men and women in our control studies and so the different sex ratio between our groups is unlikely to have been a factor in the differences observed. Smoking immediately before performance of a gastric emptying test has been shown to accelerate liquid gastric emptying\(^17\) and so our patients refrained from smoking on the day of their study. All 14 patients had been smokers, although four had reformed. We were not able to show any significant
correlation between the number of cigarettes smoked per day and the rate of liquid emptying. Further it has been shown\textsuperscript{17} that non-smokers do not differ significantly from smokers in their emptying of liquids. It would appear that any role played by cigarette smoking is an immediate one, but its mechanism remains unclear.

A deficiency of all radionuclide methods is that gastric emptying of the solid and liquid marker is measured and the effects of dilution by gastric secretion cannot be quantified. Although differences in gastric secretion rates between the control subjects and duodenal ulcer patients could theoretically have influenced the results, this appears very unlikely. Differences in gastric secretion between duodenal ulcer patients and normal subjects do not occur until 40 minutes after ingestion of a meal of neutral pH.\textsuperscript{7} The meal given to our patients was of neutral pH and differences in the rate of both liquid and solid emptying were observed before 40 minutes in most patients. In addition, dilution by gastric secretion would probably produce a tendency for delayed, rather than the observed more rapid gastric emptying in the DU patients.

The duodenum has pH sensitive receptors which regulate gastric emptying in normal subjects, probably by a hormonal mechanism.\textsuperscript{18, 19} These receptors act to keep the duodenal milieu at around a pH of 6.\textsuperscript{11} Read et al\textsuperscript{8} found that duodenal ulcer patients appear to have an impairment of their capacity to slow gastric emptying in response to an increasing load of acid in the duodenum. Such impairment might explain why liquid emptying was more rapid in our patients and one implication is that an acid load also enters the duodenum more rapidly in these patients. The rapid emptying does not appear to be related to acid hypersecretion, as many patients with normal acid output have increased fractional emptying rates.\textsuperscript{20}

Antral dysfunction has been recorded in association with delayed solid gastric emptying\textsuperscript{21} and this is a possible explanation for the changes in solid gastric emptying which we observed.

Our findings support the hypothesis that there is dysfunction of the duodenal receptors which regulate gastric emptying, in patients with duodenal ulcer disease. The mechanism of such dysfunction, however, remains poorly understood. The place of rapid gastric emptying of liquids as a cause of duodenal ulcer remains uncertain, and the alterations we have described may be a consequence rather than the cause of the ulcer.

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