The measurement of gastric transit time in obese subjects using ^{24}Na and the effects of energy content and guar gum on gastric emptying and satiety

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1. A new method has been used to measure mean gastric transit time.

2. This method, based on the absorption of ^{24}Na from the proximal small bowel, is simple, non-invasive and can be used at the bedside.

3. The mean transit time was increased by adding guar gum to a test meal.

4. There was a significant correlation between mean gastric emptying time and a subjective measure of satiety.

A simple, cheap and non-invasive method of measuring gastric emptying would be useful in both physiological research and clinical practice. Research into factors influencing gastric emptying has been performed using nasogastric aspiration, which may influence the results of the investigations. Non-invasive tests have been developed in which the subject consumes a meal labelled with a non-absorbed radioactive tracer whose passage through the stomach is followed using a gamma camera or rectilinear scanner (Tothill *et al.* 1978).

We have developed a simple method for measuring gastric emptying which depends on outflow detection, as distinct from residual detection (Zierler, 1965) and utilizes the fact that sodium is rapidly absorbed by the proximal small bowel after passing through the stomach (Love *et al.* 1973). The appearance of ingested Na in the blood can therefore provide a measure of the transit time through the stomach. The apparatus is relatively simple, and can be used at the bedside.

The most accurate assessments of hunger are probably those based on analogue rating scales (Silverstone, 1975) and gastric emptying may influence hunger (Hunt *et al.* 1975).

METHOD

Twelve over-weight in-patients were studied. Their mean age was 36 (SD ± 15·7) years, mean weight 90·6 (SD ± 14·1) kg, and percentage lean body mass (assessed by measurement of whole body potassium) 60·1 (SD ± 6·5) %. The patients had become experienced in the use of visual analogue scales for assessment of hunger and desire to eat for a minimum of 7 d before the administration of the gastric emptying tests.

After an overnight fast the patients were given 200 g of a milky drink. The drink had the composition of one of the test meals shown in Table 1. On a subsequent occasion the patients received a second test meal and the order of the meals was chosen by tossing a coin. All three meals were similar in taste.

The low-energy meal and the high-energy meal were compared in nine pairs of trials and the low-energy meal and the low-energy meal with guar gum were compared in seven pairs of trials. The relatively short half-life of ^{24}Na (13 h) made it impossible to carry out more than two measurements with one weekly delivery of isotope so only four patients were available for all three measurements. The viscosities of the test meals were estimated at 37°

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Table 1. *Composition (g/200 g) of test meals*

	Low-energy	High-energy	Low-energy with guar gum
Homogenized milk	177	69·3	177
Caloreen*	10·5	104	10·5
Double cream	10·5	24·7	10·5
Cocoa powder	2	2	2
Protein	6·0	2·68	6·0
Fat	11·9	14·7	11·7
Carbohydrate	19·2	108	19·2
Guar gum	—	—	2
Energy (J)	865	2423	865
pH	6·0	5·0	6·0
Kinematic viscosity (m^2/s)	8×10^{-5}	32×10^{-3}	59×10^{-3}

* Roussel Laboratories Ltd, Wembley; main consituent glucose polymer.

using funnels calibrated with silicone fluids. The meals were labelled with 400 kBq (11 μCi) or 800 kBq (22 μCi) ^{24}Na; the higher dose being used on the second or third occasion if appreciable activity remained after the previous test. After the drink the subject sat in an armchair for 1 h with the head resting in a foam plastic pillow fastened to the front of a 50 mm thick lead collimator. A sodium iodide crystal (75 mm diameter × 50 mm thick) was used to detect the activity resulting from ^{24}Na present in the blood; continuously for the first hour and at intervals of 30 min for a further 5 h.

Before each test the subject was asked to record 'hunger' and 'desire to eat' on a 100 mm visual analogue scale by placing crosses on lines representing ranges from 'very hungry' (zero) to 'full' (100), and from 'very great desire to eat' (zero) to 'no desire to eat' (100). They were asked to mark a further pair of such lines at intervals of 1 h for 6 h or until they decided they wanted to eat a meal, and were asked to record the time at which they ate.

The absorbed radiation for two investigations was approximately 0·5 mGy (50 mr) averaged over the whole body (International Commission on Radiological Protection, 1971). Informed consent was obtained in the manner laid down by the Northwick Park Hospital Ethical Committee and permission to use the isotope was obtained from the Department of Health and Social Security Isotope Advisory Panel.

Analysis of results

The activity detected over the head depends upon the rate of mixing of sodium in the blood as well as the transit time through the stomach. In order to determine the spectrum of transit times through the stomach a curve representing the blood concentration following an intravenous injection must be deconvoluted from a curve representing the blood concentration following a labelled meal (Love *et al.* 1973). It was considered unnecessary to determine the curve of blood activity following the intravenous injection of a second isotope in the interests of absolute measurement, since each subject acted as his or her own control. The curve of blood activity following an intravenous injection of ^{24}Na shown in Fig. 1 of Love *et al.* (1973) was used for all calculations. The resulting curve represented a spectrum of transit times through the stomach and from this the mean gastric transit time was calculated using the algorithm described by Love *et al.* (1973).

It was considered that following a test meal the patient would in time experience a sensation of maximum hunger and this was estimated as follows. If the subject experienced a desire to eat a meal during the 8 h following a test meal, he or she was allowed to do so, and this time was taken to be the time of maximum hunger. If the subject did not wish to eat during the 8 h following the test meal graphs were plotted according to the position of

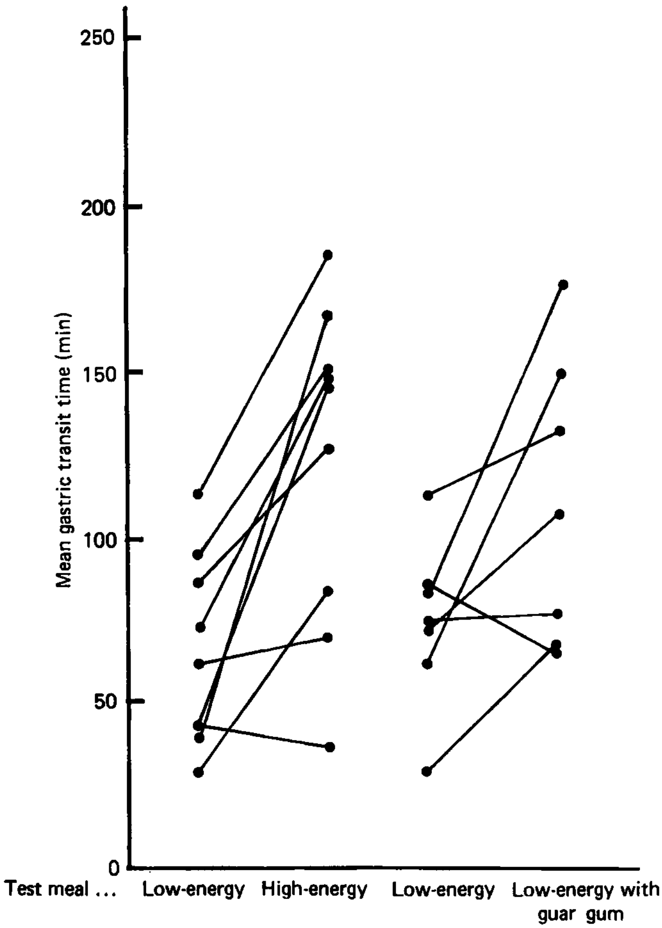

Fig. 1. Mean gastric transit times (min) for obese subjects given the following test meals; low-energy, high-energy or low-energy with guar gum; for details of test meals, see Table 1. Each line represents two measurements of mean gastric transit time on the same subject.

crosses on the visual analogue scale lines and the time elapsed since the test meal was ingested. In most cases the graphs were curves which plateaued, and the time of reaching the plateau was taken to be the time of maximum hunger. If no plateau occurred the time of maximum hunger was arbitrarily taken to be the end of the test (8 h).

The results of tests were compared using the paired *t* test, Wilcoxon's signed rank test or Kendal's τ where appropriate.

RESULTS

Fig. 1 shows the effect of the different test meals on mean gastric transit time. Each point represents one measurement in one indivdual for one test meal, so that each line represents two measurements in the same individual for different test meals. Table 2 summarizes the statistical analysis of the differences between the mean gastric transit times for the different test meals using the paired *t* test.

The time of maximum hunger often exceeded the time of the measurement (8 h) and all such results were entered as 480 min in the comparison of time of maximum hunger for the

Table 2. *The effect of different test meals on mean gastric transit time in obese subjects*

Test meal*	Gastric transit time (min) Mean	SD	Statistical significance of difference between test meals
Low-energy	64	29	$P < 0.01$ (n 9)
High-energy	123	49	
Low-energy	69	19	$P < 0.05$ (n 7)
Low-energy with guar gum	112	43	

* For details, see Table 1.

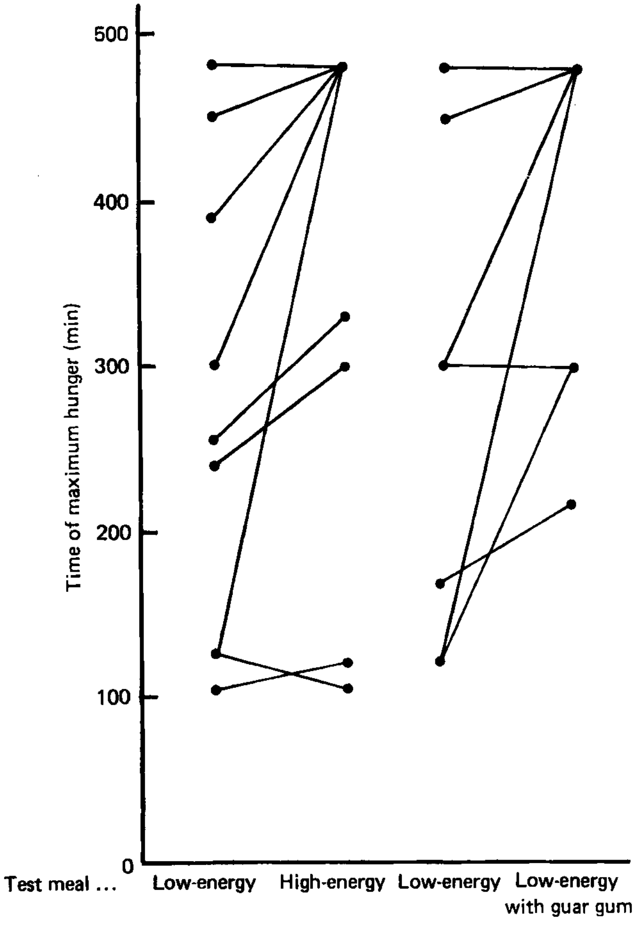

Fig. 2. Time of maximum hunger (min) for obese subjects given the following test meals; low-energy, high-energy or low-energy with guar gum; for details of test meals, see Table 1. Each line represents two estimates of the time of maximum hunger on the same subject. Differences between estimates for high and low-energy meals and for low energy meal and low-energy meal with guar gum were significant ($P < 0.05$ and $P < 0.01$ respectively).

different test meals (Fig. 2). The resulting distributions made the paired t test inappropriate so Wilcoxon's signed rank test was used to compare the times of maximum hunger for the three types of meals. The time of maximum hunger for the low-energy meal was significantly

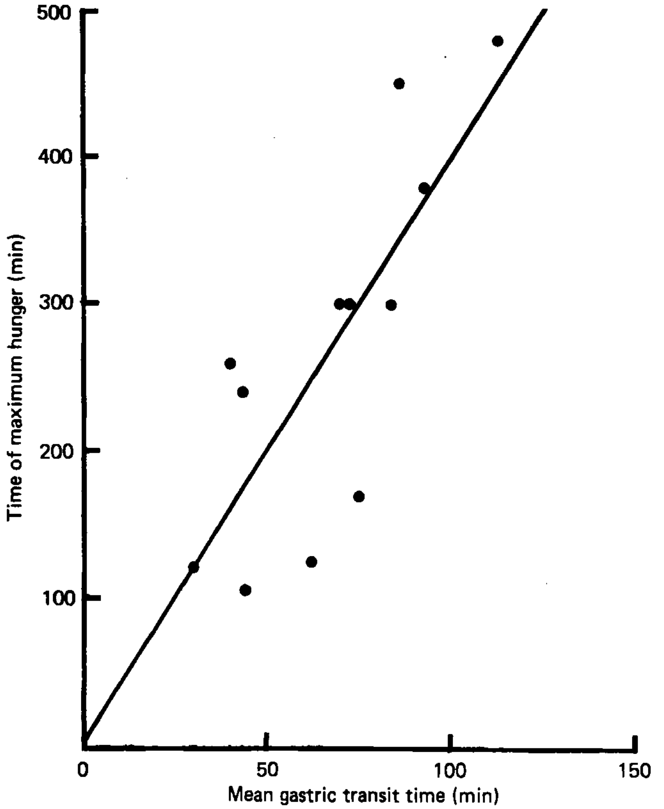

Fig. 3. Time of maximum hunger (min) *v.* mean gastric transit time (min) for obese subjects given a low-energy meal; for details of test meal, see Table 1. r 0·79, $P < 0{\cdot}01$, n 12.

less than for the high-energy meal ($P < 0{\cdot}05$) and significantly less than for the low-energy meal with guar gum ($P < 0{\cdot}01$).

Where the test meal with which the time of maximum hunger did not exceed the length of the test, i.e. for the low-energy meal, there was significant correlation between the mean gastric transit time and the time of maximum hunger (Fig. 3). Kendal's τ showed a significant correlation between mean gastric transit time and time of maximum hunger for the high-energy meal (τ 0·79, $P < 0{\cdot}05$, n 12) but no significant correlation for the low-energy meal with guar gum.

DISCUSSION

The method of measuring gastric emptying described here requires less expensive equipment than any other currently used non-invasive isotope method of measuring gastric emptying, and is unique in that it is easily performed on a ward using portable equipment. It has been suggested that the emptying of solids is as important as the emptying of liquids (Heading *et al.* 1976) and only liquid emptying can be studied using this method. This limitation also applies to methods involving naso-gastric intubation (George, 1968) which have been widely used to study post-operative disturbances of gastric function (McKelvey, 1970). Our method has the advantage that it is less unpleasant and more physiological than methods involving naso-gastric aspiration.

The results show a highly significant increase in mean gastric transit time and time of maximum hunger when the energy content of the meal was trebled. However, similar changes were produced by the addition of guar gum to the low-energy meal. The results suggest that the viscosity of the test meal is, at least in part, responsible for gastric emptying times. The effect of guar gum on mean gastric transit time is evidence in favour of its postulated mode of action in slowing glucose absorption and reducing insulin requirements in diabetes (Jenkins *et al.* 1978).

It is generally assumed that the physical presence of food in the stomach is related to satiety, and that after a set meal the rapidity of emptying of the stomach affects the rate of subsequent development of the sensation of hunger. Indeed the terms 'empty' and 'full' are in common usage to imply the presence or absence of hunger respectively. There was, however, no scientific proof for this association. Despite the fact that we clearly only have a crude estimate of a psychological function when assessing time of maximum hunger, we found a significant correlation between this factor and mean gastric transit time. Other factors may also be important in development of this subjective sensation.

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