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Comparison of aspiration and scintigraphic techniques for the measurement of gastric emptying rates of liquids in humans

E J Beckers, J B Leiper, J Davidson

Abstract

A comparison was made of two techniques to measure the rate of gastric emptying. A non-invasive scintigraphic technique using a gammacamera and an invasive aspiration technique based on dye dilution were performed simultaneously. Seven healthy male volunteers each consumed two different liquid meals on two separate occasions. Scintigraphic measurements were performed continuously with aspiration every 10 minutes for a total of one hour. Gastric emptying rates were expressed as slope values after semilog linearisation of the emptying curves. Agreement between the two methods was assessed from the individual differences and mean of the two techniques, as well as from the geometric mean, including 95% limits of agreement. The scintigraphic technique gave a 70% slower emptying rate than the dye dilution technique. However, the 95% limits of agreement are large (1·56 to 0·30), reflecting the small sample size and the large coefficient of variation in the techniques used.

Nutrition Research Centre, Department of Human Biology, University of Limburg, Maastricht, The Netherlands
E J Beckers

Department of Environmental & Occupational Medicine, University of Aberdeen, UK
J B Leiper

Department of Nuclear Medicine, Aberdeen Royal Infirmary, Aberdeen, UK
J Davidson

Correspondence to:
E J Beckers, Department of Human Biology, University of Limburg, PO Box 616, 6200 MD Maastricht, The Netherlands.

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Many studies comparing the gastric emptying rates of various meals under different conditions have been performed. Comparing the results from different laboratories is difficult as many different techniques[1-9] are used and it is not clear whether systematic or random variations occur as a result of the method used. All techniques have their specific advantages and drawbacks which, along with operator expertise and availability of apparatus, will determine the method a laboratory chooses to use. The present study was undertaken to compare a non-invasive scintigraphic technique[6] with an invasive dye dilution technique.[2-4] Scintigraphic studies employ a gammacamera which externally monitors the emptying of radionuclide beverages[6] from the stomach. As this method allows almost continuous monitoring, the shape of the emptying curve can be well defined. A disadvantage, however, is that a clear and well defined picture of the stomach has to be obtained, restricting this technique to studies in a stable position – that is, at rest only. The modified double sampling technique, in contrast, can be conducted even during intense exercise, making it of interest to exercise physiologists.[4] In addition, this technique allows the rate of gastric secretion to be calculated. An obvious disadvantage is the need for intubation of the stomach and the consequent discomfort for the volunteer or patient. Both techniques are widely used in clinical and research settings, and the aim of the present study was to compare them using liquid test meals.

Slope values for all subjects, differences, mean, SD and SEM of gastric emptying curves after semilog linearisation

Subject	Drink	Slope DS	Slope Scint	Difference scint-DS	Mean scint-DS
A	A	−0·0087	−0·0024	0·0062	−0·0055
B	A	−0·0207	−0·0153	0·0054	−0·0180
C	A	−0·0156	−0·0146	0·0010	−0·0151
D	A	−0·0189	−0·0153	0·0036	−0·0171
E	A	−0·0305	−0·0192	0·0113	−0·0248
F	A	−0·0325	−0·0288	0·0036	−0·0307
G	A	−0·0228	−0·0180	0·0048	−0·0204
Mean	A	−0·0214	−0·0162	0·0051	−0·0188
SD	A	0·0083	0·0078	0·0032	0·0079
SEM	A	0·0031	0·0030	0·0012	0·0030
A	B	−0·0040	−0·0028	0·0013	−0·0034
B	B	−0·0040	−0·0023	0·0017	−0·0031
C	B	−0·0119	−0·0045	0·0074	−0·0082
D	B	−0·0059	−0·0044	0·0015	−0·0052
E	B	−0·0070	−0·0053	0·0017	−0·0061
F	B	−0·0028	−0·0015	0·0013	−0·0021
G	B	−0·0047	−0·0043	0·0003	−0·0045
Mean	B	−0·0057	−0·0036	0·0022	−0·0047
SD	B	0·0030	0·0014	0·0023	0·0021
SEM	B	0·0011	0·0005	0·0009	0·0008

DS = modified double sampling technique.
Scint = scintigraphy.

Methods

Seven healthy male volunteers (mean (SD) age 29 (12) years, weight 72 (7) kg, height 178 (4) cm), with no history of gastrointestinal disease, who were all familiar with gastric intubation and testing, were asked to participate in two gastric emptying tests each. Approval for the study was obtained from the Joint Ethical Committee of Grampian Health Board and the University of Aberdeen. The purpose of the study and the procedures were explained to the subjects before their written consent was obtained.

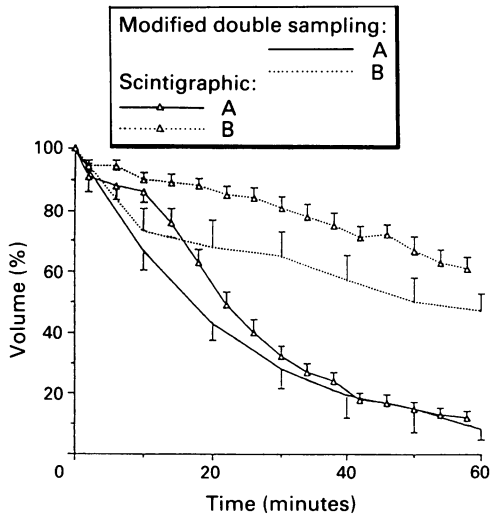

Figure 1: Mean (SEM) gastric emptying curves for drinks A and B and both techniques.

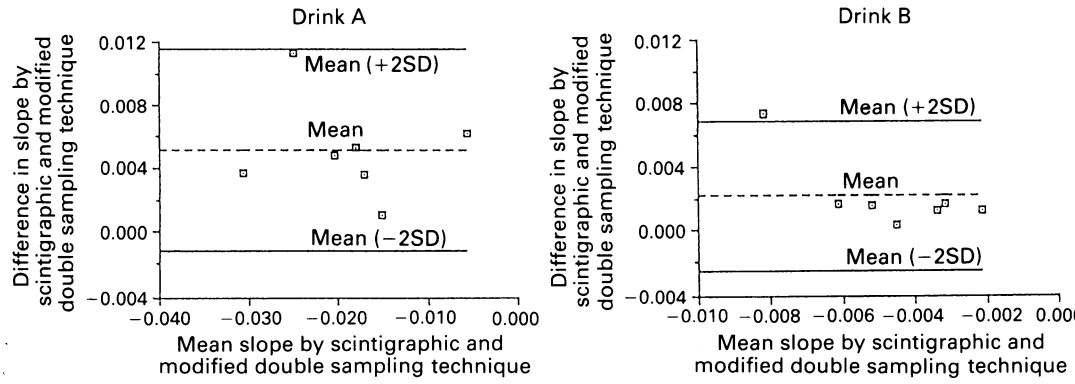

Figure 2: Difference against mean for slope values of scintigraphic and modified double sampling techniques including 95% limits of agreement (±2 SD).

DAILY PROTOCOL

Subjects arrived at the laboratory having fasted for at least eight hours. A gastroduodenal catheter (Levin type, CH 14, 125 cm, Vygon Steriel NV, Brussels) was placed in the stomach and the subjects stood in front of the gamma-camera. The test meal (8 ml/kg body weight) was administered via the catheter, mixed with the fasting gastric contents and a starting sample was taken so the initial gastric contents could be accounted for using modified double sampling technique at time zero. Time zero was taken as the moment when all of the test meal had been administered. Samples for the determination of gastric secretion and emptying were taken at 10 minute intervals for 1 hour. This technique has been described in detail elsewhere[4] and is based on George.[2] For scintigraphic data collection, subjects were imaged using a low energy general purpose collimator; the camera used was an IGE 500A Maxicamera linked to a Dec PDP II computer. Dynamic scintigraphy was performed continuously with the subjects in a standing position. Fifteen anterior and 15 posterior abdominal scans were recorded alternately over 60 seconds. Total measuring time was one hour. A region of interest was drawn around the stomach and the arithmetic mean counts of the anterior and posterior projections in that region, after correction for decay, was calculated and used to determine the emptying rate of the test meals.[10] Both techniques were performed simultaneously.

TEST MEALS

Two different liquid test meals were used. Solution A is an isotonic (296 mOsm/kg) primarily disaccharide (carbohydrate concentration 72 g/l, energy density 1·3 MJ/l) drink with added minerals, known from previous experiments[11] to empty fast. Solution B is a carbonated hypertonic (600 mOsm/kg) glucose polymer (carbohydrate concentration 193 g/l, energy density 3·1 MJ/l) drink presumed to empty slowly. Each test meal was labelled with two non-absorbable markers, ^{99m}Technetium diethylene triamine penta-acetic acid at a dose of 2 MBq for scintigraphy and 15 mg/l phenolred for double sampling. Tests with drink A and B were performed at the same time of day and one week apart for each subject to account for any circadian variation.[12]

DATA ANALYSIS

Data were analysed after semilog transformation of the gastric emptying curve and emptying rates were expressed as slope values of the resulting straight line. Gastric emptying data are commonly presented as half emptying time ($t\frac{1}{2}$) because this is an easily interpreted parameter describing the overall emptying curve which is of physiological relevance[13,14] and not just single points of the curve. In this study the data are expressed as the slope value after semilog linearisation of the gastric emptying curve. This parameter also describes the whole of the emptying curve. Drink B emptied at such a slow rate that $t\frac{1}{2}$ would have been in the range 150–200 minutes, well outside the 60 minute actual measuring range. For statistical comparison of the slope values, individual differences, and the mean of the two techniques were calculated, as well as the geometric mean after log transformation, and the 95% limits of agreement as suggested by Bland and Altman.[15] The statistical difference in emptying rates between drink A and B are expressed as p values calculated from the Wilcoxon signed rank test. All data in the text, tables, and figures are mean (SEM), unless indicated as SD.

Results

The mean time course of gastric emptying for the two drinks and both techniques is shown in Figure 1. Individual data are shown in the Table as slope values after semilog linearisation of the gastric emptying curve. The mean accuracy of the fit used, expressed as the correlation coefficient r, is 0·95 for drink A and 0·89 for drink B in the double sampling technique experiment and 0·96 and 0·90 respectively for the scintigraphy data. Also presented in the Table are the individual differences between the two techniques and their means. Figure 2 is a scattergram of the difference against the mean of the two techniques for drinks A and B. Statistical evaluation of the results (Wilcoxon signed rank test) confirmed that drink A was emptied from the stomach at a faster rate than drink B, and this was so for both techniques (double sampling $Z=-2{\cdot}366$, $p=0{\cdot}02$; scintigraphy $Z=-2{\cdot}197$, $p=0{\cdot}03$). On average, at the end of the 60 minute measuring period more than 60% of the initial bolus remained in the stomach when drink B was

given, but only 15% of drink A remained. The mean difference in slopes between the two techniques for drink A is 0·0051 with 95% limits of agreement of +0·0115 to −0·0012 and for drink B 0·0021 with limits of +0·0068 to −0·0025. After log transformation of the data the geometric mean was calculated: drink A 0·68 (95% limits of agreement 1·56 to 0·30); drink B 0·64 (95% limits 1·14 to 0·36).

Discussion

Both techniques indicate that there is a large interindividual variability in the gastric emptying rate, as reflected by the high SEM values of the double sampling technique and scintigraphy in the Table. This, however, represents a real difference between individuals rather than a lack of accuracy of the two methods. Two drinks were used to compare the two techniques in order to investigate whether there was any difference in emptying patterns between fast (A) and slow (B) emptying liquid meals using different techniques. Drink A emptied significantly faster from the stomach than drink B, as was expected (drink B had higher osmolality and a higher caloric content) regardless of the technique used. The difference in emptying between the two techniques proved to be consistent over the two drinks, as the geometric mean shows (0·68 for drink A, 0·64 for drink B). This leads to the conclusion that scintigraphy gives an emptying rate 0·7 times slower than double sampling for liquid meals, irrespective of whether they are slow or fast emptying. This finding of an underestimate of the gastric emptying rate with the scintillation technique has also been reported by several others. From studies using models of the stomach and on the basis of theoretical considerations, Lawaetz and Dige-Peterson[16] describe an overestimate of the drink volume in the stomach by 10% when using scintigraphy. Sutton *et al*[17] compared gastric emptying rates when using scintigraphy and an epigastric impedance method and found scintigraphy gave an emptying rate 15% slower than epigastric impedance. This is considered to be primarily due to gastroduodenal overlap and scattering of radiation from the gut. However, individual variation, as indicated by the large 95% limits of agreement (1·56 to 0·30) of the geometric mean, has to be taken into account. These wide limits might be due to the small sample size and the large coefficient of variation in the techniques used.[16-22] Comparison of the two techniques should therefore not be made from individual data but should be based on group means.

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