



Observational Study

Comparison of gastric emptying of solid and semi-solid meals using real-time ultrasonography in healthy Sri Lankan adults

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Abstract

BACKGROUND

Routine assessment of solid gastric emptying is challenging due to the prolonged test duration and complex meal preparation. Replacing solid test meals with easily prepared, commercially available semisolid meals and shortening the test duration can significantly enhance the feasibility and practicality of gastric emptying evaluations.

AIM

To compare the gastric emptying and antral motility of solid *vs* semi-solid meals of similar volume and nutritional consistency, and to assess the feasibility of meal substitution and reduction in test duration during the solid gastric emptying assessment.

METHODS

Thirty healthy volunteers (17 males, age: 29.4 ± 6.0 years, body mass index: 23.4 ± 2.94 and 13 females, age: 37.2 ± 11.9 years, body mass index: 22.9 ± 4.34) underwent gastric emptying by real-time ultrasonography after a solid meal and a comparable commercially prepared semi-solid meal (each meal, total calorie 350 kcal, carbohydrates 60%, fat 30% and proteins 10%), on separate dates 1 week apart. The gastric antral area was measured at 5 minutes, 15 minutes, 30 minutes, 45 minutes, 60 minutes, 90 minutes, 120 minutes, 150 minutes, 180 minutes, 210

minutes, and 240 minutes post-ingestion using a previously validated technique and compared between meals.

RESULTS

Mean and median antral areas, gastric emptying rates, gastric residual ratios, and motility index at each time point were almost similar between meals for up to 3 hours. At the end of 4 hours, the mean emptied percentage of the semisolid meal and solid meal was 81.1% and 70.6%, respectively. The emptying rate of the semisolid meal at 90 minutes significantly correlated with that of 240 minutes. There was no correlation between the solid meal emptying rates at 90 minutes and 240 minutes.

CONCLUSION

Gastric emptying, residual antral cross-sectional area and antral motility of a semisolid meal are almost similar to that of a solid meal of the same nutritional value until three hours post-ingestion. A semisolid test meal can effectively substitute a solid test meal during ultrasound assessment of gastric emptying, without compromising the validity of the results. Additionally, the ease of preparation and administration of semisolid meals enhances the overall feasibility of gastric emptying assessments.

Key Words: Antral motility; Gastric emptying; Gastric residual ratio; Solid meal; Semi-solid meal; Real-time ultrasonography

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Core Tip: Semisolids are commonly believed to empty from the stomach faster than solids, with a significantly shorter lag time. However, using semisolid and solid meals of identical volume and nutritional composition, we demonstrated that gastric emptying rates and antral motor activities were comparable for both meal types up to three hours post-ingestion, with similar half-emptying times. Real-time ultrasonography using a pre-prepared, commercially available, and culturally acceptable semisolid test meal proved to be a reliable and valid method for assessing gastric emptying. This approach offers an effective alternative to traditional solid meal gastric emptying measurements.

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INTRODUCTION

The study of the gastric emptying of a solid meal is invaluable in diseases such as gastroesophageal reflux disease, functional gastrointestinal disorders and diseases associated with autonomic neuropathy, such as diabetes mellitus[1]. With lifestyle changes, such diseases are on the rise and more and more patients present with abdominal complaints related to delayed gastric emptying, hence the need for objective testing of gastric motility before treatment.

Real-time ultrasonography is a simple, non-invasive and valid method for assessing gastric emptying and antral motility after either a liquid or a solid meal[2,3]. Yet, the methods currently employed to assess solid gastric emptying are based on the time taken by a solid meal to exit the stomach and are time-consuming, taking up to 4 hours[2], which makes it difficult to be used as a routine diagnostic test, especially in children. Therefore, a reduction of the time spent on the gastric emptying assessment test would be invaluable in clinical practice in terms of convenience to the patients and laboratory staff, as well as in research, which will significantly improve the participation of subjects. In addition, the preparation of a solid test meal is cumbersome in laboratory settings.

To overcome the shortcomings of using a solid meal as a test meal, a newer, shorter version of the conventional method (90-minute gastric emptying) has been developed by a group of Swedish investigators. They used real-time ultrasonography to determine gastric antral cross-sectional area in a single section of the stomach, defining the gastric emptying rate (GER) as the percentage reduction in antral cross-sectional area from 15 minutes (area of maximal antral dilation) to 90 minutes after the ingestion of a standardized nutrient semisolid breakfast meal (300 g rice pudding, 330 kcal). This is a convenient method for estimating gastric emptying[4]. However, due to variations in the types of diets consumed and genetic factors, gastric emptying is likely to vary between different populations with different food habits. Therefore, it is not possible to introduce techniques and test meals developed in Western countries directly to other regions of the world, including the Sri Lankan population.

The gastric emptying of a solid and semi-solid meal is somewhat similar. After ingestion of a semi-solid or solid meal, there is an initial delay called the "lag phase", followed by an emptying phase that approximates a linear pattern. The lag phase depends on the time taken to redistribute food from the proximal to the distal stomach and the mixing and grinding of solid food into small particles in the distal stomach[5,6]. The lag phase is considered to be shorter for a semi-solid meal than for a solid meal. However, no studies have been conducted to compare the exact difference in lag phase and emptying times of solid and semisolid meals of similar nutritional composition.

Various test meals have been employed in the past to measure gastric emptying by ultrasonography. The caloric content, volume, and consistency of solid meals should have been designed to conform to the usual breakfast of a particular culture. A typical Sri Lankan adult breakfast would contain approximately 350 kcal, with 60% carbohydrate, 30% fat and 10% protein[7]. However, to date, no standard test meal has been defined for use in the study of gastric emptying in Sri Lanka. For diagnostic purposes, it is convenient to have a meal that is easy to prepare and administer and is acceptable and palatable to the Sri Lankan patients.

This study was carried out with three objectives. The main objectives of this study were to compare distal stomach emptying of solid and semisolid meals of similar volume and nutritional consistency and to assess the validity of replacing solid gastric emptying with a semisolid meal that is similar in caloric content to a typical Sri Lankan breakfast, yet easy to prepare. The other objective was to assess the validity of measuring solid gastric emptying using the previously reported 90-minute method.

MATERIALS AND METHODS

The study was conducted at the Gastroenterology Research Laboratory of the Faculty of Medicine, University of Kelaniya, Ragama, Sri Lanka. Subject recruitment and data collection were conducted from December 2014 to January 2018.

Subjects

Thirty healthy adult volunteers were recruited for the study using a convenient sampling technique after obtaining written informed consent.

Inclusion criteria: (1) Healthy adults aged 18 to 40 years; and (2) Who give informed written consent for participation in the study.

Exclusion criteria: (1) Presence of a chronic disease or taking long-term medication for an illness; (2) Presence of symptoms related to the gastrointestinal tract; (3) Acute illness during the 2 weeks preceding the laboratory testing; (4) Previous surgery involving the gastrointestinal tract; and (5) Using medication affecting gastric motility during the period of study. The presence of gastrointestinal symptoms was assessed by a previously validated gastroesophageal reflux disease symptom questionnaire[8].

Test meals

Each subject was given two different test meals in random order on two separate days, one week apart, as breakfast. The calorie content of each meal was approximately 350 kcal and consisted of around 60% carbohydrate, 30% fat and 10% protein. Both meals were ingested within 10 minutes, along with 300 mL of water.

Solid meal - milk rice made with mung beans (mung kiribath)

The solid meal (mung kiribath, mung bean cooked with rice and milk; 349 kcal; 82 g) contained 52 g of carbohydrate, 10 g of protein and 11 g of fat. The mung bean (24 g) was soaked with water overnight and then microwaved with rice (40 g) and 250 mL of water, on medium-high for 15 minutes. Then, evaporated milk powder (25 g), sugar (20 g) and butter (5 g) were added to make it more palatable and to achieve the required calorie content.

Semi-solid meal (Nestum Mung)

The semi-solid meal (Nestum Mung; 347 kcal; 82 g) contained 52 g of carbohydrate, 10 g of protein and 11 g of fat. This was a commercially prepared cereal (Nestum Mung 32 g), which was mixed with water (250 mL), evaporated milk powder (25 g), sugar (20 g) and butter (5 g) in similar proportions as for the solid meal.

Assessment of gastric motility

Female subjects were examined during the follicular phase of the menstrual cycle to avoid any influence of the hormonal changes during the cycle. No participants were recruited during religious fasting or a dietary intervention. All study participants were advised to refrain from caffeine, nicotine or alcohol for 8 hours before assessing gastric motility. Drugs affecting gastric motility (*e.g.*, anticholinergics, narcotics, prokinetics and erythromycin) were stopped for 48 hours prior to the test.

The gastric motility assessments were performed in the morning after an overnight fast of 8 hours. The subjects were examined by real-time ultrasonography performed with a high-resolution real-time scanner (SIEMENS ACUSON X300, Thailand) with a 3.5 MHz convex array transducer with facilities to record and playback. Gastric motility assessments in all patients commenced between 8:00 am and 8:30 am. Both gastric motility measurements of each patient were made by the same examiner, who was blinded with respect to the test meal. The subjects were examined in a semi-recumbent position and rested in a seated position in between measurements. The antrum, superior mesenteric artery and abdominal aorta were simultaneously visualized by the transducer (Figure 1). The record-and-playback technique was employed to enhance measurement accuracy.

Measurement of the gastric motility was done using a previously described standardized ultrasound method[2]. The cross-sectional area of the antrum and frequency and amplitude of antral contractions were measured during the fasting period (0 minute) and at 5 minutes, 15 minutes, 30 minutes, 45 minutes, 60 minutes, 90 minutes, 120 minutes, 180 minutes

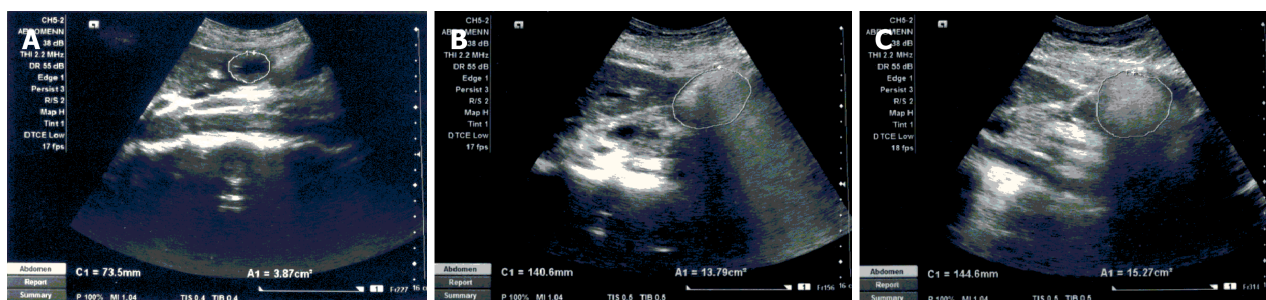


Figure 1 Ultrasonographic images showing the measurement of antral cross-sectional areas. A: Fasting; B: 5 minutes after ingestion of the semisolid test meal; C: 5 minutes after ingestion of the solid test meal.

and 240 minutes after ingestion of each test meal. At each time point, the antral cross-sectional area was estimated by tracing the mucosal side of the antrum with an in-built caliper and the frequency of antral contractions was taken as the number of contractions per consecutive 3 minutes. The amplitude was calculated from the maximum reduction of the antral area for each contraction. For each subject and type of test meal, the gastric motility parameters were calculated as follows.

For the conventional method: $GER_n = [(cross\text{-}sectional\ area\ at\ each\ point\ of\ observation - fasting\ cross\text{-}sectional\ area) / (cross\text{-}sectional\ area\ at\ 5\ minute - fasting\ cross\text{-}sectional\ area) - 1] \times 100$. Gastric residual ratio (GRR) = $(cross\text{-}sectional\ area\ at\ each\ point\ of\ observation - fasting\ cross\text{-}sectional\ area) / (cross\text{-}sectional\ area\ at\ 5\ minutes - fasting\ cross\text{-}sectional\ area) \times 100$.

For the simplified method: $GER_{90} = [(cross\text{-}sectional\ area\ at\ 90\ minutes / cross\text{-}sectional\ area\ at\ 15\ minutes) - 1] \times 100$.

For the antral motility assessment: Amplitude of antral contractions = $[(cross\text{-}sectional\ area\ at\ relaxation - cross\text{-}sectional\ area\ at\ contraction) / cross\text{-}sectional\ area\ at\ relaxation] / 100$. Antral motility index = amplitude of antral contractions \times frequency of antral contractions / 100.

To avoid the day-to-day variation in fasting antral size, for comparison of solid and semisolid meals, the antral cross-sectional area at each time point was taken after deducting the fasting antral cross-sectional area of that particular day (*e.g.*, cross-sectional area at 15 minutes = measured cross-sectional area at 15 minutes - fasting cross-sectional area). As the maximal antral cross-sectional area was seen at 5 minutes post-ingestion, it was used to calculate GER and GRR at each time point.

Statistical analysis

At an 80% power ($1 - \beta = 0.80$) and a 5% significance level ($\alpha = 0.05$), to detect a difference of GER of 10% between two meals, the minimum sample required for this crossover study was 22. Statistical analyses were conducted using PSPP version 2.0.1 (Free Software Foundation, Inc., <http://fsf.org/>). Median gastric motility parameters were compared using the nonparametric Wilcoxon signed-rank test. The GRR and GER were calculated for both the semi-solid and solid meals and correlated using the Spearman correlation coefficient. A $P < 0.05$ was considered statistically significant.

Ethical issues

Ethical approval was obtained from the Ethics Review Committee of the Faculty of Medicine, University of Kelaniya. All participants gave written informed consent. All procedures conformed to the Declaration of Helsinki.

RESULTS

A total of 30 subjects were recruited in the study. Of them, 17 (56.6%) were males (mean age: 29.4 ± 6.0 years, body mass index: 23.4 ± 2.94), and 13 were females (mean age: 37.2 ± 11.9 years, body mass index: 22.9 ± 4.34). None of them had chronic gastrointestinal disorders, nor symptoms related to the gastrointestinal tract during the previous 3 months.

Figure 2A shows the median residual gastric antral areas after ingesting solid and semisolid meals. Gastric residual antral area following both meals showed a similar biphasic pattern for the first 3 hours after the meal, with a lag phase of 60 minutes. The half-emptying time was approximately 120 minutes for both meals. The median GER of both meals did not differ significantly up to 3 hours post-ingestion, after which the solid meal emptying was slower (**Figure 2B**). At the end of 4 hours, the mean percentage emptying of the semisolid meal was 81.1%, and of the solid meal, it was 70.6%. In the semisolid meal, GER at 90 minutes significantly correlated with the GER at 240 minutes ($r = 0.594$, $P = 0.042$). There was no such correlation in the solid meal between 90-minute and 240-minute GERs ($r = 0.055$, $P = 0.852$). The median GRR (**Table 1**) and antral motility index (**Figure 2C**) at each time point did not differ significantly between the two meals. GER of the two meals showed a significant positive correlation up to three hours of post-ingestion (**Table 2**).

Table 1 Comparison of gastric residual ratios of semisolid and solid meals at different time points, mean \pm SD

Time after ingestion	Gastric residual ratios (%)		
	Semisolid meal	Solid meal	P value ¹
5 minutes	100.00	100.00	1.000
15 minutes	96.90 \pm 2.78	93.28 \pm 5.10	0.959
30 minutes	94.57 \pm 3.02	86.28 \pm 5.18	0.992
45 minutes	84.41 \pm 3.61	85.10 \pm 4.84	0.491
60 minutes	87.00 \pm 4.25	73.68 \pm 4.05	0.090
90 minutes	72.02 \pm 4.32	68.86 \pm 4.40	0.766
120 minutes	60.69 \pm 3.66	55.32 \pm 4.16	0.349
150 minutes	44.43 \pm 3.48	49.32 \pm 3.38	0.318
180 minutes	33.79 \pm 3.08	37.53 \pm 2.84	0.294
210 minutes	19.52 \pm 2.70	28.43 \pm 3.54	0.016
240 minutes	18.90 \pm 2.79	29.34 \pm 5.66	0.110

¹Wilcoxon Signed-Rank test.

Table 2 Correlation of gastric emptying rates of semisolid and solid meals at different time points

Time after ingestion	Correlation coefficient	P value ¹
5 minutes	-	-
15 minutes	0.325	0.079
30 minutes	0.203	0.283
45 minutes	0.600	< 0.001
60 minutes	0.572	0.001
90 minutes	0.628	< 0.001
120 minutes	0.521	0.003
150 minutes	0.500	0.005
180 minutes	0.412	0.026
210 minutes	0.237	0.244
240 minutes	0.309	0.355

¹Spearman correlation coefficient.

DISCUSSION

The current study was carried out to increase the feasibility of testing gastric emptying and antral motility of solids by means of a comparable semi-solid meal, using safe and non-invasive real-time ultrasonography. In this study, the pattern of gastric emptying and gastric motility parameters were not significantly different between the solid and semisolid meals up to 3 hours following ingestion of the test meal. However, total gastric emptying time was shorter after ingestion of the semisolid meal with the same nutritional composition, volume and calorie content. In addition, the GER at 90 minutes following a semisolid meal significantly correlated with gastric emptying at 240 minutes, but no such correlation was observed following a solid meal.

In this study, the maximum antral area was reached at 5 minutes post-ingestion for both meals, and there was no significant difference in the timings. A previous study conducted on Sri Lankan adults, which used bread and dhal curry as the test meal, also demonstrated a maximum antral size at 5 minutes[9]. However, the 15-minute post-ingestion maximal antral size reported in this study was significantly smaller compared to that of other previous studies[10]. It is possible that this difference is due to the fact that in the previous study, the first measurement was made at 15 minutes following ingestion.

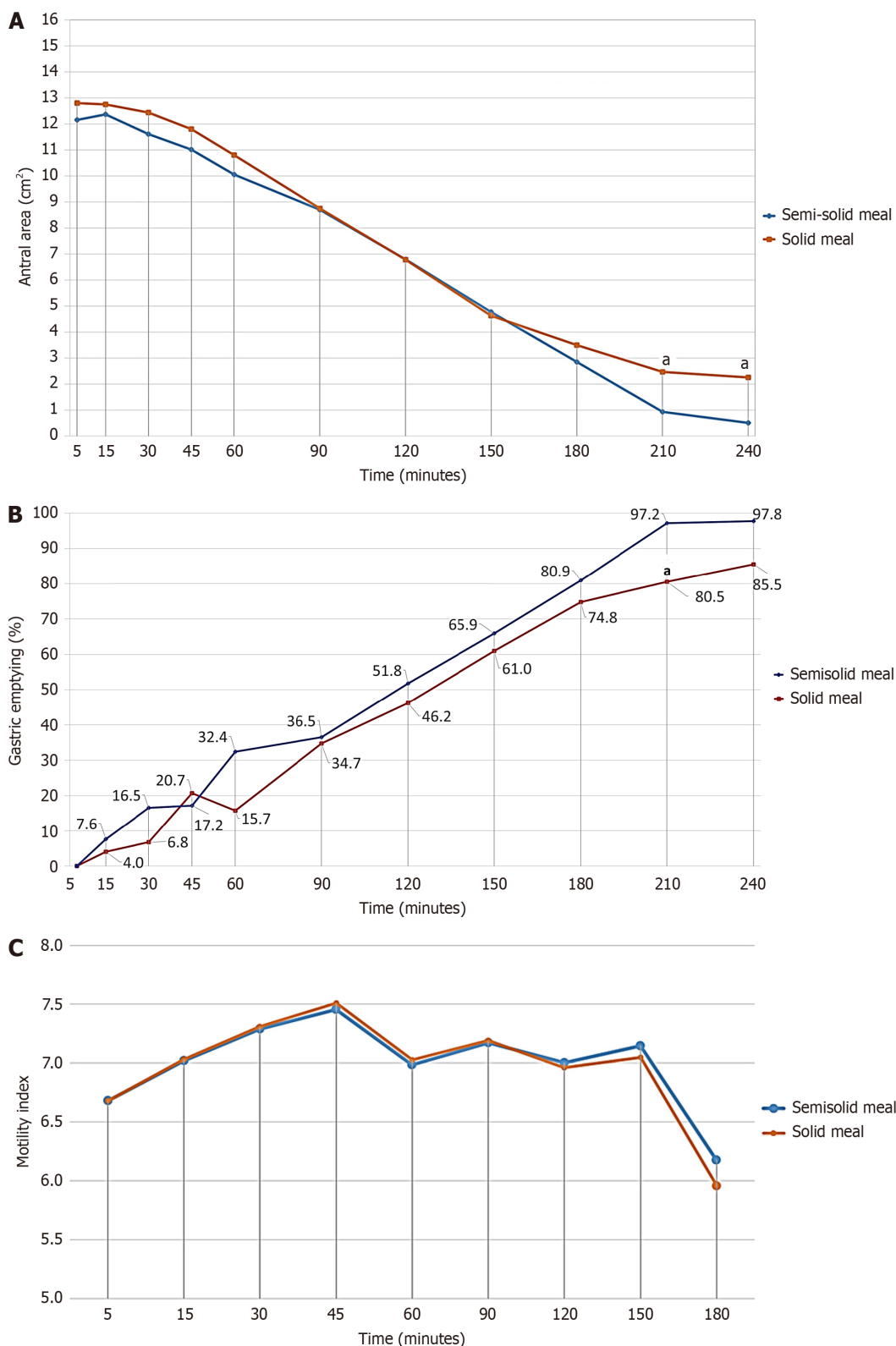


Figure 2 Comparisons of residual gastric antral size, gastric emptying, and antral motility index between solid and semisolid meals. ^a*P* < 0.05 compared with semisolid meal (Wilcoxon Signed Ranks test). A: Comparison of residual gastric antral size after ingestion of the solid and semisolid meals; B: Comparison of gastric emptying of solid and semisolid meals; C: Comparison of the antral motility index of solid and semisolid meals.

Solid foods need to undergo mechanical digestion and should be broken down into particles less than 2 mm in size before being emptied from the stomach[11]. The semisolid meal we used in this study was already in powdered form and did not need mechanical digestion; therefore, it could be emptied immediately after ingestion. Hence, we expected that the gastric emptying of the semisolid meal would be faster than that of a solid meal. However, in the present study, gastric emptying parameters, including antral areas, GERS, GRRs, and the motility index, did not show significant differences between the solid and semisolid meals during serial measurements within the first three hours post-ingestion.

In addition, the GERs of the solid and semisolid meals positively correlated up to 3 hours post-ingestion. Thereafter, the gastric emptying of the solid test meal was slower. The gastric half-emptying time is the time when 50% of the gastric contents have emptied. The half-emptying time was almost similar (120 minutes) for both meals. At the end of 4 hours, the mean emptied percentage of the semisolid meal was more than that of the solid meal (81.1% *vs* 70.6%).

Both solid and semisolid gastric emptying (GE) patterns in our study subjects showed the biphasic pattern previously described for solid gastric emptying[6,12]. Within the first 60 minutes after ingestion of both solid and semisolid meals, the reduction in GRR was smaller compared to the next 3 hours, indicating a 60-minute lag phase. This was followed by a fast, near-linear pattern of reduction in GRR, depicting the rapid gastric emptying phase. Since the semisolid meal we used in this study did not need mechanical digestion, we expected a significantly shorter lag phase for the semisolid meal. However, our findings indicate that the lag phase does not differ depending on the consistency of the meal. No previous study has compared solid and semisolid meals of the same volume and nutritional consistency. Previous studies have described a longer lag phase for a solid test meal and a relatively shorter lag phase for a liquid meal[5,13]. In those studies, the composition, volume and nutritional values of the solid and liquid meals were different, and their effects on differences in lag phases have not been considered.

Our results show that the consistency (whether solid or semisolid) of a test meal does not significantly influence the main gastric motility parameters such as gastric antral size, GER, antral motility index and GRR until the final stages of gastric emptying. Therefore, semisolid test meals could successfully replace the use of solid test meals during assessment of gastric emptying. In addition, 90 minutes GER of the semisolid meal significantly correlated with the 240 minutes GER. However, the lack of such correlation between 90-minute and 240-minute GER indicates that the 90-minute GER is not a reliable indicator of the measurement of solid gastric emptying.

Real-time ultrasonography is a preferred method of measuring GE as it is simple and non-invasive, with minimal discomfort to patients. Previous studies have shown a close correlation in gastric emptying simultaneously measured by scintigraphy and ultrasonography[4]. This technique has also shown a good inter-observer agreement[14]. The main disadvantages of using ultrasound techniques to measure solid gastric emptying were difficulty in preparing a culturally acceptable test meal in the laboratory, the need to perform ultrasound scanning for a long duration (minimum of 4 hours after a meal) and the need for well-trained staff. These are the main limitations of using this method as a routine diagnostic test, especially in children.

A group of Swedish investigators validated a shorter version (90-minute gastric emptying) of the conventional method [4]. The test meal used in that study could not be directly applied to Sri Lankan patients. In the present study, we attempted to replace the conventional long-duration solid GE test with a shorter version of the test using the semi-solid test meal acceptable to the Sri Lankan population. The reduction of the test time from 4 hours to one and a half hours and validation of commercially prepared, culturally acceptable, nutritious and palatable test meals would be more convenient to patients and laboratory staff and is also likely to improve the participation of subjects in related research activities. However, the median GER at 90 minutes observed in our study (36.5%) was lower than that reported in a previous study (63%)[4]. This difference in gastric emptying at 90 minutes may be attributed to several factors, including variations in the nutritional content, fat composition, and volume of the test meal, as well as genetic, cultural, and environmental differences across populations and regions. A previous study conducted in Sri Lanka using the same ultrasound technique assessed solid gastric emptying in both asthmatic patients and healthy controls. The gastric emptying parameters reported in healthy controls in that study (*e.g.*, half emptying time of 119 minutes, GER at 210 minutes of 71.8%, and a residual ratio at 90 minutes of 60%) closely resemble those observed in our current study, despite differences in the specific test meal used[9]. Importantly, the test meal in the previous study, like ours, reflected a typical Sri Lankan breakfast. These similarities suggest that the solid gastric emptying patterns reported in our study are representative of the physiological norm in healthy Sri Lankan individuals.

This study has several limitations. First, the real-time ultrasound techniques employed allowed assessment of gastric emptying in the distal stomach but did not evaluate proximal gastric accommodation. Second, the gastric emptying of solid and semisolid meals was measured 1 week apart, making it difficult to rule out day-to-day variations in gastric motility completely. Nevertheless, using the record-and-playback technique and assessments conducted by the same investigator enhances the validity and consistency of the findings. Third, *Helicobacter pylori* (*H. pylori*) infection has been reported to reduce the number of gastric pacemaker cells, leading to delayed gastric emptying[15]. The infection is highly prevalent in Sri Lanka, affecting approximately 70% of the population[16]. Although we did not assess *H. pylori* status in our study participants, we compared gastric motility within the same individuals following solid and semisolid meals. Therefore, any potential effect of *H. pylori* infection on gastric motility would be consistent across both meal types and unlikely to influence the comparative results. Last, we used a safe and non-invasive ultrasound technique to assess the gastric emptying after solid and semisolid meals, instead of scintigraphy, which is the gold standard. However, ultrasound techniques have been previously compared with scintigraphy and shown to be accurate in measuring gastric emptying[4,17-19]. The technique we used has been compared with the ¹³C-octanoic acid breath test and shown to be accurate[20].

CONCLUSION

This study demonstrates that solid and semisolid meals with identical nutrient composition, volume, and caloric content exhibit comparable antral distension, GERs and antral motility patterns up to 3 hours post-ingestion, with similar half-emptying times and lag phases. Real-time ultrasonography using a pre-prepared, commercially available, culturally acceptable semisolid meal provides a reliable, valid, and practical alternative to solid meal gastric emptying assessments.

The ease of preparation and enhanced feasibility of the semisolid meal further support its use in clinical and research settings.

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FOOTNOTES

Author contributions: Amarasiri L, de Silva M, de Silva HJ and Devanarayana NM contributed to the concept; Amarasiri L, de Silva M and Devanarayana NM collected the data; Amarasiri L analyzed the data and wrote the initial manuscript; Devanarayana NM, and de Silva HJ contributed by critically analyzing and revising the paper; and all authors approved the final version of the manuscript.

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REFERENCES

- 1 Camilleri M, Hasler WL, Parkman HP, Quigley EM, Soffer E. Measurement of gastrointestinal motility in the GI laboratory. *Gastroenterology* 1998; **115**: 747-762 [RCA] [PMID: 9721173 DOI: 10.1016/S0016-5085(98)70155-6] [FullText]
- 2 Haruma K, Kusunoki H, Manabe N, Kamada T, Sato M, Ishii M, Shiotani A, Hata J. Real-time assessment of gastroduodenal motility by ultrasonography. *Digestion* 2008; **77** Suppl 1: 48-51 [RCA] [PMID: 18204262 DOI: 10.1159/000111488] [FullText]
- 3 Bolondi L, Bortolotti M, Santi V, Calletti T, Gaiani S, Labò G. Measurement of gastric emptying time by real-time ultrasonography. *Gastroenterology* 1985; **89**: 752-759 [RCA] [PMID: 3896910 DOI: 10.1016/0016-5085(85)90569-4] [FullText]
- 4 Darwiche G, Almér LO, Björgell O, Cederholm C, Nilsson P. Measurement of gastric emptying by standardized real-time ultrasonography in healthy subjects and diabetic patients. *J Ultrasound Med* 1999; **18**: 673-682 [RCA] [PMID: 10511299 DOI: 10.7863/jum.1999.18.10.673] [FullText]
- 5 Camilleri M, Malagelada JR, Brown ML, Becker G, Zinsmeister AR. Relation between antral motility and gastric emptying of solids and liquids in humans. *Am J Physiol* 1985; **249**: G580-G585 [RCA] [PMID: 4061646 DOI: 10.1152/ajpgi.1985.249.5.G580] [FullText]
- 6 Siegel JA, Urbain JL, Adler LP, Charkes ND, Maurer AH, Krevsky B, Knight LC, Fisher RS, Malmud LS. Biphasic nature of gastric emptying. *Gut* 1988; **29**: 85-89 [RCA] [PMID: 3343018 DOI: 10.1136/gut.29.1.85] [FullText]
- 7 Wickramanayake LW. Requirements of Energy and Protein. In: Wickramanayake TW. Food and Nutrition. 3rd ed. Colombo: Hector Kobbekaduwa Agrarian Research and Training Institute, 1996: 30-55
- 8 Amarasiri LD, Pathmeswaran A, De Silva AP, Dassanayake AS, Ranasinha CD, De Silva J. Comparison of a composite symptom score

- assessing both symptom frequency and severity with a score that assesses frequency alone: a preliminary study to develop a practical symptom score to detect gastro-oesophageal reflux disease in a resource-poor setting. *Eur J Gastroenterol Hepatol* 2010; **22**: 662-668 [RCA] [PMID: 19491697 DOI: 10.1097/MEG.0b013e32832cfe12] [FullText]
- 9 **Amarasiri WA**, Pathmeswaran A, de Silva AP, Dassanayake AS, Ranasinha CD, de Silva HJ. Gastric motility following ingestion of a solid meal in a cohort of adult asthmatics. *J Neurogastroenterol Motil* 2013; **19**: 355-365 [RCA] [PMID: 23875103 DOI: 10.5056/jnm.2013.19.3.355] [FullText] [Full Text(PDF)]
 - 10 **Darwiche G**, Björgell O, Almér LO. The addition of locust bean gum but not water delayed the gastric emptying rate of a nutrient semisolid meal in healthy subjects. *BMC Gastroenterol* 2003; **3**: 12 [RCA] [PMID: 12793910 DOI: 10.1186/1471-230X-3-12] [FullText] [Full Text (PDF)]
 - 11 **Kong F**, Singh RP. Disintegration of solid foods in human stomach. *J Food Sci* 2008; **73**: R67-R80 [RCA] [PMID: 18577009 DOI: 10.1111/j.1750-3841.2008.00766.x] [FullText]
 - 12 **Hellström PM**, Grybäck P, Jacobsson H. The physiology of gastric emptying. *Best Pract Res Clin Anaesthesiol* 2006; **20**: 397-407 [RCA] [PMID: 17080692 DOI: 10.1016/j.bpa.2006.02.002] [FullText]
 - 13 **Collins PJ**, Houghton LA, Read NW, Horowitz M, Chatterton BE, Hedde R, Dent J. Role of the proximal and distal stomach in mixed solid and liquid meal emptying. *Gut* 1991; **32**: 615-619 [RCA] [PMID: 2060870 DOI: 10.1136/gut.32.6.615] [FullText]
 - 14 **Irvine EJ**, Tougas G, Lappalainen R, Bathurst NC. Reliability and interobserver variability of ultrasonographic measurement of gastric emptying rate. *Dig Dis Sci* 1993; **38**: 803-810 [RCA] [PMID: 8482177 DOI: 10.1007/BF01295904] [FullText]
 - 15 **Liu B**, Dong J, Wang S, Yu H, Li Z, Sun P, Zhao L. Helicobacter pylori causes delayed gastric emptying by decreasing interstitial cells of Cajal. *Exp Ther Med* 2021; **22**: 663 [RCA] [PMID: 33986828 DOI: 10.3892/etm.2021.10095] [FullText] [Full Text(PDF)]
 - 16 **Fernando N**, Holton J, Vaira D, DeSilva M, Fernando D. Prevalence of Helicobacter pylori in Sri Lanka as determined by PCR. *J Clin Microbiol* 2002; **40**: 2675-2676 [RCA] [PMID: 12089306 DOI: 10.1128/JCM.40.7.2675-2676.2002] [FullText]
 - 17 **Hveem K**, Jones KL, Chatterton BE, Horowitz M. Scintigraphic measurement of gastric emptying and ultrasonographic assessment of antral area: relation to appetite. *Gut* 1996; **38**: 816-821 [RCA] [PMID: 8984016 DOI: 10.1136/gut.38.6.816] [FullText]
 - 18 **Benini L**, Sembenini C, Heading RC, Giorgetti PG, Montemezzi S, Zamboni M, Di Benedetto P, Brighenti F, Vantini I. Simultaneous measurement of gastric emptying of a solid meal by ultrasound and by scintigraphy. *Am J Gastroenterol* 1999; **94**: 2861-2865 [RCA] [PMID: 10520834 DOI: 10.1111/j.1572-0241.1999.01429.x] [FullText]
 - 19 **Gomes H**, Hornoy P, Liehn JC. Ultrasonography and gastric emptying in children: validation of a sonographic method and determination of physiological and pathological patterns. *Pediatr Radiol* 2003; **33**: 522-529 [RCA] [PMID: 12811435 DOI: 10.1007/s00247-003-0954-1] [Full Text]
 - 20 **Aoki S**, Haruma K, Kusunoki H, Hata J, Hara M, Yoshida S, Tanaka S, Chayama K. Evaluation of gastric emptying measured with the ¹³C-octanoic acid breath test in patients with functional dyspepsia: comparison with ultrasonography. *Scand J Gastroenterol* 2002; **37**: 662-666 [RCA] [PMID: 12126243 DOI: 10.1080/00365520212508] [FullText]



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