Published in final edited form as:

Neurogastroenterol Motil. 2013 June ; 25(6): 542–546. doi:10.1111/nmo.12099.

Simplifying the Measurement of Gastric Accommodation using SPECT

Priya Vijayvargiya, Michael Camilleri, Andrea Shin, Mary Breen, and Duane Burton

Clinical Enteric Neuroscience Translational and Epidemiological Research (CENTER), Mayo Clinic, Rochester, MN

Abstract

Background—Noninvasive single photon emission computed tomography (SPECT) has been validated as a test for postprandial gastric volume accommodation, with volumes measured twice over 30 minutes and averaged. The purpose of this study is to simplify the SPECT measurement of gastric accommodation.

Methods—The primary aim of this study was to compare 2 postprandial gastric volume measurements with data collected retrospectively from 443 patients and healthy volunteers who had undergone SPECT in the last decade. The differences in the two gastric volumes were compared in the entire group and each subgroup, and the correlation between the 2 measurements and their differences across a wide range of gastric volumes were plotted.

Key Results—There was a median difference of <2% ($p=0.041$) between postprandial scan 1 (757 mL) and scan 2 (743 mL), with significant correlation ($r_s = 0.859$, $p<0.01$) and excellent agreement (S.D. 60 mL) between the 2 scans across the entire range of observed postprandial gastric volumes.

Conclusions & Inferences—A single postprandial scan can detect gastric accommodation with the same accuracy as averaging 2 postprandial scans. These data support simplifying SPECT measurement of postprandial gastric volume with a scan in the first 15 minutes after a meal.

INTRODUCTION

Gastric accommodation is a vagally-mediated, meal-induced reduction in gastric tone facilitating the ingestion of volume loads without increase in pressure. Impaired gastric accommodation contributes to early satiety, nausea, bloating, and vomiting (1). A variety of tests can measure gastric accommodation: single photon emission computed tomography (SPECT), barostat, three-dimensional ultrasound and MRI.

SPECT measurement of gastric volume change with meal ingestion (2) has demonstrated comparability to barostat measurements (3), reliability and reproducibility as a noninvasive approach (4). This technique utilizes intravenous ^{99m}Tc pertechnetate, which is taken up and excreted by parietal and non-parietal cells in the gastric mucosa. A dual headed gamma camera performs multiple 360° sweeps, acquiring images from which data are reconstructed using filtered-back projection (Ramp-Butterworth filter, order 10, cut-off 0.45 Nyquist) to

Address for correspondence: Michael Camilleri, M.D., Mayo Clinic, 200 First St. S.W., Charlton 8-110, Rochester, MN 55905, tele: 507-266-2305, camilleri.michael@mayo.edu.

AUTHORS' CONTRIBUTIONS

PV, MC and AS wrote the manuscript; MC, MB and DB collected and analyzed the data; MC performed statistical analysis.

DISCLOSURES/COMPETING INTERESTS

The authors report no conflicts of interest relevant to this article.

create transaxial images. These images are transferred to a workstation, and algorithm software (Analyze^{AVW} PC 2.5) reconstructs the images to produce a 3D representation of the entire gastric volume (5). Vasavid et al. (6) adapted the original method from Mayo Clinic to measure gastric volumes, which were calculated from transaxial gastric images using Image J software; they also performed the imaging every 10 minutes for 50 minutes after Ensure® meal (250 mL).

The intra-gastric barostatically-controlled balloon showed that relaxation of gastric tone was almost immediate, maximal by 5 minutes after the meal (7) and maintained for at least 45 minutes. Thus, when SPECT was originally introduced to measure postprandial gastric volume accommodation, two postprandial images were obtained over the first 30 minutes, and the average reported as the postprandial volume (2) in clinical and research practice. However, subsequent studies showed that maximum relaxation occurs within 15 minutes after a meal (8), and there were small (<5%) differences between the first and second postprandial volumes (9).

We have interrogated a research database in which all studies were conducted in the same laboratory and images analyzed by the same operator of the image analysis software (DD) to evaluate differences in two sequential estimates of postprandial gastric volumes obtained during the first 30 minutes after a 300mL Ensure® (Abbott Labs, Abbott Park, IL, USA) meal to determine whether a simpler approach utilizing only one postprandial scan would be accurate. Reducing from 2 to 1 scan will reduce expenses, decrease the time required to perform the test and may increase application of this non-invasive method of measuring gastric accommodation at other institutions.

The aim of this study was to compare first and second postprandial gastric volumes using data obtained from research participants over the last decade (1999–2009) to identify a simplified procedure using only one set of postprandial images.

METHODS

Study subjects included healthy volunteers who were categorized as normal weight, overweight, or obese, and patients suffering from dyspepsia, meal-related dyspepsia and type 2 diabetes mellitus. SPECT images were collected in a retrospective manner from all subjects using previously recorded research data. All participants had previously provided written informed consent. This research database study was approved by the Mayo Clinic Institutional Review Board. The meal-related dyspepsia patients were considered a separate group and were not included in the dyspeptic subgroup. (See Appendix 1 for list of previously published articles) Some of the original data assessed inter-individual variability and consequently had volunteers with multiple SPECT studies (4). For the present study, we included only the earliest SPECT study and removed 58 studies in individuals who had >1 study. Studies in which only one measurement of postprandial gastric volume was available (usually for technical reasons) were not considered (n=12).

The method has previously been described in detail (8). Briefly, participants were placed in the supine position, and received an intravenous injection of ^{99m}Tc-sodium pertechnetate (10mCi). Dynamic tomographic images of the gastric wall were acquired using a dual-headed gamma camera (SMV Fx-80 SPECT System; General Electric). Three sets of images were taken: fasting, and 0–15 min and 15–30 min after 300mL Ensure® (Abbott Labs, Abbott Park, IL, USA). All the images were analyzed by one technologist using image processing libraries (AVW 3.0, Biomedical Imaging, Mayo Clinic) were used to obtain a three-dimensional rendering of the stomach and calculate gastric volume (4).

Statistical Analysis

The Wilcoxon signed rank test was used to compare values for first and second postprandial volumes for all subjects (primary comparison) and secondary comparisons were conducted within each subgroup of participants (healthy, obese, overweight, dyspepsia, meal-induced dyspepsia, type 2 diabetes). Agreement between postprandial volume 1 and postprandial volume 2 were assessed using Spearman correlation and Bland-Altman plots.

RESULTS

Demographics

A total of 443 participants were included in the analysis including 63 individuals with dyspepsia, 12 with meal-related dyspepsia and 8 with type 2 diabetes mellitus. Among healthy volunteers, there were 138 subjects categorized as normal weight, 140 as overweight and 118 as obese (Table 1).

Comparison of First and Second Postprandial Gastric Volumes

Results of first and second postprandial volumes are shown in Table 1. All values are expressed as median (IQR) values. Data from all volunteers showed a significant difference ($p=0.04$) between median values for first (757 mL) and second (743 mL) postprandial volumes; however the difference was less than 2%. In the subgroups, the only differences in postprandial volumes were noted in healthy controls of normal BMI; the difference in median volumes was 45mL, an estimated 6% difference.

There was excellent agreement ($r_s=0.859$, $p<0.01$) between the two postprandial estimates (Figure 1 Upper Panel). The corresponding Bland Altman plot (Figure 1 Lower Panel) shows intra-subject difference between first and second postprandial gastric volumes in relation to the average postprandial volume in each subject. The graph displays a consistent variability throughout the range of average postprandial volumes and a standard deviation of the difference in volumes of 60 mL.

DISCUSSION

This study shows an overall variation of less than 2% between postprandial gastric volumes 1 and 2 among all subjects with a high degree of agreement in the 2 measurements. There was no significant difference between first and second postprandial volumes within each of the subgroups other than normal BMI healthy controls in which the difference was ~6%. These findings support the use of a simplified approach to SPECT with removal of the second postprandial measurement.

The variation in postprandial volume estimates is not regarded as clinically significant, relative to the median postprandial gastric volume of 750 mL noted in this study. The Bland Altman plot provides robust support for this conclusion. Thus, the standard deviation of the difference in the first and second postprandial volume measurements across all participants was 60 mL and 59.2 mL in the healthy control group. Two standard deviations, which contain 95% of the data, equal 120 mL. With the observed median fasting and postprandial volumes of 222 mL and 760 mL respectively in 138 healthy controls, the postprandial minus fasting volume is 538 mL. Even with a 120 mL error in the postprandial volume, the difference would be 418 mL greater than the volume of liquid nutrient ingested (300 mL). Therefore, the single scan method would demonstrate gastric volume accommodation in the vast majority of healthy controls.

Prior gastric accommodation studies using the intragastric barostatically-controlled balloon have shown that maximum gastric accommodation after a liquid meal occurs in the first 20 minutes (9). The first SPECT study of gastric accommodation found the largest total and proximal gastric volume in the second (12–21 minutes) scan (2). However, another study that utilized a solid meal showed a maximum gastric accommodation at 15 minutes with a slow progressive decline in postprandial gastric volumes every 15 minutes for the next hour (8). Vasavid et al. found similar results with a maximum gastric volume within 10 minutes after ingestion of a liquid meal, with postprandial measurements conducted every 10 minutes for 50 minutes (6). Our current data is consistent with the latter observations. The postprandial scan conducted at 0–15 minutes involves 5 minutes for drinking the liquid meal, proper patient and machine setup, and rotation of the SPECT camera through 360 degrees, typically during 5–15 minutes. The resulting scan represents the gastric volume measured during the 15 minutes.

This single scan will detect reduced gastric volume accommodation, but, given the time required to register the three dimensional volume with noninvasive SPECT imaging, it is unable to discern qualitative changes in the pattern of gastric volume change such as prolonged or delayed onset of accommodation, or quantitative measurements such as the absolute maximum gastric volume or the time to reach that volume. On the other hand, it is unclear that these descriptions of the accommodation response (which are measured with the invasive electronic barostat) provide clinically relevant information. Moreover, the proportion of patients with functional dyspepsia with reduced gastric accommodation is ~50% using SPECT (1) and using the intra-gastric barostat (11). A direct comparison of simultaneous SPECT and barostat measurement of gastric accommodation showed a high degree of correlation (R^2 0.7) for the postprandial to fasting gastric volume ratio (3).

Thus, we recommend that a single postprandial SPECT scan at 0–15 minutes is an accurate and efficient method to determine appropriate gastric accommodation.

Acknowledgments

We thank Mrs. Cindy Stanislav for excellent secretarial assistance.

FUNDING

Dr. Camilleri is supported by NIH grant DK67071

Abbreviations

SPECT single photon emission computed tomography

References

1. Bredenoord AJ, Chial HJ, Camilleri M, Mullan BP, Murray JA. Gastric accommodation and emptying in evaluation of patients with upper gastrointestinal symptoms. *Clin Gastroenterol Hepatol*. 2003; 1:264–272. [PubMed: 15017667]
2. Kuiken SD, Samsom M, Camilleri M, et al. Development of a test to measure gastric accommodation in humans. *Am J Physiol*. 1999; 277:G1217–G1221. [PubMed: 10600819]
3. Bouras EP, Delgado-Aros S, Camilleri M, et al. SPECT imaging of the stomach: comparison with barostat and effects of sex, age, body mass index, and fundoplication. *Gut*. 2002; 51:781–786. [PubMed: 12427776]
4. Breen M, Camilleri M, Burton D, Zinsmeister AR. Performance characteristics of the measurement of gastric volume using single photon emission computed tomography. *Neurogastroenterol Motil*. 2011; 23:308–315. [PubMed: 21210894]

5. Kim D-Y, Delgado-Aros S, Camilleri M, et al. Noninvasive measurement of gastric accommodation in patients with idiopathic nonulcer dyspepsia. *Am J Gastroenterol*. 2001; 96:3099–3105. [PubMed: 11721755]
6. Vasavid P, Chaiwatanarata T, Gonlachanvit S. The reproducibility of 99mTc-pertechnetate single photon emission computed tomography (SPECT) for measurement of gastric accommodation in healthy humans: evaluation of the test results performed at the same time and different time of the day. *J Neurogastroenterol Motil*. 2010; 16:401–406. [PubMed: 21103421]
7. Thumshirn M, Camilleri M, Saslow SB, Williams DE, Burton DD, Hanson RB. Gastric accommodation in non-ulcer dyspepsia and the roles of *Helicobacter pylori* infection and vagal function. *Gut*. 1999; 44:55–64. [PubMed: 9862826]
8. Burton DD, Kim HJ, Camilleri M, et al. Relationship of gastric emptying and volume changes after a solid meal in humans. *Am J Physiol*. 2005; 289:G261–G266.
9. Manini, ML.; Camilleri, M. Gastric volume and accommodation measurement by SPECT and barostat. In: Parkman, HP.; McCallum, RW.; Rao, SSC., editors. *GI Motility Testing: A Laboratory and Office Handbook*. Thorofare, NJ: SLACK Incorporated; 2011. p. 109-120.
10. Liao S-S, Camilleri M, Kim D-Y, Stephens D, Burton DD, O'Connor MK. Pharmacological modulation of human gastric volumes demonstrated noninvasively using SPECT imaging. *Neurogastroenterol Motil*. 2001; 13:533–542. [PubMed: 11903914]
11. Kindt S, Tack J. Impaired gastric accommodation and its role in dyspepsia. *Gut*. 2006; 55:1685–1691. [PubMed: 16854999]
12. Kuiken SD, Samsom M, Camilleri M, et al. Development of a test to measure gastric accommodation in humans. *Am J Physiol*. 1999; 277:G1217–G1221. [PubMed: 10600819]
13. Liao S-S, Camilleri M, Kim D-Y, Stephens D, Burton DD, O'Connor MK. Pharmacological modulation of human gastric volumes demonstrated noninvasively using SPECT imaging. *Neurogastroenterol Motil*. 2001; 13:533–542. [PubMed: 11903914]
14. Kuo B, Camilleri M, Burton D, et al. Effects of 5-HT₃ antagonism on postprandial gastric volume and symptoms in humans. *Aliment Pharm Ther*. 2002; 16:225–233.
15. Chial HJ, Camilleri M, Burton D, Thomforde G, Olden KW, Stephens D. Selective effects of serotonergic psychoactive agents on gastrointestinal functions in humans. *Gastroenterology*. 2002; 122:A26.
16. Delgado-Aros S, Vella A, Camilleri M, et al. Effects of glucagon-like peptide-1 and feeding on gastric volumes in diabetes mellitus with cardio-vagal dysfunction. *Neurogastroenterol Motil*. 2003; 15:435–444. [PubMed: 12846732]
17. Castillo EJ, Delgado-Aros S, Camilleri M, et al. Effect of an oral CCK-A agonist, GI181771X, on gastric functions in healthy humans. *Gastroenterology*. 2003; 124:A223.
18. Delgado-Aros S, Chial HJ, Camilleri M, et al. Effects of a kappa opioid agonist, asimadoline, on satiation and gastrointestinal motor and sensory functions in humans. *Am J Physiol*. 2003; 284:G558–G566.
19. Chitkara DK, Delgado-Aros S, Bredenoord AJ, et al. Functional dyspepsia, upper gastrointestinal symptoms, and transit in children. *J Pediatr*. 2003; 143:609–613. [PubMed: 14615731]
20. Cremonini F, Foxx-Orenstein A, Camilleri M. Effects of the somatostatin analog, octreotide, on postprandial symptoms and gastric accommodation in obesity. *Neurogastroenterol Motil*. 2004; 16:655.
21. Camilleri CE, Carlson PJ, Camilleri M, et al. A study of candidate genotypes associated with dyspepsia in a U.S. community. *Am J Gastroenterol*. 2006; 101:581–592. [PubMed: 16464220]
22. Cremonini F, Camilleri M, Vazquez Roque M, et al. Obesity does not increase effects of synthetic ghrelin on human gastric motor functions. *Gastroenterology*. 2006; 131:1431–1439. [PubMed: 17101319]
23. Vazquez-Roque MI, Stephens D, Burton D, et al. Sibutramine significantly delays gastric emptying without altering volume or postprandial symptoms in obesity. *Gastroenterology*. 2006; 130:A294.
24. Camilleri M, Bharucha AE, Ueno R, et al. Effect of a chloride channel activator, lubiprostone, on gastrointestinal transit, gastric sensory and motor functions in healthy humans. *Am J Physiol*. 2006; 290:G942–G947.

25. Grudell ABM, Camilleri M, Burton DD, Stephens DA. Effect of a proton pump inhibitor on postprandial gastric volume, emptying and symptoms in healthy human subjects: a pilot study. *Aliment Pharmacol Ther.* 2006; 24:1037–1043. [PubMed: 16984497]
26. Park M-I, Camilleri M, O'Connor H, et al. Effect of different macronutrients in excess on gastric sensory and motor functions and appetite in normal- weight, overweight and obese humans. *Am J Clin Nutr.* 2007; 85:411–418. [PubMed: 17284737]
27. Andrews CN, Bharucha AE, Camilleri M, et al. Effects of glucagon-like peptide-1 (GLP-1) and sympathetic stimulation on gastric accommodation in humans. *Neurogastroenterol Motil.* 2007; 19:716–723. [PubMed: 17727392]
28. Sweetser S, Camilleri M, Zinsmeister AR, Low PA, McKinzie S. Do autonomic function and α 2 adrenergic genotypes predict IBS phenotype? *Am J Gastroenterol.* 2007; 102:S503.
29. Esfandiyari T, Camilleri M, Busciglio I, Burton D, Baxter K, Zinsmeister AR. Effects of a cannabinoid receptor agonist on colonic motor and sensory functions in humans: a randomized, placebo-controlled study. *Am J Physiol.* 2007; 293:G137–G145.
30. Bharucha AE, Fidler J, Camilleri M, et al. Comparison of gastric volumes measured by MRI and SPECT. *Neurogastroenterol Motil.* 2007; 19:421–422.
31. Manini ML, Burton DD, Meixner DD, et al. Feasibility and application of 3-dimensional ultrasound for measurement of gastric volumes in healthy adults and adolescents. *J Pediatr Gastroenterol Nutr.* 2009; 48:287–293. [PubMed: 19274782]
32. Odunsi ST, Vazquez Roque MI, Camilleri M, et al. Effect of alginate on satiation, appetite, gastric function and selected gut satiety hormones in overweight and obesity. *Obesity.* 2010; 18:1579–1584. [PubMed: 19960001]
33. Breen M, Camilleri M, Burton DD, Zinsmeister AR. Performance characteristics of the measurement of gastric volume using single photon emission computed tomography. *Neurogastroenterol Motil.* 2011; 23:308–315. [PubMed: 21210894]

APPENDIX

Publications from Dr. Camilleri's laboratory of previously performed gastric accommodation studies by SPECT conducted in patients with type 2 diabetes mellitus, dyspepsia, meal-related dyspepsia and healthy volunteers (normal weight, overweight and obese) from which data were derived in a retrospective manner for the current study.

Figure 1. Correlation of postprandial gastric volumes of scans 1 and 2 (mL): Upper panel – bold dashed line indicates the line of identity; solid line indicates the line of regression.

Groups of participants showing measured gastric volumes during fasting and in two postprandial scans, and the intragroup comparisons of the first and second scans (by signed rank test)

Table 1

	All Volunteers	Normal Weight	Overweight	Obesity	Dyspepsia	Meal Related Dyspepsia	Type 2 Diabetes
N	443	138	140	118	63	12	8
Fasting (mL)	229 (188,281)	222 (182,278)	232 (188,276)	225 (188,273)	260 (230, 13)	221 (207,286)	266 (185, 275)
Scan 1 (mL)	757 (678, 831)	781 (701, 837)	738 (653, 830)	721 (655, 802)	777 (688, 912)	747 (664, 917)	769 (679, 806)
Scan 2 (mL)	743 (669, 834)	736 (689, 835)	739 (645, 836)	729 (656, 807)	778 (682, 903)	786 (706, 898)	774 (685, 813)
P value	0.041	0.0041	0.408	0.277	0.596	0.339	0.742