Published in final edited form as:

J Pediatr Gastroenterol Nutr. 2009 March ; 48(3): 287–293.

Feasibility and Application of 3-Dimensional Ultrasound for Measurement of Gastric Volumes in Healthy Adults and Adolescents

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Abstract

Objectives—Abnormal gastric accommodation to a meal results in dyspepsia. Current methods to measure gastric volume (GV) are invasive or involve ionizing radiation. The aims of this study were: 1. To compare fasting and postprandial (PP) GVs measured by ^{99m}Tc-SPECT and 3-dimensional ultrasound (3D-US) in adults; 2. To assess the performance characteristics of 3D-US measurement of GV during fasting and postprandially; 3. To develop normative data of GVs in 24 healthy adolescents.

Methods—Eleven adults underwent SPECT and 3D-US simultaneously to measure GV, and a second 3D-US alone within a week of the first study. Twenty-four adolescents underwent one 3D-US measurement. Each study included fasting, 300 mL Ensure[®] meal, and 0-30 min PP GV measurements.

Results—3D-US identifies GV accommodation to 300 mL Ensure[®]. Delta (0-30 min average PP-fasting) GV was 444 mL (median, IQR 422, 534) for 3D-US and 543 mL (median, IQR 486, 564) for SPECT, ($p=0.15$). There were larger interindividual coefficients of variation (COVs) for GV by 3D-US (60.3% fasting and 21.3% average PP) compared to 19% fasting and 9.2% PP for SPECT. Intraindividual COV for the two 3D-US measurements in adults were 84% fasting and 44% average PP. The estimated GVs for the adolescent group (median, 25th-75th IQR) were 33 (18-53mL) fasting, 330 (284-357mL) 30 min PP, and 281 (240-324mL) for delta GV.

Conclusion—3D-US is a promising method to measure GV accommodation to a meal. Large COVs reflect the learning stage in development of this promising technique.

Keywords

gastric accommodation; 3-dimensional ultrasound; single photon emission computed tomography (SPECT)

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Conflict of Interest: The authors have no conflicts of interest regarding this paper.

Background

Functional abdominal pain and symptoms of irritable bowel syndrome (IBS) are common in community adolescents and frequently result in use of health care resources (1). Disorders of gastrointestinal transit and accommodation contribute to the development of dyspepsia and abdominal pain in children (2,3). Other studies of children with functional abdominal pain showed hypersensitivity of hollow organs such as the stomach (4). Disturbances of gastric function, as well as age and gender, account for 50% of the variance in the symptoms of adult patients with dyspepsia (5).

To date, most of the literature investigating gastric accommodation has used the barostat balloon (as per oral intubated measurement of tone) or ^{99m}Tc -single photon emission computed tomography (SPECT) which measures gastric volume (GV). SPECT has some disadvantages that reduce its applicability in children or adolescents: exposure to ionizing radiation, the need for an intravenous injection, and the need for specialized equipment. The radiation exposure limits its application in females who are known to be pregnant and in children, or when repeated measurements are needed such as in therapeutic studies. As a result, there are no normal SPECT-based data documenting the normal GV during fasting and after a meal in children.

Alternative noninvasive approaches that avoid ionizing radiation include three-dimensional ultrasound (3D-US) and MRI (6-10) which is used at few specialized centers; the two methods require further validation (11). Using 3D-US, Olafsdottir et al., has shown impaired proximal stomach accommodation and intragastric maldistribution of a liquid meal in children with functional abdominal pain (12,13).

Ultrasonography has several potential advantages including competitive pricing, point of care capability, and lower likelihood to induce stress. On the other hand, operator dependence and technical challenges associated with body habitus and abdominal pannus may compromise the ability of ultrasound to measure GV. Therefore, there is a need for formal validation of the 3D-US technique and to obtain data from healthy adolescent controls to be used in assessing the GV of symptomatic children and adolescents. The availability of a noninvasive method to measure GV without radiation exposure may usher in a novel clinical evaluation for children and adolescents with abdominal pain and dyspepsia, allow for longitudinal studies, explore effects of medications, and study the mechanisms of patients' symptoms.

The study hypothesis was that, in healthy participants, 3D-US is accurate, reproducible, and can be applied to measure fasting and postprandial GV in adolescents.

The study aims were: 1. To compare fasting and postprandial (PP) GVs measured simultaneously by ^{99m}Tc -SPECT (standard test) and 3D-US in adults; 2. To assess the performance characteristics of 3D-US measurement of GV, inter-individual coefficient of variation (inter-COV) and intra-individual COV (intra-COV) for two 3D-US estimates of fasting and PP GV; 3. To develop normative data for fasting and postprandial GV in 24 asymptomatic adolescents.

Methods

Study Design

The study was conducted in two parts: First, 12 healthy adults underwent SPECT and 3D-US in random order (aim 1); one week after the first ultrasound examination, a second ultrasound examination was conducted in all participants (aim 2). In the third aim of the study, 24 adolescents (12 males, 12 females, 12 aged 13-15 years, 12 aged 16-17 years) underwent a single ultrasound determination of fasting and postprandial GV.

Participants

The protocol was reviewed and approved by the Mayo Clinic Institutional Review Board, and signed informed consent was obtained. The study enrolled 12 healthy adults for the first two aims and 24 healthy adolescents for the third aim. Adult participants were 18-65 years and adolescents were 13-17 years of age. The main eligibility criteria were body mass index (BMI) of 18 to 32 kg/m², negative urine pregnancy test for women of childbearing potential, absence of gastrointestinal symptoms on an abridged version of the validated Bowel Disease Questionnaire (14), medications, prior surgeries or illnesses that could interfere with the conduct or interpretation of the study.

SPECT Procedure to Measure Fasting and Postprandial Gastric Volume

This was conducted as described in several studies from our lab in the last decade (15). We used a noninvasive method to measure gastric volume during fasting and 30 minutes after 300 mL of Ensure® (316 Kcal) using single photon emission computed tomography (SPECT). Subjects were placed in a supine position on the imaging table with the detectors over the upper abdomen. Participants received an intravenous injection of ^{99m}Tc-sodium pertechnetate, which is taken up by the parietal and non-parietal cells of the gastric mucosa, allowing visualization of the stomach wall. At 10 minutes after the intravenous injection of the radioactive marker, tomographic images of the gastric wall were obtained throughout the long axis of the stomach using a dual-head gamma camera (Multispect II, Siemens, U.S.A.) that rotates around the body. This allows assessment of the radiolabeled circumference of the gastric wall rather than the intragastric content.

Using image processing libraries (AVW 3.0, Biomedical Imaging, Mayo Foundation), a three-dimensional rendering of the stomach was obtained and its volume (mL) calculated. We have previously validated the method in vitro and in vivo (15). In healthy volunteers, simultaneous measurements of postprandial gastric volume changes with SPECT and the barostat balloon device (the current gold standard to measure GV) were strongly correlated (15). There is high intra-observer reproducibility of measurements of gastric volume with this technique. Intra-observer COV (at average 9 months) is ~13% for SPECT measurements (16).

3D-Ultrasound Equipment

A commercially available ultrasound scanner (Voluson® E8, GE Healthcare Ultrasound, Wauwatosa, WI, USA) was used with an external transducer (1.4-5.8 MHz, model RAB 2-5-D) capable of automated volume acquisition through an elevational sweep angle of up to 85°. Data were stored on the Voluson® E8 local hard drive. Data processing and volume estimation were calculated using the on board Voluson® E8, GE Healthcare Ultrasound proprietary software.

3D-Ultrasound Procedures

For 3D data acquisition, subjects were scanned immediately before ($t = -5$ min) and after 300 ml of ENSURE® (Ross Laboratories, Abbott Park, IL) drink ingestion ($t = 0$), followed by further imaging at $t = 10, 20$, and 30 minutes. Ultrasound data sets were acquired with the transducer held stationary in the position optimal for each individual to allow complete stomach visualization utilizing appropriate breath control and patient positioning. This was necessary because the axis, shape, and size of the stomach vary between individuals and at different times in the postprandial period. Subjects were instructed not to move and the stomach was scanned via automated sweeps of approximately 5 – 10 seconds. When gastric contractions were observed during acquisition, data were discarded and the acquisitions repeated. All data acquisition and analysis were performed by one investigator (DM). Examples of gastric images

by 3D-US and SPECT for the same subject immediately after ingestion of the 300 ml ENSURE® meal are shown in Figure 1.

Primary and Secondary Endpoints

Primary endpoints were: fasting, postprandial (PP), and postprandial change (delta, Δ) in GV measured by 3D-US in adults and adolescents.

Secondary end points were:

- a. Intra- and inter-individual coefficients of variation (COV) in adults for fasting and postprandial GV;
- b. Accuracy of 3D-US in measurement of fasting and postprandial GV, relative to simultaneous measurements by SPECT, using Bland-Altman plot.

Sample Size Assessment

The primary emphasis of this study was estimation and assessment of the agreement of 3D-US with SPECT. From a previous study, the intra-individual COVs for SPECT imaging of 12 overweight and 11 obese adults were 26% fasting, 13% PP, and 19% for delta GV (17). The sample size used in the study was powered to detect clinically important differences, 50 ml in delta (PP-fasting) gastric volume, between 3D-US and SPECT and between the two measurements by 3D-US.

Statistical Analysis

We compared fasting and PP GV measured by 3D-US and SPECT, calculated inter-individual COV and intra-individual COV for GV by 3D-US, and assessed accuracy of two replicates of 3D-US using Bland-Altman plot. Intra-subject COV% ($100 \times \text{SD of differences} / \text{grand mean of differences}$) were estimated and a Bland-Altman plot examined to check for bias associated with different GV. The distribution of 3D-US volumes in the 24 adolescents was summarized, and estimates of 25th and 75th percentiles were generated.

Results

Study Subjects and Demographics

A total of 36 healthy subjects completed the study protocols. US images of one adult participant were not available for volume estimation (because of loss of data which could not be retrieved). The final data analysis included 35 participants, 11 adults (6 males and 5 females) and 24 adolescents (12 of each gender). The mean ($\pm$ SD) age for the adult group was 34.2 ± 13 years, with mean BMI of 25 ± 3.65 kg/m². The mean age for the adolescent group was 15.3 ± 1.37 years, with mean BMI of 21.3 ± 2.7 kg/m². The studies were completed without adverse events and were well tolerated by all participants.

Adult Group Fasting and Postprandial GV

Fasting, average 0-30 minutes postprandial, and delta (PP-fasting) GVs in adults are summarized in Table 1. Note that the median gastric accommodation (delta GV) volume was greater than 300 mL, which was the meal volume, in the first US measurement and equal to the meal volume during the second 3D-US measurements. During the simultaneous measurements, delta GV was 444 mL (median, IQR 422, 535) for 3D-US and 543 mL (median, IQR 486, 564) for SPECT ($p=0.15$).

Fasting and Postprandial GV in Adolescents

Fasting, average 0-30 minutes postprandial, and delta GVs in adolescents are summarized in Table 2. Figure 2 summarizes 3D-US data (median, IQR, and range). The estimated GVs from the adolescent group, median (25th-75th IQR) were: 33mL (18-53mL) fasting, 330mL (284-357mL) average 0-30 min PP, and 281mL (240-324mL) for delta GV.

Effect of Gender, Age and BMI on Gastric Accommodation by 3D-Ultrasound

There was no effect of gender on gastric accommodation in the combined group of adolescents and adults (male 316.5 mL, IQR 246-351; female 316 mL, IQR 363-427, $p=0.621$). There was a weak overall correlation between age and gastric accommodation ($r=0.38$, $r^2=0.145$, $p=0.024$); the correlation between BMI and gastric accommodation was not significant ($r=0.20$, $r^2=0.04$, $p=0.26$).

Comparing US vs. SPECT for Measuring GV

A box and whiskers plot showing the median and IQR of both fasting and 0-30 minutes average PP GVs for SPECT and 3D-US is shown in Figure 3. Despite the difference in actual volumes, the magnitude of increase in volume seen after meal ingestion with SPECT is quite similar to 3D-US.

In Figure 4, the Bland-Altman plot compared delta GVs by both techniques. Note that most of the volumes were within 100 mL difference. This reflects fairly good US estimates of gastric accommodation compared to SPECT.

Reproducibility of Two Measurements of GVs by 3D-US

In Figure 5, the Bland-Altman plot compares delta GVs on the two US measurements. Intraindividual COV for both US measurements were 84% for fasting, 44% for average 0-30 minutes postprandial, and 60% for delta GVs.

Discussion

In the present study, we have demonstrated that 3D-US is feasible, can be conducted safely in adults and adolescents, and provides a fairly accurate estimate of GVs when compared to scintigraphy (SPECT) in healthy adults.

3D-US has been used previously to measure volumes of intra-abdominal organs, including the stomach. In vitro, Gilja et al. has demonstrated excellent correlation between true and 3D-US estimated volumes of porcine kidney (18) and fluid-filled porcine stomach (18,19). Another study also showed good correlation between MRI and 3D-US in volume estimation of human kidneys with low intra-individual COV for the repeated US volume estimates (20). However, the kidney is a solid organ and a fluid filled stomach does not have a gastric air bubble. Therefore, we embarked on in vivo validation studies in humans.

Tefera et al. reported a close correlation and agreement between true and estimated volumes using 3D-US of a barostat bag filled with soup positioned in the proximal stomach of six healthy subjects (21). They also observed low inter-observer variation (21). While these studies suggest that 3D-US may allow a precise measurement of gastric accommodation, comparison of this technique with one of the gold standards, SPECT, has hitherto not been performed. To our knowledge, therefore, this is the first study comparing GV estimates by 3D-US to SPECT.

3D-US was able to detect GV accommodation to an Ensure® meal in adults and adolescents. The increase in GV after the Ensure® meal ingestion was equal to or greater than the meal size, 300 mL, in most participants in both age groups, reflecting true gastric accommodation. The

median delta GV using SPECT was 543ml compared to 444ml using 3D-US ($P=0.15$), reflecting fairly close estimation of gastric accommodation by US compared to SPECT. We showed a gastric accommodation equal to or greater than meal volume. On the other hand, the gastric accommodation volumes estimated by Gilja et al. were smaller than meal volume (19). This might be explained by the lower caloric content of the meal used by Gilja et al., which was associated with faster gastric emptying (19), compared to the 1 kcal/ml nutrient liquid meal in our study.

Gilja et al. had also previously estimated GV and calculated the variability in volume measurement in 14 healthy adults using 3D-US (19). The inter-individual COV was up to 52% PP compared to a maximum of 27% in our study. The intra-individual COV for PP GV, for 6 repeated US measurements conducted daily for 6 days in one subject, was 34.3% compared to 44% in current study. The slightly smaller variability found by Gilja et al. reflects greater familiarity with the individual subject anatomy when performing 6 studies in the same individual (19) rather than 2 studies in 11 individuals in our study.

Technical Pitfalls

There were some technical difficulties that contributed to smaller GVs during fasting and postprandially using 3D-US compared to SPECT. First, the presence of air in the stomach, mainly during fasting, made it difficult to identify the shadowed boundaries of the stomach. Second, the inability to obtain full stomach views because the 3D-US elevational sweep does not exceed 85° degrees did not allow full detection of the distal parts of the stomach. This added to a distorted stomach shape, especially when pressure was applied through the US probe to achieve better contact of the probe with the abdominal wall, possibly resulting in smaller estimated GV. Finally, SPECT measures gastric volume including gastric wall thickness (2), while 3D-US measures only intragastric volume. Therefore, it is likely that SPECT overestimates true gastric volume measurements, as shown by Bharucha et al. in comparison with MRI (11).

There was an additional difficulty encountered in obtaining 3D-US images in the adolescent group. The US transducer was not maintained in full contact with the adolescent's abdominal wall, due to a more lean body habitus. In order to ensure there was a medium to conduct the ultrasound waves, extra gel was applied to form a 'wedge' to fill in the gap between the transducer and the abdominal wall.

The higher average fasting GV seen on the second US in adults compared to the first US measurement in the same adults reflects improved volume estimates as part of a learning curve with a new technique. With experience, the lateral decubitus position seemed to provide an optimal view of the stomach. This change in technique may have contributed to the high intraindividual COV (84%) between two fasting 3D-US measurements.

The intraindividual COV (44%) of postprandial GV between the two 3D-US measurements is also, in part, a reflection of possibly two factors. First, there may be a day to day variation in the normal changes in gastric volume in response to a meal. It has been previously demonstrated that the intraindividual COV is 13% for PP GV using SPECT (16,17). Second, the change in position during the second 3D-US imaging series to the left lateral decubitus position likely resulted in better gastric image quality and volume estimation.

The high intraindividual COV (84% for fasting, 44% for average 0-30 minute postprandial, and 60% for delta GVs) of two repeated 3D-US measurements might limit its value in estimating GVs in studies that require repeated measurements. It is necessary that this high variation be minimized in order for the test to have clinical and research utility; one approach in future studies to reduce the variation is to standardize data acquisition, such as participant

positioning and 3D-US probe placement. Therefore, further validation studies are needed to overcome the pitfalls encountered in the current study.

Given the coefficient of variation in the estimates of delta or accommodation volume, further validation studies comparing 3D-US with a current standard, such as SPECT, will require 52 participants to identify a mean difference of >50 mL which would be a clinically relevant difference in the estimation of gastric accommodation by the two methods.

Conclusion

3D-US provides a fairly accurate estimate of gastric accommodation, when compared to SPECT. It is safe and may be a generally applicable method that can be used in adolescents with upper gastrointestinal symptoms. The variability seen with measurements reflects, in part, a learning curve. We perceive that the performance characteristics of the test will improve with further standardization of this technique.

Acknowledgements

We thank the nursing staff of the Mayo Clinic Clinical Research Unit and Cindy Stanislav for secretarial support. The study was enabled by the GI Imaging and Physiology Core of the Mayo Clinic CTSA grant (NIH RR0024150), and the use of a loaned Voluson[®] E8, from GE Healthcare Ultrasound.

References

1. Hyams JS, Burke G, Davis PM, Rzepski B, Andrulonis PA. Abdominal pain and irritable bowel syndrome in adolescents: a community-based study. *J Pediatr* 1996;129:220–6. [PubMed: 8765619]
2. Chitkara DK, Camilleri M, Zinsmeister AR, Burton D, El-Youssef M, Freese D, Walker L, Stephens D. Gastric sensory and motor dysfunction in adolescents with functional dyspepsia. *J Pediatr* 2005;146:500–5. [PubMed: 15812453]
3. Chitkara DK, Delgado-Aros S, Bredenoord AJ, Cremonini F, El-Youssef M, Freese D, Camilleri M. Functional dyspepsia, upper gastrointestinal symptoms, and transit in children. *J Pediatr* 2003;143:609–13. [PubMed: 14615731]
4. Di Lorenzo C, Youssef NN, Sigurdsson L, Scharff L, Griffiths J, Wald A. Visceral hyperalgesia in children with functional abdominal pain. *J Pediatrics* 2001;139:838–43.
5. Delgado-Aros S, Camilleri M, Cremonini F, Ferber I, Stephens D, Burton DD. Contributions of GV and gastric emptying to meal size and postmeal symptoms in functional dyspepsia. *Gastroenterology* 2004;127:1685–94. [PubMed: 15578506]
6. Gilja OH, Hausken T, Odegaard S, Berstad A. Ultrasonography and three-dimensional methods of the upper gastrointestinal tract. *Eur J Gastroenterol Hepatol* 2005;17:277–82. [PubMed: 15716650]
7. Gilja OH, Hatlebakk JG, Odegaard S, Berstad A, Viola I, Giertsen C, Hausken T, Gregersen H. Advanced imaging and visualization in gastrointestinal disorders. *World J Gastroenterol* 2007;13:1408–21. [PubMed: 17457973]
8. De Zwart IM, Mearadji B, Lamb HJ, Eilers PH, Masclee AA, de Roos A, Kunz P. Gastric motility: comparison of assessment with real-time MR imaging or barostat measurement initial experience. *Radiology* 2002;224:592–7. [PubMed: 12147861]
9. Hoad CL, Rayment P, Spiller RC, Marciani L, Alonso Bde C, Traynor C, Mela DJ, Peters HP, Gowland PA. In vivo imaging of intragastric gelation and its effect on satiety in humans. *J Nutr* 2004;134:2293–300. [PubMed: 15333719]
10. Camilleri M. New imaging in neurogastroenterology: an overview. *Neurogastroenterol Motil* 2006;18:805–12. [PubMed: 16918759]
11. Bharucha AE, Fidler J, Camilleri M, Camp J, Stapleton R, Burton D, Robb R, Riederer SJ. Comparison of GV measured by MRI and SPECT. *Neurogastroenterol Motil* 2007;19:421–2.

12. Olafsdottir E, Gilja OH, Aslaksen A, Berstad A, Fluge G. Impaired accommodation of the proximal stomach in children with recurrent abdominal pain. *J Pediatr Gastroenterol Nutr* 2000;30:157–63. [PubMed: 10697134]
13. Olafsdottir E, Gilja OH, Tefera S, Fluge G, Berstad A. Intragastric maldistribution of a liquid meal in children with recurrent abdominal pain assessed by three-dimensional ultrasonography. *Scand J Gastroenterol* 2003;38:819–25. [PubMed: 12940433]
14. Talley NJ, Phillips SF, Wiltgen CM, Zinsmeister AR, Melton LJ III. Assessment of functional gastrointestinal disease: the bowel disease questionnaire. *Mayo Clin Proc* 1990;65:1456–79. [PubMed: 2232900]
15. Bouras EP, Delgado-Aros S, Camilleri M, Castillo EJ, Burton DD, Thomforde GM, Chial HJ. SPECT imaging of the stomach: comparison with barostat, and effects of sex, age, body mass index, and fundoplication. *Single photon emission computed tomography. Gut* 2002;51:781–6. [PubMed: 12427776]
16. De Schepper H, Camilleri M, Cremonini F, Foxx-Orenstein A, Burton D. Comparison of GV in response to isocaloric liquid and mixed meals in humans. *Neurogastroenterol Motil* 2004;16:567–73. [PubMed: 15500513]
17. Vazquez Roque MI, Camilleri M, Clark MM, TePoel DA, Jensen MD, Graszer KM, Kalsy SA, Burton DD, Baxter KL, Zinsmeister AR. Alteration of gastric functions and candidate genes associated with weight reduction in response to sibutramine. *Clin Gastroenterol Hepatol* 2007;5:829–37. [PubMed: 17544870]
18. Gilja OH, Thune N, Matre K, Hausken T, Odegaard S, Berstad A. In vitro evaluation of three-dimensional ultrasonography in volume estimation of abdominal organs. *Ultrasound Med Biol* 1994;20:157–65. [PubMed: 8023428]
19. Gilja OH, Detmer PR, Jong JM, et al. Intragastric distribution and gastric emptying assessed by three-dimensional ultrasonography. *Gastroenterology* 1997;113:38–49. [PubMed: 9207260]
20. Gilja OH, Smievoll AI, Thune N, et al. In vivo comparison of 3D ultrasonography and magnetic resonance imaging in volume estimation of human kidneys. *Ultrasound Med Biol* 1995;21:25–32. [PubMed: 7754576]
21. Tefera S, Gilja OH, Olafsdottir E, Hausken T, Hatlebakk JG, Berstad A. Intragastric maldistribution of a liquid meal in patients with reflux oesophagitis assessed by three dimensional ultrasonography. *Gut* 2002;50:153–8. [PubMed: 11788552]

Abbreviations used

COV	coefficient of variation
3D	three dimensional
GV	gastric volumes
IQR	interquartile range
MRI	magnetic resonance imaging
PP	postprandial
SPECT	single photon emission computed tomography
US	

ultrasound

Figure 1.

Gastric images by 3D-US and SPECT for the same subject immediately after ingestion of the 300 ml ENSURE® meal. A. 3-dimensional ultrasound images showing anterior, superior and transverse ultrasound images of the stomach. B. SPECT

Figure 2. Summary data (median, IQR, and range) for adolescent fasting and postprandial GV by 3D-US

Figure 3. Summary data (median, IQR, and range) for adult fasting and postprandial GV by 3D-US and SPECT

Figure 4.
Bland Altman plot comparing adult's delta GV by 3D-US and SPECT

Figure 5.
Bland Altman plot comparing adult's delta GV on the two 3D-US measurements

Table 1
Measurements of GV's, Median, 25th-75th Interquartile Range (IQR), and Interindividual COV in 11 Healthy Adults by Both Techniques

	Fasting GV mL		Postprandial GV mL		Delta (PP-F) GV mL	
	Median (IQR)	COV %	Median (IQR)	COV %	Median (IQR)	COV %
SPECT	273 (253-317)	19	815 (771-864)	9.6	543 (485-564)	9.2
US 1	129 (71-183)	60.3	611 (514-641)	21.3	444 (422-535)	29.1
US 2	218 (125-284)	46.8	470 (439-520)	27	311 (158-387)	49.4

Measurements of GV's, Median, 25th-75th Interquartile Range (IQR), and Interindividual COV (%) in 24 Healthy Adolescents by 3D-US

Table 2

	Fasting GV mL		Postprandial GV mL		Delta (PP-F) GV mL	
	Median (IQR)	COV %	Median (IQR)	COV %	Median (IQR)	COV %
US	33 (18-53)	75	330 (284-357)	26	281 (240-324)	21