SmartPill Capsule for Assessment of Gastric Emptying – Comparison with Simultaneous Gastric Emptying Scintigraphy.


Introduction: Gastric emptying scintigraphy (GES), using a radiolabeled solid phase meal, is conventionally used to measure gastric emptying. Recently, a wireless capsule SmartPill, which measures pH, pressure, and temperature throughout the GI lumen, has been developed for ambulatory assessment of GI transit. The emptying of this capsule from the stomach seems to correlate with return of the migrating motor complex after eating. We have previously reported good correlation using the SmartPill to differentiate normal subjects from patients with gastroparesis. The aim of this analysis was to determine the ability of the SmartPill to differentiate subjects with normal and delayed gastric emptying when SmartPill pH recordings are performed simultaneously with gastric emptying scintigraphy. Methods: In a multicenter study, simultaneous measurement of transit of the pH/pressure recording SmartPill and GES was performed in 86 normal subjects and in 60 patients with previously diagnosed gastroparesis. Subjects stopped medications that affect gastric pH and transit for one week. The SmartPill capsule was ingested after an overnight fast and gastric emptying scintigraphy was then performed simultaneously with imaging every 30 min for 4 hours after ingestion of a $^{99m}$Tc-SC radiolabeled low fat meal (120 g Eggbeaters, 2 pieces of bread with strawberry jam; 255 kcal, 2% fat) and 120 cc water. After 6 hours, subjects were given Ensure. The gastric residence time (GRT) of the SmartPill was determined as the time after capsule and meal ingestion to a rapid rise in pH upon reaching the alkaline of the small intestine. Gastric emptying scintigraphy was assessed as the amount of radioactivity remaining in the stomach; delayed gastric emptying was defined as >10% retention at 4 hours. Receiver operating characteristic (ROC) curves were used to optimize sensitivity and specificity of SmartPill GRT to differentiate the patient groups. Results: Successful recordings of both SmartPill and scintigraphy were obtained in 77 normal subjects and 48 patients with previously diagnosed gastroparesis. In normal subjects, the median time for emptying of the SmartPill was 215 minutes and the 95% confidence intervals were (199, 225). In patients with a history of gastroparesis, the median time for emptying of the SmartPill was >360 minutes and the 95% confidence interval were (322, >360). In patients with a history of gastroparesis, delayed gastric emptying by scintigraphy on the day of the study was documented in 24 of 48 (50%). In normal subjects, gastric emptying was normal by scintigraphy in 71 of 77 (92%). Using ROC analysis, a 4 hour cut off value of the SmartPill GRT was best to identify subjects with gastroparesis or as normal based on their history with sensitivity of 82% and specificity of 74%. A 5 hour cut off value of the SmartPill GRT was best to identify subjects with delayed or normal gastric emptying based on scintigraphy on the day of the test with sensitivity of 83% and specificity of 83%. Conclusion: The gastric residence time of the SmartPill capsule is able to identify abnormal gastric emptying with good sensitivity and specificity. Thus, this study suggests the SmartPill can be used as a novel non-radioactive method for assessing gastric emptying in health and disease in the physician office setting.
Non-digestible Capsule (SmartPill) as a Novel Diagnostic Tool for Detecting Motility Impairment within the Gut.

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Background: The unique features within an intraluminal environment (changes in pH and contractility) could help to identify the transition points along the alimentary tract that could serve as a basis for the measurement of GI transit times. Aim: To compare the results captured by a non-digestible capsule (SmartPill) in regards to small bowel transit time (SBTT) and colon transit time (CTT) among healthy subjects and gastroparetics. Methods: 23 patients with GP, 12 diabetics (DM) and 11 idiopathic (ID) 16F, mean age of 45, 20-66 range and 55 asymptomatic controls (C) 21F, mean age of 32, 19-57 range, participated in this multicenter study. After an overnight fast all subjects swallowed the capsule equipped with sensors measuring pressure, pH and temperature with data being collected by a portable recording device. The time between ingestion of capsule and the rapid, sustained rise of and at least 3 pH units from baseline and exceeding pH 4.0 was defined as GRT. Later on, a sudden drop of more than 1 pH unit for longer than 5 min. was regarded as an ileo-cecal (I-C) arrival. By subtracting GRT from I-C junction arrival time, SBTT was calculated, and in turn CTT was then able to be determined. Mann-Whitney and t-test were used for statistical analysis. Time was expressed in minutes. Results: In GP the median SBTT was not significantly longer than in C (300 vs. 281, NS). Also the SBTT between DM and ID was similar (mean ±SD: 294±92 vs. 312±165, NS). Median CTT in patients with GP was significantly longer than in C (1507 vs. 1026, P<0.001). Both subgroups of GP (DM & ID) also exhibited significant differences in terms of CTT versus C (median: 1623 vs. 1026, P=0.003; 1507 vs. 1026, P=0.043, respectively). The GP DM and ID differed numerically in CTT but it was not significant (mean ±SD: 2625±1992 vs. 1595±651, NS). Conclusions: 1. The significantly longer CTT in patients with DM and ID gastroparesis indicates that the motor abnormality involves not only the stomach but also the colon; 2. SmartPill may have an important clinical role for diagnosis of impaired motility in different parts of the gut as well as monitoring therapeutic interventions.
Motility Patterns in the Distal Bowel Associated with Luminal Acidic pH Changes.

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Introduction: With the passage from the small intestine into the colon, the intraluminal environment changes. The cecum, compared to the distal ileum, represents a potentially less contractile reservoir where colonic bacteria cause an acidic change in pH. The gut passage of a non-digestible solid with pH and pressure sensors (SmartPill capsule) may be able to document this transition. Hypothesis: A significant pH drop is seen hours after the gastric emptying. We hypothesize that the pH drop recorded by the capsule is due to its ileo-cecal passage and is associated with motility changes. Aims: To quantify and compare the motility patterns (pressure and amplitudes of contractions) before and after the pH drop. Methods: 104 volunteers (49 males, 55 females) swallowed the SmartPill (SP) after an overnight fast together with a standardized meal and 120 cc water. The rapid pH changes from acidic to alkaline (> 4 and at least 3 unit rise from baseline gastric pH) marked the emptying of the ingested capsule from the stomach into the duodenum. On the capsule’s recordings, approximately 5.5 hours after the capsule’s gastric emptying, a drop in pH > 1 unit for more than 5 minutes is seen. The frequency and amplitude of contractions were analyzed from 30 min before the beginning of the pH drop to 30 min after. These parameters were then compared by two-sample unequal variance t test. Results: The average time from the gastric emptying to the pH drop is 5 hrs 23 min. The frequency of contractions for the 30 min before the pH drop is 3.99 contractions/min (95% CI 3.99±0.014), and for the 30 min after the drop is 2.1 contractions/min (95% CI 2.1±0.01), p<0.0001. The mean amplitude of contractions was not different between the time periods chosen (19.6 mmHg before, 19.4 mmHg after the pH drop, p = 0.8). The motility index for the 30 min before the pH change is 1.54, for the 30 min after is 0.91, p<0.0001. Conclusion: The pH drop that appears after the gastric emptying is associated with a highly significant change in motility patterns suggesting that the combined change in pH and motility could mark the transition between the distal ileum and the cecum. Research funded by SmartPill Corporation.
Characterization of Gastroduodenal Motility in Healthy Subjects and Patients with Gastroparesis Using an Ambulatory Capsule.

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Introduction: Do the patients with gastroparesis, in addition to delayed gastric emptying, have gastroduodenal motility abnormalities that can be identified and described using capsule technology? Aim: To compare pressure patterns between healthy subjects and patients with gastroparesis. Methods: In a multicenter study, healthy subjects and patients with gastroparesis swallowed the SmartPill (SP) capsule after an overnight fast together with a standardized meal (120 g Eggbeaters, 2 pieces of bread with jam; 255 kcal, 2% fat) and 120 cc water. The rapid and persistent luminal pH rise (above 4 and at least 3 unit rise from baseline gastric pH) marked the emptying of the ingested SmartPill from the stomach into the duodenum. The frequency and amplitude of contractions recorded by the capsule were analyzed in 20 minutes intervals from 60 min before gastric emptying (GE) to 60 min after. These parameters for patients and controls were compared for each time interval by two-sample unequal variance t test. Results: 66 healthy subjects (42M/24F) and 38 patients, 16 diabetic/22 idiopathic (8M/30F) were studied. When comparing patients to the control group, for (-60 to –40 min) and (-40 to –20 min) before gastric emptying, patients had significant lower frequency of contractions  (0.6 /min, [95% CI 0.3-0.9] and 0.8 /min, [95% CI 0.4-1.2] respectively) compared to healthy subjects (1.2 /min, [95% CI 1.0-1.4], p< 0.002 and 1.4 /min, [95%CI 1.2-1.6], p <0.009 respectively). When comparing healthy subjects (N) with subtypes of gastroparesis, a highly significant difference in the frequency of contractions is seen for the diabetic group (D) earlier (–60 to –40 min) before the emptying (frequency for N = 1.2/min, for D=0.45 /min, p<0.0001). The differences in frequency for the idiopathic (I) group had stronger significance in a later period (–40 to –20 min) (frequency for N= 1.39 /min, for I= 0.70 /min, p <0.002), suggesting variation in the motility abnormalities that potentially differentiate the 2 gastroparetic groups. There was no difference in the mean amplitude of contractions for patients and controls. Conclusion: An ambulatory capsule SmartPill measuring contractile patterns can demonstrate differences in upper GI motility between healthy volunteers and subtypes of patients with gastroparesis. Research funded by SmartPill Corporation.
Selective Intragastric pH Dysregulation in Diabetic vs. Idiopathic Gastroparesis: Relation to Degree of Gastric Stasis.


Background: The gastric acid milieu is poorly understood in gastroparesis of different etiologies and with different degrees of stasis. Demographic and clinical differences suggest diabetic and idiopathic gastroparesis have distinct pathophysiology. Diabetics with gastroparesis may have associated bacterial overgrowth, which also is seen with achlorhydria, whereas dyspeptics with delayed gastric emptying often respond to acid suppressing drugs suggesting differences in gastric acidity in the 2 disorders. Recently, an ingested capsule was developed which continuously measures luminal pH (SmartPill Corp.). Hypotheses: We hypothesized (i) gastric pH profiles show differential impairment in diabetic vs. idiopathic gastroparesis and (ii) abnormal pH profiles relate to the severity of gastric stasis.

Methods: 64 healthy controls and 44 patients with gastroparesis on prior scintigraphy (20 diabetic, 24 idiopathic) from 7 centers were analyzed. Acid suppressants were stopped for 1 week before study. After capsule ingestion, subjects consumed test meals (120 g Egg Beater, bread, jam, and 120 ml water; 255 kcal) with 1 mCi $^{99m}$Tc-sulfur colloid. pH was measured every 5 sec; scintiscans were acquired every 30 min x 4-6 h. Results: Basal pH was higher in diabetics (3.64±0.41) than controls (1.90±0.18)(P=0.001) and idiopathics (2.41±0.42)(P<0.05). Meal-evoked peak pH was greater in diabetics (4.98±0.32) than idiopathics (3.89±0.39)(P=0.04) and was intermediate in controls (4.48±0.14). This declined to pH nadirs that were higher in diabetics (1.50±0.23) than controls (0.58±0.11)(P<0.001). Idiopathics (0.93±0.31) were similar to controls. Summed fed reacidification quantified by areas under pH curves (AUC)(pH x hr) was greatest in diabetics (4.10±0.51) indicating less acidity than controls (2.93±0.20)(P=0.01) and idiopathics (2.61±0.40)(P=0.02). 90% emptying times (T90) were similar in diabetics (249±15 min) and idiopathics (249±16 min) but higher than controls (162±5 min). Versus controls, patients with profound stasis (T90>300 min) had higher basal pH (3.91±0.55), peak pH (5.30±0.50), nadir pH (2.23±0.42), and AUC (4.63±0.86)(all P<0.05). Basal pH (2.54±0.36), peak pH (3.99±0.30), nadir pH (0.74±0.17), and AUC (2.79±0.29) in mild gastroparesis (T90<300 min) were similar to control. Conclusions: Diabetics with gastroparesis exhibit lower gastric acidity than healthy controls while idiopathic gastroparetics are nearly normal. Patients with severe gastric stasis exhibit higher pH than control regardless of etiology. This characterizes important physiologic differences in diabetic and idiopathic gastroparesis of varying severity which may impact on consequences of gastric acid dysregulation including dyspeptic symptoms, vitamin and mineral absorption, and bacterial overgrowth.
Introduction: Gastric emptying scintigraphy (GES) using a radiolabeled solid phase meal, is widely used to measure gastric emptying but the technique is non-ambulatory, involves radiation and is performed variably. Recently an ambulatory wireless capsule SmartPill (SP) which measures pH and pressure of the GI lumen when swallowed has been developed. The rapid luminal pH change from acidic to alkaline marks the transit of the ingested SP from the stomach into the duodenum. Aim: 1) To demonstrate the correlation between gastric residence time (GRT) as determined by the gastric emptying of the SP and the gastric emptying time of a radiolabeled meal in both healthy subjects and patients with documented gastroparesis, 2) To demonstrate that GRT can discriminate between healthy subjects and gastroparetics.

Methods: In a multicenter study, simultaneous measurements of transit of SP and GES was performed in 86 healthy subjects and in 60 patients with previously diagnosed gastroparesis based on scintigraphy. SP was ingested after an overnight fast and then GES was performed in a standardized fashion with imaging taken up to 6 hours after ingestion of a 99mTc-SC radiolabeled meal (120 g Eggbeaters, 2 pieces of bread with jam; 255 kcal, 2% fat) and 120 cc water. Correlations between GRT and time to 50% emptying (T-50%), time to 90% emptying (T-90%) were performed. Receiver operating characteristic (ROC) curves were used to summarize the sensitivity and specificity in differentiating the normal subjects from gastroparetic patients for the T-50, T-90%, and GRT. Results: The correlation between GRT and T-90% emptying was 0.85±0.06 and for T-50% emptying, 0.66±0.15. The c statistic for the area under the ROC curve (AUC) assessing overall diagnostic accuracy for classifying normals and gastroparetics for GRT was 0.83 (95% CI 0.74-0.87) and for T-90%, 0.85 (95% CI 0.80-0.90), not statistically different from each other. The AUC for T-50% was 0.77 (95% CI 0.70-0.83). The cutoff point that maximizes both sensitivity and specificity for T-90%, 182 min, gave a sens of 84.8% and spec of 77.9%, whereas the cut off point for T-50% was 102, giving a sens of 71% and a spec of 74%. The cutoff for GRT was 240 min, giving 85% sens and 72% spec. Conclusion: The GRT of the SP has a high correlation with T-90% of scintigraphy suggesting that the GRT more closely represents a time near the end of the emptying of a solid meal. The study demonstrates that GRT of the SP was able to differentiate normals from gastroparetics similar to scintigraphy. This study suggests that the SmartPill can be used as a novel ambulatory method for assessing gastric emptying in health and disease.
Postprandial Gastric Acid Neutralization-Reacidification Measured with an Ingested pH Telemetry Capsule: Correlation with Emptying of Digestible and Indigestible Solids.

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Background: Gastric emptying profiles of digestible and indigestible solids exhibit distinct temporal characteristics which are proposed to relate to specific gastric motor patterns. Recently, an ingestible telemetry capsule was developed which continuously measures luminal pH and pressure (SmartPill Corp.). Using this method, indigestible solid emptying is measured by detecting the abrupt pH rise as the capsule passes into the duodenum. It is well known that gastric pH transiently neutralizes with solid meal ingestion and reacidifies with subsequent acid secretion and gastric emptying. 

Hypothesis: We hypothesized that intersubject differences in postprandial gastric pH profiles reflect differential rates of emptying of digestible solids. 

Methods: Data from 25 healthy volunteers and 45 patients with documented gastroparesis on prior scintigraphy from 7 centers were analyzed. Acid suppressants were discontinued for 1 week prior to study. Following capsule ingestion, subjects consumed standardized solid meals (120 g Egg Beater, 60 kcal; bread, 120 kcal; jam 74 kcal; and 120 ml water—72% carbohydrate, 24% protein, 2% fat) with 1 mCi ⁹⁹Tc-sulfur colloid tracers. Luminal pH measurements were obtained every 5 sec; scintiscans were acquired every 30 min for 4-6 h.

Results: Meal ingestion elicited initial pH rises to a mean of 4.40±0.18 followed by slow declines to stable pH nadirs of 0.93±0.12 prior to capsule emptying. The time to empty 90% of the digestible radiolabelled meal on scintigraphy correlated modestly with the time needed to reduce gastric pH by 50% from the peak to the nadir values (pHT50)(r=0.47). pHT50 values correlated less well with duodenal passage of the indigestible capsule (r=0.30). In subjects with delayed scintigraphic emptying (<90% emptied at 240 min), pHT50 values were significantly prolonged (64.7±12.9 min) vs. those with normal emptying (≥90% emptied at 240 min)(25.8±2.2 min)(P=0.0001). The positive predictive value of a pHT50 value of ≥60 min for detection of delayed solid emptying defined scintigraphically was 89%, whereas the negative predictive value was 78%.

Conclusions: Quantification of intragastric pH neutralization and subsequent reacidification recorded by an ingested telemetry capsule after consumption of a nutrient meal can provide a measure of gastric emptying of digestible solids which correlates with accepted scintigraphic methods and which complements the ability of the capsule to assess indigestible solid emptying. The capability to concurrently determine gastric emptying of both digestible and indigestible solids may be an important research and clinical tool in future investigations.
**Postprandial Gastric Acid Neutralization and Reacidification in Diabetic vs. Idiopathic Gastroparesis: Relation to Degree of Gastric Stasis.**

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**Background:** Gastric acid-related complaints including GERD are prevalent in patients with gastroparesis, especially with diabetes. Demographic and clinical differences in diabetic and idiopathic gastroparesis suggest the two conditions have distinct pathophysiology. Though acid-associated symptoms have been related to autonomic neuropathy, the acid milieu of the stomach in gastroparesis is poorly understood. Further, the roles of different etiologies of gastroparesis and the magnitude of gastric stasis on gastric pH are unknown. Recently, an ingestible telemetry capsule was developed to continuously measure luminal pH and pressure (SmartPill Corp.). **Hypotheses:** We hypothesized (i) severely delayed gastric emptying is associated with increased gastric acidity and (ii) postprandial pH profiles differ in diabetic vs. idiopathic gastroparesis suggesting dissimilar disease pathogenesis.

**Methods:** Data from 44 patients with gastroparesis on prior scintigraphy (20 diabetic, 24 idiopathic) from 7 centers were analyzed. Acid suppressants were stopped x 1 week prior to study. After capsule ingestion, subjects consumed standard meals (120 g EggBeaters, bread, jam, and 120 ml water; 255 kcal) with 1 mCi ⁹⁹Tc-sulfur colloid. Luminal pH was measured every 5 sec; scintiscans were acquired every 30 min x 4-6 h. **Results:** Meals elicited initial pH rises that were greater in diabetics (4.98±0.32) than idiopathics (3.89±0.39)(P=0.04). This declined to stable pH nadirs which were similar in diabetics (1.50±0.23) and idiopathics (0.93±0.31)(P=0.16). Cumulative postprandial reacidification was quantified by measuring areas under pH curves (AUC) from meal ingestion to the time of nadir pH. AUCs (pH x hr) were greater in diabetics (4.10±0.51) than idiopathics (2.61±0.40) indicating less gastric acidity after eating in diabetics (P=0.02). Times for 90% gastric emptying (T90) were similar in diabetics (249±15 min) and idiopathics (249±16 min). Compared to those with mild gastroparesis (T90 300 min), patients with profound stasis (T90>300 min) had higher peak pH (5.30±0.50 vs. 3.99±0.30), nadir pH (2.23±0.42 vs. 0.74±0.17), and AUC (4.63±0.86 vs. 2.79±0.29)(all P<0.03).

**Conclusions:** Diabetics with gastroparesis exhibit lesser degrees of postprandial gastric acidity than idiopathic gastroparetics that are not due to differences in gastric emptying rates. However, those with profound stasis exhibit higher rather than lower gastric pH regardless of etiology. These findings suggest that the pathophysiology of diabetic gastroparesis differs from idiopathic disease and indicate that factors other than low gastric pH may contribute to symptoms in diabetics with gastric retention.
ABSTRACT BODY: Gastric emptying scintigraphy (GES) using a radiolabeled solid-phase meal is currently considered the gold standard to detect gastroparesis. It is, however, performed in a variable manner at different institutions. A method to standardize gastric emptying using a low fat (EggBeaters) meal with imaging at 0, 1, 2 and 4 hours postprandially has been suggested (Tougas et al, Am J Gastro 2000;95:1456). Extending GES from 2 to 4 hours has also been advocated to detect more patients with gastroparesis (Guo et al, DDS 2001;46:24). The optimal duration of GES to maximize sensitivity and specificity for detecting gastroparesis has not been established. AIM: To determine the optimal duration of GES for detecting gastroparesis. METHODS: In a multicenter study evaluating the emptying of a pH/pressure recording capsule (SmartPill), GES was performed in 86 normal subjects and in 60 patients with previously diagnosed gastroparesis (37 idiopathic, 23 diabetic) based on scintigraphy within the past 2 years. GES was repeated in a standardized fashion with imaging at 0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, and 4 hours after ingestion of a 99mTc-sulfur colloid radiolabeled meal (120 g EggBeaters, 2 pieces of bread with strawberry jam; 255 kcal, 2% fat) and 120 cc water. Receiver operating characteristic (ROC) curves were used to optimize sensitivity and specificity for differentiating gastroparetic patients from normal subjects for the 50% emptying time (T-50), 90% emptying time (T-90), and the percent retention (%R) at each imaging time. The concordance statistic (c-statistic) denotes the area under the ROC curve and is a global measure of diagnostic utility. RESULTS: The c-statistic was greater for %R at 3 hours (c=0.843) than at 1 hour (0.670), 2 hours (0.792), or 4 hours (0.816). It was also greater than that for T-50 (c=0.766) and similar to that for T-90 (c=0.849). The cutoff point that maximizes both sensitivity and specificity for T-90, 182 min, gives a sensitivity and specificity of 84.8% and 77.9%, respectively, whereas the cutoff point for %R at 3 hours, 9% retention, gives 85.0% and 75.6%, and the cutoff point for %R at 4 hours, 3% retention, gives 70.0% and 73.2%. CONCLUSIONS: Using the previously validated EggBeaters meal, T-90 is better than T-50 to differentiate patients with previously diagnosed gastroparesis from normal subjects. The percent retention at 3 hours provides diagnostic utility similar to the 90% emptying time and avoids the need for data extrapolation. To optimally detect gastroparesis, assessment of gastric emptying at times greater than 2 hours is needed with the percent retention at 3 hours being the best individual time point.
Making a Diagnosis of Gastroparesis Reduces Diagnostic Cost and Unnecessary Surgeries in Patients with Recurrent Nausea and Vomiting.

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Gastroparesis (GP) is a disorder defined by delayed gastric emptying. Symptoms of GP are non-specific and the diagnosis is often overlooked. Extensive medical resources may be spent for its diagnostic workup. AIM: To determine the extent of medical utilization in diagnosing GP in subjects with recurrent nausea and vomiting. METHODS: Potential subjects were identified at University of Louisville and University of Michigan from Jan 2001 through Dec 2003 using ICD billing codes for GP, miscellaneous gastric, nausea, vomiting, and nausea with vomiting. Outpatient records were reviewed in chronological order. Study criteria were nausea and vomiting ≥ 3 months and documented gastroparesis by delayed gastric scintigraphy or residual solid food by EGD despite overnight fast. Those <18 years old and non-ambulatory individuals were excluded. Diagnostic tests were separated into 3 categories: endoscopic, radiographic (including scintigraphy), and motility. Type and number of each diagnostic test and surgical procedure was obtained before and after making the diagnosis of GP. Cost of diagnosis was calculated using Medicare 2005 physician and hospital outpatient payment schedule for Kentucky and Michigan. Mann-Whitney U, Wilcoxon signed-rank and paired McNemar’s tests were utilized.

RESULTS: 240 charts were reviewed. 141 subjects (median age 46 yrs, 79% female) met study criteria. Results are shown in table. There was a high variability in total diagnostic cost among the subjects. Gender, age, and etiology of GP did not significantly affect the total diagnostic cost. Cost associated with endoscopies was significantly greater than radiographic and motility testing (p<0.01). Total diagnostic cost decreased significantly after the diagnosis of GP was made. Prior to diagnosis of GP, 56 subjects (40%) had cholecystectomy, compared to only 1 of the remaining 85 subjects (1%) after diagnosis. 23 subjects (16%) had laparoscopy/laparotomy before diagnosis of GP, compared to 3 subjects (2%) after diagnosis. CONCLUSIONS: Diagnostic cost of GP in patients with chronic nausea and vomiting was quite variable. Establishing a diagnosis of GP significantly reduced the cost associated with testing and number of unnecessary surgeries unrelated to GP.

<table>
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<th>Before diagnosis of gastroparesis</th>
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<tr>
<td>Total</td>
<td>4 (1-21)</td>
<td>*$1,581 ($246-$8,480)</td>
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†Median (range); *p< 0.01
Gastroduodenal Motility Measured in Health and Disease During Transit of an Ambulatory Capsule- SmartPill.

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3. SmartPill Corporation, Buffalo, NY, USA.

Introduction: Differences in GI luminal pressure patterns between healthy normals (N) and patients with gastroparesis (GP) could give insight into pathophysiology. Pressure measurements in the antrum and duodenum have traditionally been performed with invasive indwelling manometry catheters. SmartPill is a wireless ambulatory capsule that measures luminal pH and pressure as it courses throughout the GI tract after being swallowed. Passage of the indigestible solid SmartPill from the stomach into the duodenum appears to occur near the end or soon after the gastric emptying of a solid meal or during the fasting state when MMCs occur. Aims: To compare pressure patterns between normal subjects and patients with gastroparesis as defined by a previously abnormal gastric scintigraphy. Methods: In 2 centers, healthy subjects and patients swallowed the SmartPill (SP) after an overnight fast together with a standardized meal of 120 g Eggbeaters, 2 pieces of bread with jam; 255 kcal, 2% fat) and 120 cc water. The rapid pH change from acidic to alkaline (>3 unit rise from baseline gastric pH) marked the emptying of the ingested SmartPill from the stomach into the duodenum. The frequency and amplitude of contractions recorded by the capsule were counted in 30 minute intervals from 60 min before gastric emptying (GE) to 60 min after the capsule left the stomach. These parameters for Ns and GPs were then compared for each time interval by two-sample unequal variance T test. Results: 21 Ns (13M/8F, mean age 30.8) and 16 GPs ((4M/12F, mean age 40.9 (9 diabetic/7 idiopathic)) were studied. Mean contraction frequency and pressure amplitudes in both groups for 30 min intervals are summarized in the table below. Gastroparetics had lower gastric contraction frequencies in the time period –60 to –30 min (preceding gastric emptying) compared to normals, p<0.02. There were no differences in contraction amplitudes between the 2 groups. Conclusion: 1. This new ambulatory technology represented by SmartPill detected impaired gastric (antral) motility in GP compared to normals. 2. Decreases in frequency in gastroparetics prior to emptying of an indigestible solid may reflect neurogenic abnormalities in Phase II fasting response. 3. Contraction patterns in health and disease throughout the gut can be measured with the SmartPill Capsule.

<table>
<thead>
<tr>
<th></th>
<th>30-60 m before GE</th>
<th>0-30 m before GE</th>
<th>0-30 m after GE</th>
<th>30-60 m after GE</th>
</tr>
</thead>
<tbody>
<tr>
<td>N Freq (#contr/min)</td>
<td>1.2</td>
<td>1.3</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>GP Freq(#contr/min)</td>
<td>0.7</td>
<td>1.3</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td>P val</td>
<td>0.01</td>
<td>0.93</td>
<td>0.46</td>
<td>0.44</td>
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<tr>
<td>N Ampl(mmHg)</td>
<td>26.7</td>
<td>39.1</td>
<td>21.5</td>
<td>16.6</td>
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<tr>
<td>GP Ampl(mmHg)</td>
<td>29.0</td>
<td>49.6</td>
<td>25.4</td>
<td>17.7</td>
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<tr>
<td>P val</td>
<td>0.74</td>
<td>0.36</td>
<td>0.08</td>
<td>0.42</td>
</tr>
</tbody>
</table>
A New Non-Scintigraphic Method for Measuring Gastrointestinal Transit in Gastroparetic Patients.

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Background: Clinical diagnosis and therapy of motility disorders could be enhanced by better methodology for assessing Gastric Residence Time (GRT) as well as GI Total Transit Time (TTT) providing opportunity to improve correlation of symptoms with transit tests.

The aim of the study: The aims of this study were to compare TTT and its major components GRT and small/large bowel transit time (SLBTT), measured with a new diagnostic capsule (SmartPill) in asymptomatic volunteers (Controls, C) and compare with corresponding values recorded in patients with gastroparesis (GP).

Methods: 60 patients with GP: 23 diabetics (DM), 37 idiopathic (ID); 50 F & 10 M, mean age of 42 (range 19-66) mean BMI 26.3 (range 16.8-41.8) and 87 asymptomatic controls (C) 32F & 55M, mean age of 31 (range 19-57 years), with mean BMI 25.8 (range 17.9-41.1) participated in this multicenter study. After an overnight fast all subjects swallowed a wireless GI monitoring capsule (SmartPill) equipped with sensors that measured pressure, pH, and temperature. After initial data gathering at the study site, subjects returned to their normal ambulatory environment with parameters being captured by a portable recording device. Gastric Residence Time (GRT) was defined as the time from ingestion to an abrupt sustained rise in pH to >4 and at least a rise of 3 pH units from the baseline. GRT <30 was excluded from calculations. The TTT was measured from the time of ingestion of the wireless capsule until a drop in temperature or abrupt loss of signal associated with a bowel movement confirmed by patients’ diary. By subtracting GRT from TTT, SLBTT was calculated. Mann-Whitney Rank Sum Test was used to address statistical data.

Results: In GP the median TTT was significantly longer than in controls (48.3 h vs 26.9 h, P<0.001), as was GRT (10.2 vs 3.7 h, P<0.001) as well as SLBTT (29.5 vs 22.2 h, P<0.001). Additionally, the TTT in patients with GP of diabetic etiology was significantly prolonged compared to patients with ID GP (60.1 vs 32.1 h, P=0.036). As was the SLBTT in DM GP compared to ID GP (53.1 vs 28.2 h, P=0.014). TTT, GRT, and SLBTT were similar for both genders among gastroparetics.

Conclusions: 1. Significant differences in GRT, TTT, and SLBTT were observed between GP and controls by utilizing non-scintigraphic capsule technology.
2. Diabetic GP patients exhibit a prolonged SLBTT consistent with contributions from neuropathy, hyperglycemia, and other factors.
3. SmartPill has research and diagnostic potential for assessment of GI tract function in health and disease including physiologic and pharmacologic studies.
Background: Although the clinical tests for gastric residence time (GRT) have been evolving, estimation of the small/large bowel transit time (SLBTT) and gastrointestinal total transit time (TTT) poses more of a challenge for imaging technology.

The aim of the study: To evaluate a new methodology for assessing the GRT, SLBTT, and TTT based on a diagnostic capsule (SmartPill) in asymptomatic volunteers.

Methods: Eighty seven asymptomatic subjects (32F & 55M), mean age of 31 (range 19-57 years); mean BMI of 25.8 (range 17.9-41.1); after an overnight fast swallowed a wireless GI monitoring capsule (SmartPill ACT-I) equipped with sensors that measured pressure, pH, and temperature. After initial data gathering at the study site asymptomatic subjects returned to their usual daily environment, with parameters being captured by a portable recording device. Gastric residence time (GRT) was defined as the time from ingestion to a sudden rise in pH to >4 of at least 3 pH units from the baseline. GRT <30 min was excluded from calculations. The TTT was measured from the time of ingestion of the wireless capsule until there was a drop in temperature or abrupt loss of signal associated with a bowel movement confirmed by patients’ diary. By subtracting GRT from TTT we calculated SLBTT. T-test compared TTT female vs males; Mann-Whitney Rank Sum Test calculated GRT and SLBTT in regard to gender and Pearson PMC test addressed correlations between BMI and TTT. Data are presented as mean ±1SD or median.

Results: All normal subjects had a mean GRT of 4.67 ±4.47 hours, mean SLBTT of 25.1 ±14.1 hours and mean TTT of 29.4 ±14.3 hours. Mean TTT among females was longer 34.8 ±17.7 hours, compared to males 26.3 ±11.0 hours (P=0.020). Median GRT for females and males was similar, 3.8 vs 3.67 hours. SLBTT of 25.3 hours in females was prolonged compared to 21.4 hours in males (P=0.05). There were correlations between BMI and TTT (r=-0.323; p=0.0086), BMI and SLBTT (r=-0.26; p=0.035), but not for BMI and GRT (r=-0.092; p=0.42).

Conclusions:
1. The SmartPill capsule represents a novel, non-scintigraphic advance for assessing not only gastric residence, but also small bowel and colon transit times.
2. In normal subjects small/large bowel transit time was longer in females than males.
3. Longer small/large bowel transit time correlates with higher BMI in both genders.
4. This technology has potential for clinical and research applications in neuromuscular gut disorders.