Gastric Emptying Scintigraphy*

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In 1966, Griffith et al. used "a standard breakfast of ordinary food" labeled with chromium-51 to report the first use of gastric emptying scintigraphy (GES). As the procedure was refined over the years, investigators realized the importance of the radiotracer binding to the meal to produce accurate results. To achieve the highest-efficiency labeling, early investigators injected ^{99m}Tc–sulfur colloid (^{99m}Tc-SC) into a vein on a chicken's wing, and it accumulated in the Kupffer cells in the liver. After 15 minutes, the investigators butchered the chicken and removed the liver. The livers were then cooked, mixed with stew—to make it more appetizing and increase the volume—and fed to the patient. Thankfully, better methods evolved.

The literature shows the use of a variety of other foods for GES, such as pancakes, cheese, milk, or oatmeal. A recent study by Farrell et al. found an assortment of unusual meals currently being used, including honey buns, corn flakes and milk, peanut butter sandwiches, egg salad sandwiches, egg burritos, and McDonalds Egg McMuffins. In addition, a variety of meal preparation methods was observed, such as adding the tracer to eggs after cooking rather than before.

Although GES using radiolabeled meals is considered the gold standard for evaluating patients with gastrointestinal motility disorders, gastroenterologists—who refer patients for the test and manage them based on the results—have questioned the reliability of GES. The issue lies in inconsistent results due to lack of standardized procedure for the type of meal used, patient positioning, image acquisition frequency and duration, and quantitation method. Lack of standardization affects reported normal values and, thus, comparison of results between institutions. Discrepant test results complicate patient treatment decisions.

To address the lack of consistency and standardization, an expert panel of gastroenterologists from the American Neurogastroenterology and Motility Society and nuclear medicine physicians from the Society of Nuclear Medicine and Molecular Imaging (SNMMI) published a consensus guideline for solid meal GES in 2008. The guideline simplified the procedure and established standardized normal values. It also provided recommendations for precise patient preparation, meal composition, acquisition method, and image processing that should be adhered to by all laboratories.

RATIONALE/INDICATIONS/CONTRAINDICATIONS

Physiologically, there are two parts of the stomach with distinct functions (Figure 1). The proximal fundus serves as a reservoir for solid and liquid food. When food enters, the stomach muscle relaxes and accommodates the volume ingested. The body of the stomach is the largest portion. Food is churned and broken into smaller particles, mixed with enzymes and gastric juice and pre-digested. The fundus controls the rate of emptying by generating a pressure gradient between the stomach and the duodenum. The distal stomach, the antrum, grinds food into 1 to 2 mm particles to pass through the pyloric sphincter. Imaging of a radiolabeled meal allows assessment of the physiologic gastric functions of accommodation, grinding, and emptying. Counts in the stomach are directly proportional to the volume of the meal in the stomach at any particular time. GES measures normal, delayed, or accelerated rate of emptying. The goal of testing is to identify patients with gastric motility problems who will benefit from either prokinetic drugs or other treatments to alleviate their symptoms.

Physicians refer patients for GES to confirm or exclude gastroparesis (delayed gastric emptying or gastric stasis) as the cause of symptoms. The symptoms of gastroparesis include nausea (92% of patients), vomiting (84%), postprandial bloating (75%), and early satiety (60%). Gastroparesis may be caused by diabetes, infections, neuromuscular conditions, autoimmune and connective tissue diseases, cancer, or postsurgical effects, or it may be idiopathic.

Patients are also referred for GES due to dyspepsia. *Dyspepsia* is any pain or discomfort in the upper abdomen, nausea, vomiting, belching, bloating, distension, fullness, or early satiety. The pathophysiology of dyspepsia is unclear and complex, and in 50% of patients, no cause is found.

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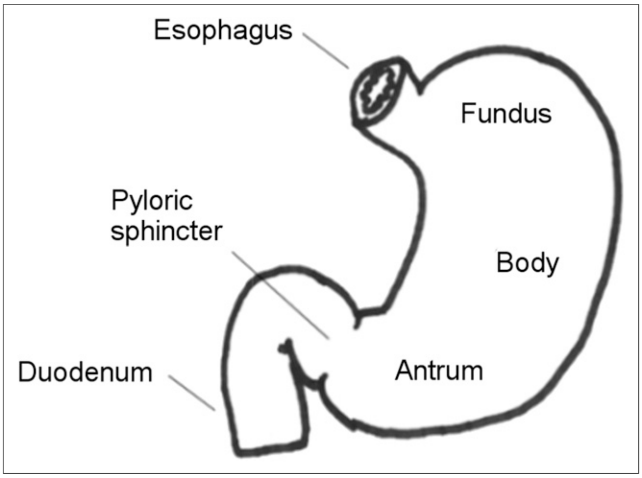

FIGURE 1. Stomach regions. The proximal fundus functions as a reservoir (accommodation) for food while the distal antrum grinds and mixes food.

Rapid gastric emptying, also called "dumping syndrome," is often seen after gastric surgery for peptic ulcer disease. Early dumping symptoms, which occur in the initial hour after eating, include diarrhea, abdominal discomfort, nausea, bloating and vasomotor symptoms. Late dumping symptoms include diaphoresis, palpitations, weakness, and fainting due to reactive hypoglycemia from an exaggerated insulin response.

In general, the clinical indications for GES include insulin-dependent diabetes and post-prandial symptoms or diabetes with poor blood glucose control; dyspepsia not associated with ulcers; severe esophagitis caused by reflux; unexplained nausea, vomiting, weight loss, upper abdominal discomfort, bloating, or early satiety; and assessment of response to treatment with motility drugs.

GES is contraindicated for patients with allergies to eggs or any other component of the meal. In addition, GES is contraindicated in patients with hypoglycemia (blood glucose level $<$ 40 mg/dL). Hyperglycemia (blood glucose level $>$ 275 mg/dL) may be contraindicated and is discussed further in the next section.

PATIENT PREPARATION/EDUCATION/FOOD/ MEDICATION RESTRICTIONS

Several patient factors influence the rate of gastric emptying. Strict adherence to patient preparation instructions is critical to ensure standardization and validity of the results.

The patient should not eat or drink anything after midnight the day before the test. At a minimum, the patient should not eat or drink within the 4 to 6 hours prior to the study. The study should be performed in the morning when the rate of gastric emptying is increased.

Premenopausal women should be studied within the first 10 days of their menstrual cycle to prevent radiopharmaceutical administration to a potentially pregnant woman and to avoid hormonal effects on gastrointestinal motility. Research demonstrates that gastric emptying of solids varies with the phases of the menstrual cycle. Emptying is slower during the luteal phase (post-ovulation), which correlates with elevated serum levels of progesterone. There is no significant variation in emptying of liquids during the menstrual phase.

Blood glucose levels should be reasonably controlled, as hyperglycemia delays gastric emptying. The morning of the test, insulin-dependent diabetic patients should monitor and adjust their dose of insulin. Ideally, the patient's blood sugar level should be lower than 200 mg/dL. If the serum glucose is greater than 275 mg/dL at the time of testing, the test should not be performed; alternatively, serum glucose may be lowered with insulin to $<$ 275 mg/dL. Patients should be instructed to bring their insulin and glucose monitor with them to the test. Glucose level should be tested and recorded prior to meal ingestion, and the value should be included in the final report. Half of the usual morning dose of insulin is generally administered along with the radiolabeled meal. Only half of the insulin dose is administered because the patient is not able to eat for 4 hours once the study begins.

Patients should not smoke the morning of the test or until after the test is complete. Smoking is known to slow gastric emptying of solids.

A focused history of diseases such as a hiatal hernia, gastroesophageal reflux, and esophageal motility disorders should be obtained. In addition, previous stomach or abdominal surgery that can alter the shape or route of emptying should be noted.

Finally, the patient must be instructed about the logistical demands of the test, such as the content of the meal, requirement to consume the meal in less than 10 minutes, length of the procedure, number of images acquired, activity restrictions, and position between images.

Numerous medications can alter the rate of gastric emptying—either intentionally or as a side effect—and should be withheld before the procedure. The time the medication should be withheld is based on the half-life of the drug, but it generally is in the range of 48 to 72 hours.

Prokinetic agents enhance the rate of gastric emptying and should be withheld at least 2 days prior to the test unless the efficacy of these medications is being tested. Prokinetic agents include metoclopramide (Reglan), cisapride (Propulsid), domperidone (Motilium) and erythromycin.

In patients with gastroparesis, prokinetic agents may demonstrate normal gastric emptying.

- Opiate analgesic medications that delay gastric emptying such as meperidine (Demerol™), codeine, morphine, and oxycodone (Oxycontin, Percodan, Percocet) should be withheld for 2 days. Use of opiate analgesics could result in a false diagnosis of delayed gastric emptying.
- Anticholinergic antispasmodic agents are usually stopped for 2 days and include dicyclomine (Bentyl), Donnatal, hyoscyamine (Levsin), and glycopyrrolate (Robinul).
- Antidepressants, calcium channel blockers, gastric acid suppressants and aluminum-containing antacids should also be discontinued, usually for 48 to 72 hours.
- Laxatives should not be taken the day before the test.

- Other medications that may affect gastric emptying include atropine, nifedipine progesterone, octreotide, theophylline, benzodiazepine, and phenolamine.

The patient may take other medications with a small amount of water prior to the test. If the patient has severe nausea and vomiting at the time of the test, serotonin receptor (5-HT-3) antagonists such as ondansetron (Zofran) may be given.

IMAGING PROCEDURE

Gastric emptying is a complex physiologic process controlled by the physical and chemical composition of the GES meal, sympathetic and parasympathetic innervation of the stomach, and circulating neuroendocrine transmitters. The type of food, volume, and caloric content significantly affect the rate of gastric emptying. In order to have any value, the GES meal and protocol must be closely followed. Table 1 details the factors that affect the gastric emptying rate. Normal rates of gastric emptying have been established and validated for the recommended meal based on these factors.

Solid Meal Study

The standardized meal consists of 120 grams (4 oz.) of liquid egg whites such as Egg Beaters (ConAgra Foods), which is the equivalent of the whites of two large eggs (see Table 2). The liquid egg white is mixed with 18.5 to 37 MBq (0.5–1.0 mCi) of ^{99m}Tc-SC and cooked in the microwave or on a nonstick griddle. The egg mixture is stirred once or twice during cooking and cooked until it has the texture of a firm omelet.

For accurate results, the radiotracer must bind tightly to the solid component of the meal and remain within the gastrointestinal tract. ^{99m}Tc-SC is the preferred radiopharmaceutical because it is not absorbed within the gastrointestinal tract and binds to the albumin (egg white protein), denaturing as it cooks. Note, ^{99m}Tc-SC does not bind to egg yolks. The goal of labeling eggs whites with ^{99m}Tc-SC is to keep the meal from being absorbed or binding to the mucous membranes in either the stomach or intestine.

TABLE 1
Factors that Affect the Rate of Gastric Emptying

Factors that Increase the Rate of Emptying	Factors that Decrease the Rate of Emptying
Liquids	Solids
Small particle size	Large particle size
Low fiber or low residue	High fiber
Proteins and carbohydrates	Fats
Low calorie	High calorie
Large volume	Small volume
Alkaline	Acidic
Hot food	Cool food
Early in the day	Late in the day
Activity	Sedentary
Upright	Lying down
Absence of pain	Pain
Lying on right side	Lying on left side
Male	Female
Prokinetic, erythromycin	Narcotics, anticholinergic
Reserpine, anticholinesterases, guanethidine, cholinergic agents	(Atropine), tricyclic antidepressants, phenothiazines

TABLE 2
Standardized Gastric Emptying Meal

120 g (4 oz.) of liquid egg whites (99% real eggs, cholesterol free, fat-free and low calorie)
2 slices of white bread
30 g strawberry jam
120 ml (4 oz.) water
18.5–37 MBq (0.5–1.0 mCi) ^{99m}Tc-SC

Egg substitute is preferred over fresh whole eggs because it has a high binding percentage and is less likely to disintegrate in gastric fluid. If the tracer separates from the protein, the test results will vary because the meal becomes a part-solid, part-liquid mixture. Approximately 80% of ^{99m}Tc-SC remains bound to the egg substitute at 3 hours. Egg substitute also maintains firmer consistency than whole eggs. The labeling efficiency is approximately 85%.

The egg mixture is also served with two slices of toasted white bread spread with 30 g of strawberry jam and 120 ml (4 oz.) of water. The meal is usually served as a sandwich to decrease the time required for ingestion, but it may be eaten separately if the patient desires. The entire meal has a caloric content of 255 kcal composed of 72% carbohydrate, 24% protein, 2% fat, and 2% fiber.

The patient must eat the entire meal as quickly as possible, ideally in less than 10 minutes. If the patient is unable to ingest the entire meal, a minimum of 50% of the meal must be consumed. If less than 50% of the meal is ingested, the results may overestimate the rate of gastric emptying, so the study cannot be considered diagnostic. The technologist should document the time it takes the patient to ingest the meal and the percentage of the meal consumed.

Acquisition. A large field-of-view camera with a low-energy, all-purpose collimator is used to acquire images in word mode with a 128 × 128 matrix. The energy window is peaked at 140 keV ± 20%. Images are acquired in the upright or standing position for 1 minute in both anterior and posterior projections with the distal esophagus, stomach, and proximal small intestine in the field of view. The images may be acquired simultaneously using a dual-head camera or sequentially using a single-head camera. There is no significant difference in the results between images acquired simultaneously versus images acquired sequentially.

If the patient is unable to stand, images may be acquired supine in the left anterior oblique (LAO) position, although the rate of gastric emptying may be significantly decreased in the supine position. If the patient is imaged in the supine position, a dual-head camera is positioned above and below the patient. If a single-head camera is used, the images are usually acquired in the LAO view.

The standardized consensus protocol recommends acquisition of images immediately upon ingestion of the meal

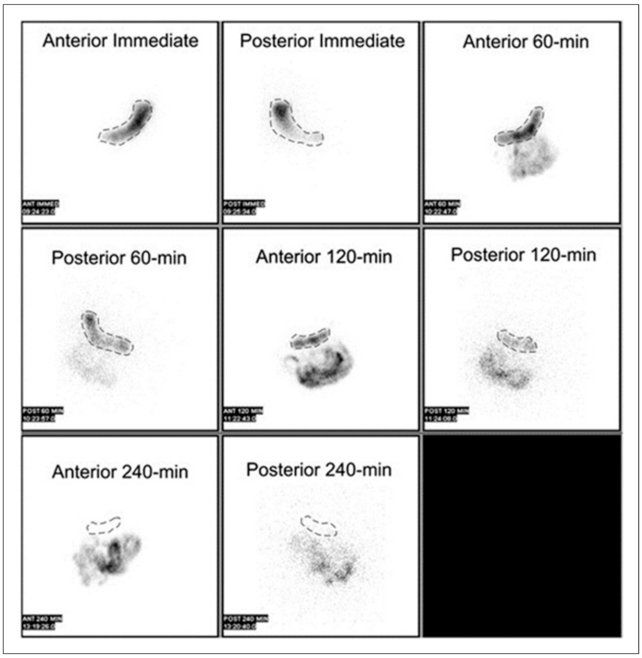

FIGURE 2. Normal gastric emptying study demonstrating correct regions of interest in both the anterior and posterior projections on initial, 1-hour, 2-hour, and 4-hour images. *This image was originally published in* JNMT. *Vijayakumar V. Assessment of the Practical Role of a Radionuclide Low-Fat-Meal Solid Gastric Emptying Study.* J Nucl Med Technol. *2006; 34:82–85. © SNMMI.*

and then repeated at hourly intervals of 1, 2, and 4 hours. The same camera must be used for all images. A ^{57}Co marker placed on the xiphoid process is helpful for repositioning the patient and drawing regions of interest during later processing. Imaging at 30 minutes may be helpful if rapid gastric emptying or impaired fundal accommodation is suspected. Imaging can be discontinued prior to 4 hours if less than 10% of the original stomach contents remains in the stomach.

Recent research suggests the importance of obtaining images for up to 4 hours. Delayed gastric emptying is detected with higher sensitivity at 4 hours than at 2 hours. Images at 4 hours detect gastroparesis 30% more often. Imaging at 0, 1, 2, and 4 hours allows for the identification of both rapid and delayed gastric emptying, which is important because they are treated differently, although the symptoms are similar.

Between images, the patient should rest in the sitting position, minimizing walking and activity. Stair climbing, other diagnostic imaging tests, and other appointments should be avoided during the 4-hour test.

Variations

Liquid Study. Gastric emptying of liquids is a simple process because the meal does not need to be ground into small particles to pass through the pyloric sphincter. As liquid enters the stomach, the fundus relaxes to accommodate the volume. Smooth muscle in the fundus contracts, creating a pressure gradient between the fundus and pylorus. Liquids begin to leave the stomach almost immediately after ingestion. Liquids usually empty from the stomach in about 30 minutes.

The volume of liquid is the main determinant of the rate of liquid gastric emptying. The larger the volume of liquid, the more rapid the rate of emptying. As volume decreases, emptying slows. The caloric content of the liquid also affects the rate of emptying. The liquid used should equilibrate quickly and not be absorbed from the gastrointestinal tract.

For liquid gastric emptying studies, 300 ml of water mixed with 18.5 to 37 MBq (0.5–1.0 mCi) of ^{99m}Tc–diethylenetriaminepentaacetic acid (DTPA) is most commonly used. The mixture should be rapidly swallowed through a straw.

Acquisition. Imaging begins immediately after ingestion of the liquid. A large field-of-view camera with a low-energy, all-purpose collimator is used to image the patient in the semi-upright (30–45 degree) position. The camera is positioned in the left anterior oblique position with the stomach and upper abdomen in the field of view. Continuous images are acquired at 60 seconds for 30 minutes. A 128 × 128–word mode matrix is used with a 20% window set on the 140 keV photopeak of ^{99m}Tc.

Dual Isotope Liquid/Solid Study. Historically, it was believed that liquid gastric emptying studies were less

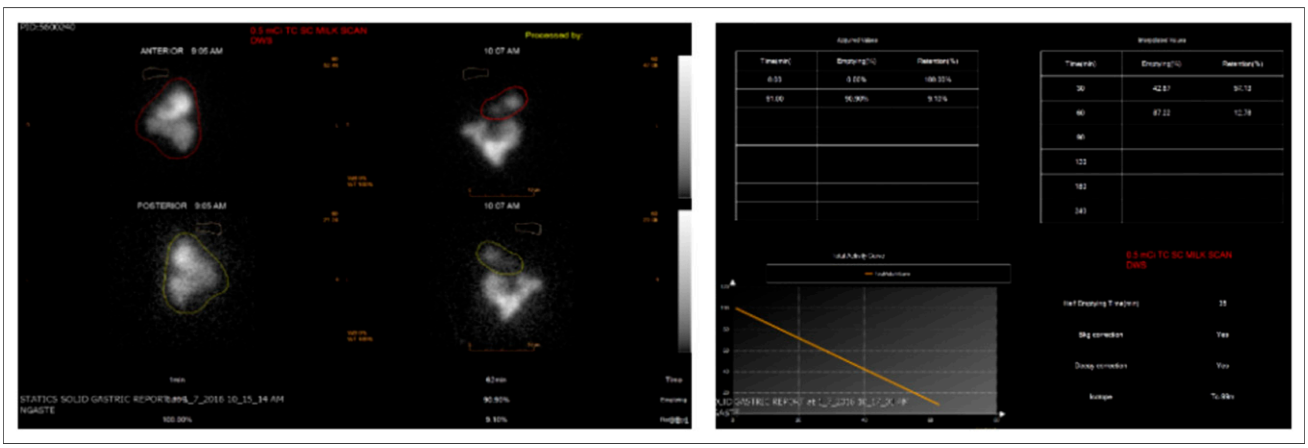

FIGURE 3. Normal liquid gastric emptying study using 0.5 ^{99m}Tc-SC added to milk. Anterior and posterior images (right) at 0 and 60 minutes. Half-time emptying curve (left). *Images courtesy of Leonie L. Gordon, MD, FACNM Medical University of South Carolina, Charleston, SC.*

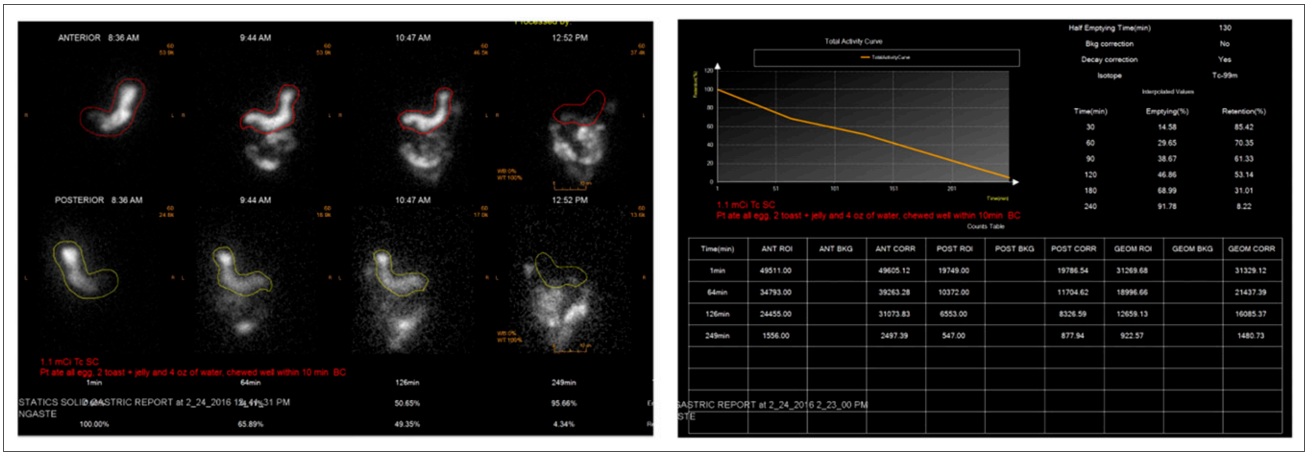

FIGURE 4. Normal solid gastric emptying study. (Top) Anterior and posterior images at 0 and approximately 1, 2 and 4 hours. (Bottom) Region counts from the anterior and posterior images and geometric mean. The percent retention at 4 hours is 8.2%. *Images courtesy of Leonie L. Gordon, MD, FACNM Medical University of South Carolina, Charleston, SC.*

sensitive for detecting gastroparesis than solid studies. However, recent studies comparing liquid-only studies with solid-only studies found that liquid-only studies detected gastroparesis more frequently. A patient may have normal solid and liquid, abnormal liquid and normal solid, normal liquid and abnormal solid, or abnormal liquid and abnormal solid results. Delayed liquid gastric emptying may be seen in 30% to 35% of patients with a normal solid gastric emptying study. Research has shown that postprandial fullness and early satiety are associated with delayed gastric emptying of liquids; therefore, there is added diagnostic value in combining liquid and solid gastric emptying studies.

When a liquid/solid study is performed, liquids empty from the stomach more rapidly than the solids, but at a slower rate than if a liquid study were performed alone. When there is rapid passage of water from the stomach while solid materials are retained, this is known as "solid-liquid discrimination."

Acquisition. Liquid and solid gastric emptying studies can be performed sequentially on the same day. The liquid is performed first using 7.4 MBq (0.2 mCi) of ^{111}In-DPTA in water followed by the solid meal using ^{99m}Tc-SC. Dual isotope liquid and solid gastric emptying studies may also be performed simultaneously. Because ^{111}In-DTPA is chemically inert, it does not bind to the components of the solid meal and does interfere with the results of the solid meal.

A medium energy collimator is used with the camera, set up for dual acquisition energy discrimination of the ^{99m}Tc photopeak (20% window, 140 keV) and ^{111}In (20% window, 274 keV).

Alternative Meals. For patients allergic to eggs or any of the other meal components, gluten-sensitive patients, or patients who will not eat the standardized meal, alternative meals may be used. Oatmeal or liquids such as milk or Ensure shakes have been used; however, there is limited data on normal values available for these meals.

Radiation Exposure

The ICRP 106 model estimates that ingestion of 37 MBq (1.0 mCi) ^{99m}Tc-SC for a gastric emptying study would impart an approximate effective dose of 0.8 mSv (0.08 rem) in an adult male. The critical organ for this study is the upper large intestine, which would receive 0.2 mGy (0.02 rad). Ingestion for an adult female of 37 MBq (1 mCi) ^{99m}Tc-SC would impart an approximate effective dose of 1.0 mSv (0.10 rem). The critical organ for this study is the lungs, which would receive 0.3 mGy (0.03 rad). The effective dose for ingestion of 37 MBq (1.0 mCi) ^{111}In-DTPA is not available.

PROCESSING

Evaluation of the images alone is not useful for the determination of rapid or delayed gastric emptying. To quantify the results, regions of interest (ROI) are drawn around the stomach on all anterior and posterior images. The ROI must include the antrum and fundus regions of the stomach (Figure 2). Care must be taken to ensure no activity from the adjacent

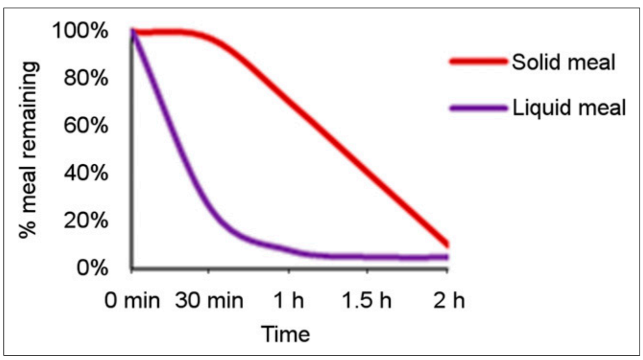

FIGURE 5. Normal gastric emptying curves. For solid meal (red), there is an initial 20-30 m lag period as the antrum reduces meal particle size and mixes with gastric acid. After the lag period, the solid material empties from the stomach in a linear fashion. The liquid meal (purple) immediately begins to leave the stomach and empties in an exponential pattern.

TABLE 3
Normal Solid Gastric Emptying Values

Imaging Time	Lower Normal Limit[a]	Upper Normal Limit[b]
0 minutes		
0.5 hours	70%	
1 hour	30%	90%
2 hours		60%
3 hours		30%
4 hours		10%

[a]For the lower normal limit, lower values suggest rapid gastric emptying.

[b]For upper normal limit values, a greater value suggests delayed gastric emptying.

Reprinted with permission from Abell TL, Camilleri M, Donohoe K, et al. Consensus recommendations for gastric emptying scintigraphy: a joint report of the American Neurogastroenterology and Motility Society and the Society of Nuclear Medicine. J Nucl Med Technol. 2008;36:44–54.

small bowel is included within the region; however, if the images demonstrate loops of small bowel on the initial image, then that area should be included in the region so that the entire ingested activity is used for comparison. Because the study is performed over 4 hours and ^{99m}Tc has a 6-hour half-life, radioactive decay correction must be performed.

The fundal portion of the stomach is relatively posterior to the antral portion. Ingested material moves through the stomach superiorly to inferiorly, from left to right, and posterior to anterior. Therefore, the counts obtained from the regions of interest must be attenuation corrected. If the images are not attenuation corrected, the rate of gastric emptying can be underestimated by 10% to 30%, most commonly in patients with large body habitus.

The most frequently used and easiest method of attenuation correction is to use the geometric mean, which results in only a 3% to 4% error in counts. The geometric mean is calculated by taking the square root of the anterior counts multiplied by the posterior counts for each time point.

$$Geometric\ \ mean = \sqrt{\left(Counts_{anterior}\ \ x\ \ Counts_{posterior}\right)}$$

The results of the decay-corrected geometric means are used to determine the percent remaining in the stomach at each time point (1, 2, and 4 hours) by dividing the total counts at the time point by the initial total counts. The percent remaining in the stomach is graphed over time.

If the images are acquired in the left anterior oblique projection, the geometric mean does not need to be calculated because the movement of the stomach contents is roughly parallel to the camera head and the attenuation effects are

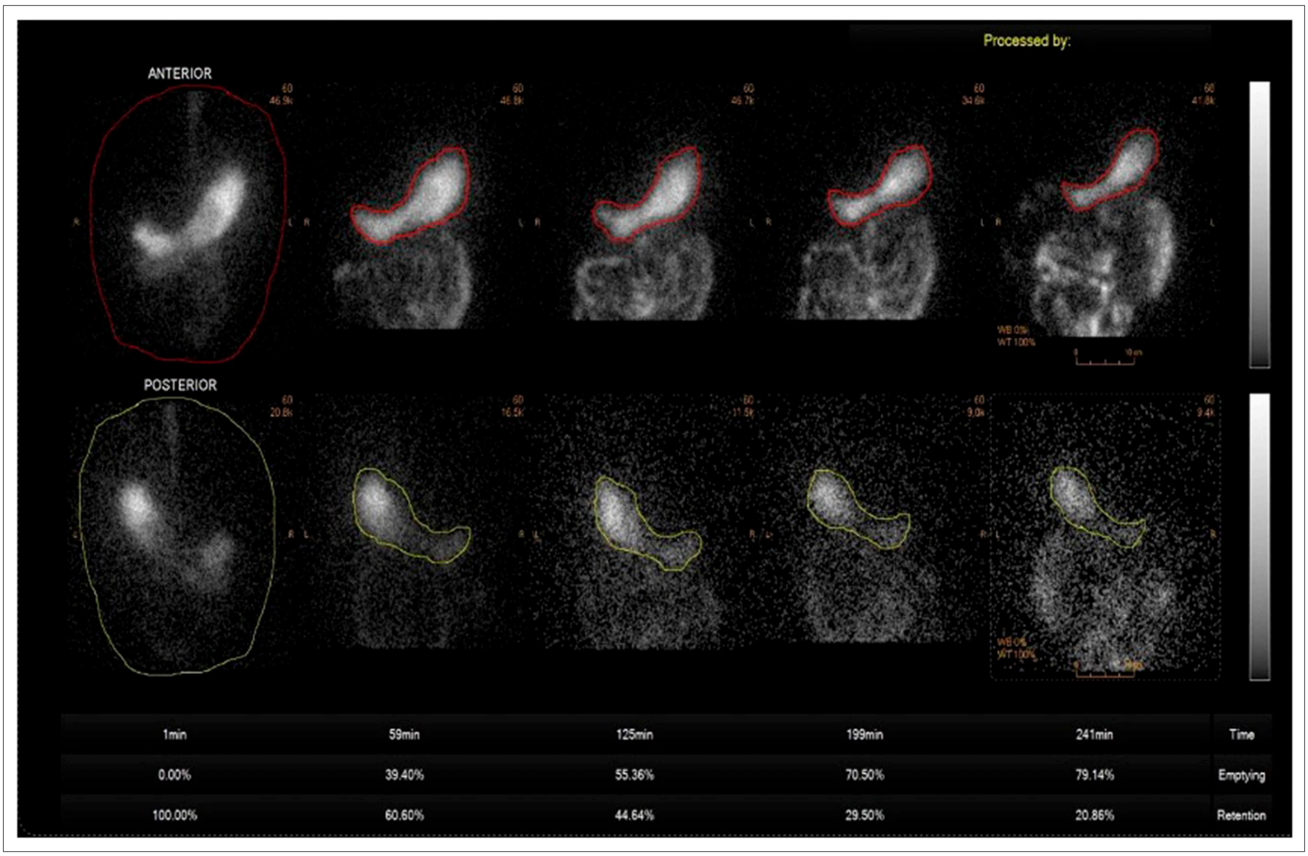

FIGURE 6. Abnormal solid gastric emptying study delayed emptying with 20.9% retention at 4 hours. At top, anterior images; at bottom, posterior images. *Images courtesy of Jon A. Baldwin, MD, University of Alabama at Birmingham, Birmingham, AL.*

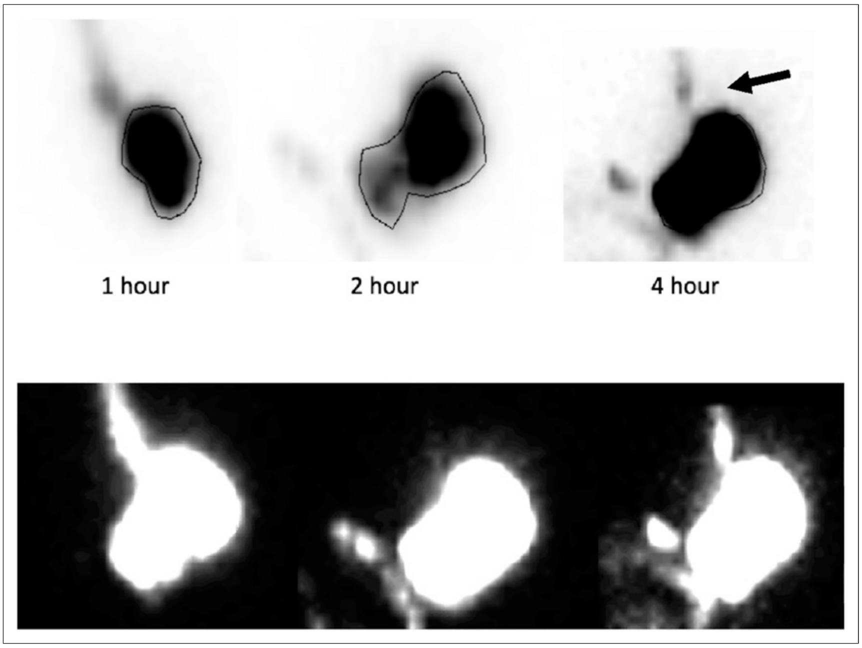

FIGURE 7. Abnormal gastric emptying study demonstrating delayed emptying and esophageal reflux (arrow). At top: normal intensity display. At bottom: inverted images with increased intensity. *Images courtesy of Lorraine M. Fig, MD, FACNM VA Ann Arbor Healthcare System, Ann Arbor, MI.*

minimized. No significant differences in emptying times have been demonstrated between images acquired in the anterior/posterior views versus the left anterior oblique view; however, the geometric mean method is considered the most accurate.

In the past, some facilities calculated the time for half of the counts to leave the stomach (T½). This method is not recommended in the consensus document, as T½ may be potentially less accurate than percent retention, especially for patients with delayed emptying, where extrapolation is needed to calculate T½ if half of the meal does not leave the stomach during the test.

Dual Isotope Liquid/Solid Study

When both solid and liquid gastric emptying are performed, scatter correction must be performed to correct for down-scatter of the ^{111}In photons into the ^{99m}Tc 140 keV window. However, scatter correction can be avoided if the dose ratio of ^{99m}Tc to ^{111}In is at least 4:1.

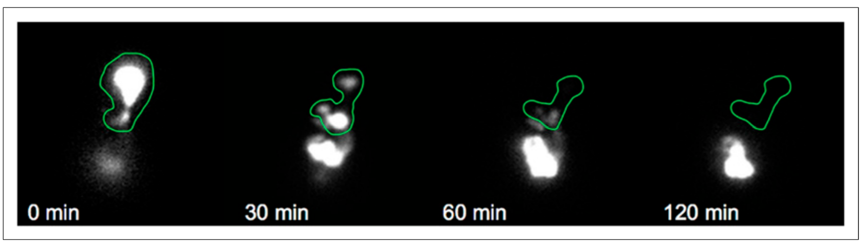

FIGURE 8. Abnormal gastric emptying study demonstrating rapid gastric emptying or dumping syndrome. The percentage retention at 30 minutes, 60 minutes, and 120 minutes was 40%, 5%, and 1%, respectively. *Images courtesy of Lorraine M. Fig, MD, FACNM VA Ann Arbor Healthcare System, Ann Arbor, MI.*

Liquid Study

For liquid gastric emptying, a region of interest is drawn around the stomach, and time-activity curves are generated. The emptying half time is determined as the time in minutes when counts become half of the peak counts or an exponential mathematical fit of half time can be calculated. Decay correction and attenuation correction are not necessary. Normal values for liquid gastric emptying have not been well validated, and T½ of 23 minutes ± 3 standard deviations is considered normal (Figure 3).

IMAGE INTERPRETATION

Normal Results

Upon ingestion of the radiolabeled meal, liquids rapidly diffuse throughout the stomach, while solids concentrate primarily in the fundus (accommodation) until they are moved down into the antrum by fundal contractions. The initial localization of the solid material in the fundus is apparent on the initial images. A transverse photopenic band between the fundus and antrum may be seen on later images (Figure 4). After the solids move into the antrum, contractions of the antrum grind the solids into 1 to 2 mm particles to pass through the pylorus. The time to accomplish this is known as the lag period and normally lasts 20 to 30 minutes, during which minimal gastric emptying occurs.

Once the small particles are mixed with gastric acid, they empty from the stomach in a linear fashion at the same rate as liquids. This emptying results from the pressure gradient caused by the fundus (Figure 5). The results of a liquid gastric emptying study demonstrate the liquid rapidly leaving the stomach in an exponential manner with no lag phase. As the volume of liquid decreases, the rate of emptying slows.

Normal values for gastric emptying of solids for the standardized protocol and meal were established by Tougas et al. using 123 normal subjects from 11 medical institutions in the United States, Canada, and Europe. The normal values were set using the median and 95th percentile (Table 3). A study is considered not delayed if the value at 2 hours is less than 60% and at 4 hours is less than 10%.

Abnormal Results

A study is considered to have delayed gastric emptying if there is more than 60% of the solid meal remaining at 2 hours or more than 10% of the meal remaining at 4 hours.

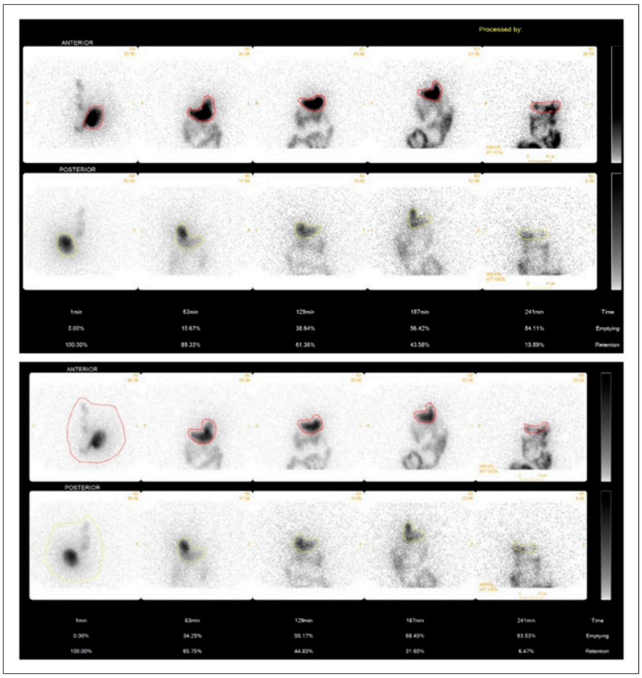

FIGURE 9. Solid gastric emptying study demonstrating the effects of region of interest placement (top). On the immediate image, the region of interest is incorrectly drawn around only the fundus. Residual activity in the esophagus and activity in the antrum is not included. The percent remaining in the stomach at later times is falsely elevated because fewer initial counts (denominator) were used in the calculation. At 4 hours, the percent remaining in the stomach is abnormal at 15.9% (bottom). The region of interest is correctly drawn including the esophagus and antrum. When the counts at 4 hours are divided by this higher total activity, the percentage of meal remaining in the stomach is now normal at 6.4%. *Images courtesy of Jon A. Baldwin, MD, University of Alabama at Birmingham, Birmingham, AL.*

Greater than 10% at 4 hours has been determined to be one of the best discriminators between a normal and abnormal study (Figures 6 and 7).

The results indicate rapid emptying if there is less than 70% retention at 30 minutes or less than 30% in the stomach at 1 hour (Figure 8).

Sensitivity/Specificity/Accuracy

Gastric retention of greater than 60% at 2 hours has a sensitivity of 100% but a specificity of only 20% for detecting delayed gastric emptying. However, gastric retention of greater than 10% at 4 hours has been demonstrated to have a sensitivity of 100% and specificity of 70% for delayed gastric emptying. These findings demonstrate the importance of continuing the test out to 4 hours. On the other hand, less than 30% retention at 1 hour has been shown to have a sensitivity of 90% and a specificity of 90% for rapid gastric emptying. Thus, initial imaging combined with images obtained at 1, 2, and 4 hours after the meal provides an excellent strategy to evaluate gastric emptying to detect suspected gastric stasis or dumping syndromes.

ARTIFACTS

Several factors can affect the results of gastric emptying studies. Many factors such as medications at the time of testing, poor glycemic control, smoking, duration of testing and quantitative method have been described above. There are additional factors that may cause over estimation or underestimation of the rate of emptying.

Incomplete meal ingestion may suggest more rapid emptying. Prolonged time to ingest the meal causes a delay in acquiring the initial image that is used to calculate the percentage of retention. Vomiting a portion of the meal after the acquiring the initial image lowers the amount of the meal retained in the stomach and erroneously appears as rapid emptying.

Incorrect region of interest placement can also falsely affect the rate of emptying. Two scenarios can occur. If the region of interest drawn on the initial image at 0 minutes (denominator) does not include the total activity, the calculated percentage of the meal remaining in the stomach will be falsely elevated (Figure 9). If the region of interest drawn on the 1-, 2-, or 4-hour images (numerator) includes small bowel activity, the percentage of the meal remaining in the stomach will also be falsely elevated. Both situations could result in a study being interpreted as abnormal.

SUMMARY

GES is performed to evaluate patients with symptoms associated with delayed or rapid gastric emptying. It is considered the gold standard for measuring the rate of gastric emptying. However, considerable variability in test performance has limited its usefulness due to a lack of established, standardized normal values that can be compared between institutions. To address this problem, the American Neurogastroenterology and Motility Society and the Society of Nuclear Medicine and Molecular Imaging published a consensus guideline for solid meal GES in 2008. This recommendation details precise patient preparation, meal content, acquisition method, and image processing that should be strictly adhered to by all laboratories.

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