

Gastric Emptying Study With Tc-99m Labeled Meals

OVERVIEW

- a) A *Gastric Emptying Study* is a radionuclide diagnostic imaging study. The most common type of gastric emptying study is a procedure that is done by nuclear medicine physicians using a small amount of radioactivity that measures the speed with which food empties from the stomach and enters the small intestine.
- b) Gastric emptying studies are used for evaluating patients who are having symptoms that may be due to slow and, less commonly, rapid emptying of the stomach. The symptoms of slow emptying are primarily nausea, vomiting, abdominal pain, and abdominal fullness after eating. The symptoms of rapid emptying are diarrhea, weakness, or light-headedness after eating
- c) During the clinical evaluation of gastrointestinal symptoms suspected to be caused by a motility disorder, it may be difficult for clinicians to determine if the symptoms are caused by upper and/or lower GI tract dysfunction. In clinical practice, it is therefore helpful to evaluate motility throughout the entire GI tract. At present, whole-gut transit scintigraphy (combined gastric emptying, small bowel and colon transit) is a relatively easy study to perform and in some centers is a frequently used and validated method to assess pan-gut motility.
- d) Treatment selection may be guided by the finding of upper, lower or combined GI transit abnormalities. In addition, in patients with chronic constipation who are being considered for surgical colectomy, an assessment of upper GI motility is important since upper GI dysmotility may reduce the clinical response to surgical treatment.

1. RADIOPHARMACEUTICAL UTILIZED

- a) The most commonly used radiopharmaceutical is Tc-99m labeled egg whites (albumin).

b) The following standardized meal has been recommended by the American Neurogastroenterology and Motility Society and the SNMMI. Reference values have been obtained through a multicenter trial. If another meal is used, the reference values cited for this standardized meal do not apply.

- 118 mL (4 oz.) of liquid egg whites (e.g., Eggbeaters [ConAgra Foods, Inc.] or an equivalent generic liquid egg white)
- Two slices of toasted white bread c. 30 g of jam or jelly
- 120 mL of water

c) Meal preparation

- Mix 18.5–37 MBq (0.5–1 mCi) of Tc-99m sulfur colloid into the liquid egg whites.
- Cook the eggs in a microwave or on a hot nonstick skillet
- Stir the eggs once or twice during cooking and cook until firm—to the consistency of an omelet.
- Toast the bread and spread the jelly on the toasted bread.
- The meal may be eaten as a sandwich to decrease the time required for ingestion; if preferred, the eggs and toast may be eaten separately.

d) An alternative for patients unable to eat eggs due to allergy or other reasons is Tc-99m labeled oatmeal.

e) Meal preparation

- Empty a packet of plain instant oatmeal into a beaker,
- Add ~ 1 ounce hot water, enough to wet the oatmeal.
- Add 1 ml of prepared Tc-99m sulfur colloid.
- Mix to insure homogeneity.
- Add more hot water to achieve desired consistency of the oatmeal.
- Cook for 3-4 minutes on a hot plate.
- Add sugar to increase palatability.

f) Other meals

- A historical note: The first gastric emptying meal ever used (1975, Temple University, Philadelphia) was *in vivo* labeled chicken livers. Although still the best gastric emptying agent, keeping live chickens in a hospital is not an option, so this was a short-lived project.
- An anion exchange resin, Chelex-100, readily binds to most foods and is extremely stable *in vivo*. Not commonly used.
- For tracing the flow of a liquid meal through the GI tract, the most common and least expensive meal is Tc-99m DTPA.

2. CHARACTERISTICS OF THE RADIONUCLIDE

Tc 99m decays by isomeric transition with a physical half-life of 6.02 hours. The principal photon that is useful for detection and imaging studies has a percent abundance of 89.07 % and the energy is 140.5 KeV.

- a) The specific gamma ray constant for Tc 99m is 0.78 R/millicurie-hr at 1 cm.
- b) The first half-value layer is 0.017 cm of lead (Pb) and the first tenth value layer is 0.08 cm of Pb.

3. DRUG AVAILABILITY

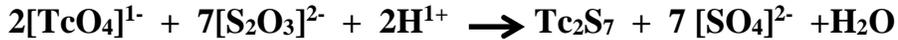
- a) Tc-99m sulfur colloid is readily available from all central radiopharmacies, as are all required food items.

4. Tc-99m OVALBUMIN: DETERMINATION OF RADIOLABELING EFFICIENCY

- a) To determine labeling efficiency of ovalbumin with Tc-99m, a sample of the cooked egg white is placed in a centrifuge tube and broken into small pieces.
- b) 10 ml of H₂O are added and tube is capped and then shaken for a few sec.
- c) The tube may be permitted to sit until contents have settled completely or may be spun for 1-2 min in a clinical centrifuge
- d) The supernatant liquid is then decanted into a separate tube and both tubes are counted in a well counter.
- e) The labeling efficiency =
$$\frac{\text{activity in egg whites} \times 100\%}{\text{activity in liquid} + \text{egg whites}}$$

5. RADIOCHEMICAL REACTION

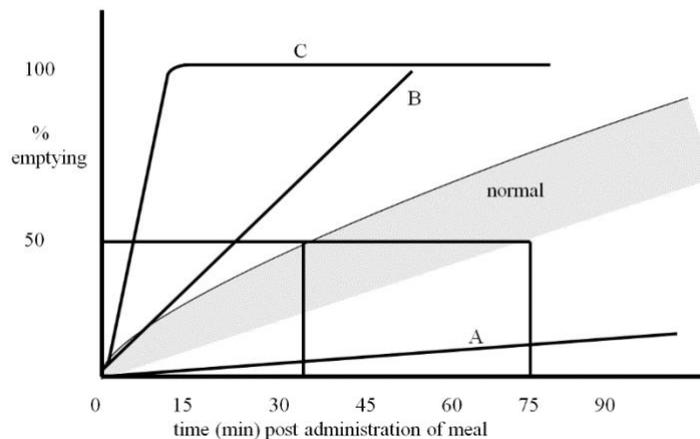
- Unlike other Tc-99m radiopharmaceuticals, preparation of Tc-SC does not require a REDOX (reduction/oxidation) reaction to reduce the oxidation number of Tc. There is therefore no stannous ion in a sulfur colloid cold kit.
- The reaction is thought to be the following (published by J Steigman and W Eckelman in *The Chemistry of Technetium in Medicine*, 1992)



6. NORMAL PARAMETERS OF A SOLID PHASE GASTRIC EMPTYING STUDY

- In the diagram below note that the normal range has a fair amount of variability in it. Meal is defined in paragraph 2.b) above.

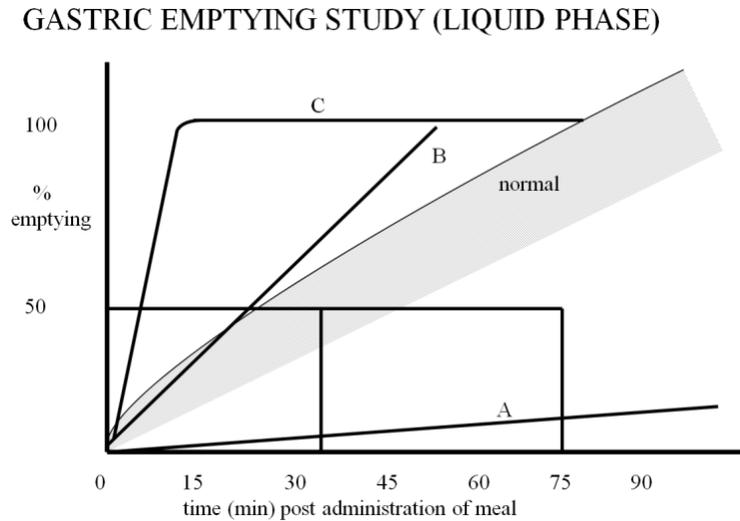
GASTRIC EMPTYING STUDY (SOLID PHASE)



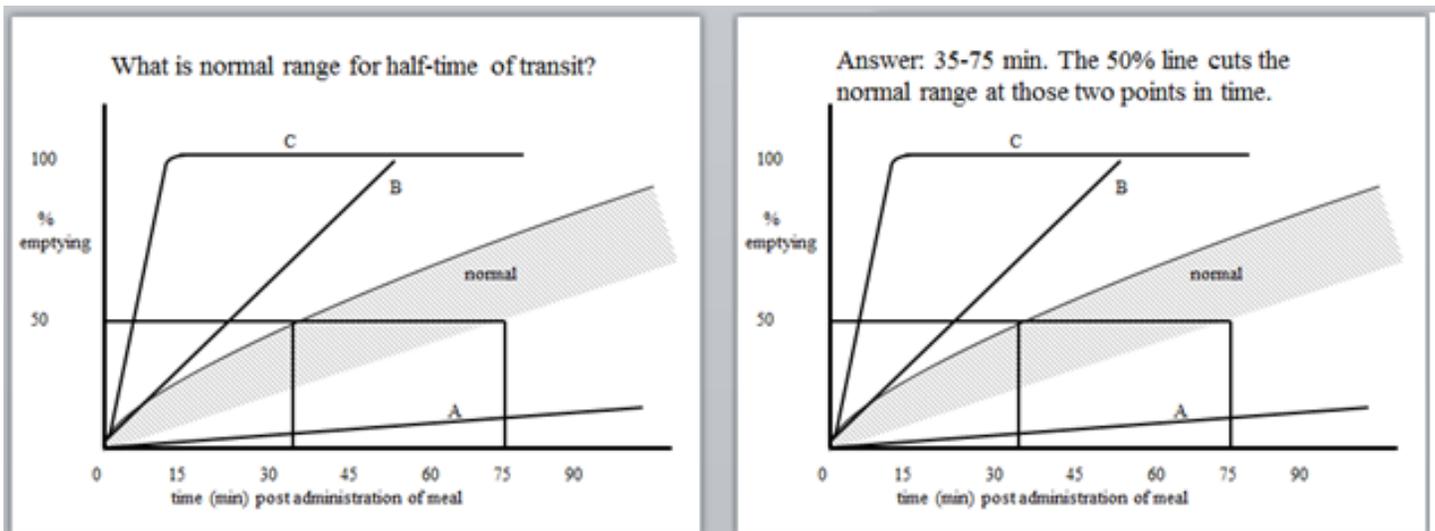
- Curve A represents a markedly decreased emptying rate compared to normal. This is the pattern observed in the case of gastric paresis.
- Curve B represents a gastric emptying rate significantly more rapid than normal.
- Curve C represents Dumping Syndrome, in which essentially complete gastric emptying has occurred within 10-15 following consumption of the meal.

7. NORMAL PARAMETERS OF A LIQUID PHASE GASTRIC EMPTYING STUDY

- a) In the diagram below note the increased slope of the normal range compared to that in the solid phase diagram. This is expected since liquid emptying is faster than solid emptying.



8. DETERMINATION OF THE HALF TIME OF TRANSIT FOR THE NORMAL



RANGE IN THE CURVE BELOW

9. TYPICAL ADMINISTERED DOSE OF Tc-OVALBUMIN FOR ADULTS

- a) The usual ORALLY administered activity for adult patients is 0.5-1.0 mCi,

10. PATIENT PREPARATION FOR BLOOD POOL IMAGING

**(adapted from “[Procedure Guideline for Adult Solid-Meal Gastric-Emptying Study 3.0]”
reprinted from <http://snmmi.files.cms-plus.com/docs/Guideline%20for%20Adult%20Gastric%20Emptying.pdf>, © SNMMI Inc.)**

- a) The patient should take nothing by mouth for a minimum of 4 h before initiation of the study. It is preferable for the patient to take nothing by mouth starting at midnight and then to be given the radiolabeled meal in the morning.
- b) The patient should be advised of the logistical demands of the procedure (e.g., the meal to be used, the time required for eating the meal [<10 min] and for imaging, the number of images required, and what the patient is allowed to do between images).
- c) Instructions for diabetic patients: a. Insulin-dependent diabetic patients should bring their glucose monitors and insulin with them. The serum glucose level at the time of meal ingestion should be recorded and included in the final report. b. Diabetic patients should have their diabetes under good control, with the blood sugar ideally less than 200 mg/dL. Diabetic patients should monitor their glucose level and adjust their morning dose of insulin as needed for the prescribed meal.
- d) Premenopausal women should ideally be studied on days 1–10 of their menstrual cycle, if possible, to avoid the effects of hormonal variation on gastrointestinal motility.
- e) Prokinetic agents such as metoclopramide, tegaserod, domperidone, and erythromycin are generally stopped 2 d before the test unless the test is done to assess the efficacy of these drugs.
- f) Medications that delay gastric emptying, such as opiates or antispasmodic agents, should generally also be stopped 2 d before testing. Some other medications that may have an effect on the rate of gastric emptying include atropine, nifedipine, progesterone, octreotide, theophylline, benzodiazepine, and phentolamine.

12. DRUG ADMINISTRATION PROCEDURE

- a) The meal is fed orally to the patient.

13. IMAGING PROTOCOLS

**(adapted from “[Procedure Guideline for Adult Solid-Meal Gastric-Emptying Study 3.0]”
reprinted from <http://snmmi.files.cms-plus.com/docs/Guideline%20for%20Adult%20Gastric%20Emptying.pdf>, © SNMMI Inc.)**

- a) The radiolabeled test meal should be ingested as quickly as possible, optimally within 10 min.
- b) The technologist should record how long it took the patient to ingest the meal and whether any portion of the meal was not eaten.
- c) The method should be standardized as to environmental conditions, such as ambient noise, lighting, or other factors affecting patient comfort.
- d) The reference values are based on this standard imaging methodology endorsed by the SNMMI and the American Neurogastroenterology and Motility Society.
- e) Images are obtained in a format of at least 64 x 64 pixels using a general-purpose collimator or a low energy high-resolution collimator. A 128 · 128 word mode image matrix is recommended. The photopeak settings are 20% at the 140-keV peak for ^{99m}Tc.
- f) Anterior and posterior planar images (or a single left anterior oblique image) with the distal esophagus, stomach, and proximal small bowel in the field of view should be obtained for 1 min immediately after ingestion of the meal.
- g) Repeated images are obtained in the same projection(s) for 1 min at hourly intervals up to 4 h on the same camera as was used for the initial images. If imaging shows that more than 10% of the tracer remains in the stomach at 1, 2, or 3 h, recent literature cites the need to obtain images for up to 4 h, suggesting that retention of more than 10% of the meal in the stomach at 4 h is abnormal and is also the best discriminator between normal and abnormal results. Anterior and posterior views allow calculation of a geometric mean (the geometric mean is the square root of the product of counts in the anterior and posterior regions of interest [ROIs]), which more consistently represents the amount of tracer in the ROI, independent of anterior–posterior movement between the fundus and antrum. The geometric mean is preferably calculated from anterior–posterior data obtained simultaneously with a dual-head g-camera; however, sequential anterior and posterior images from a single-head camera may also be used. Although some institutions acquire images in the left anterior oblique view with a single-head camera, this method is less reliable in compensating for attenuation than is the geometric mean method.
- h) Follow-up studies should always be done under the same conditions as the first study (e.g., same meal, collimator, and analysis program)

14. IMAGE PROCESSING

- a) An ROI is drawn around the activity in the entire stomach in anterior and posterior views (or the left anterior oblique view, if acquired). The ROI should include any visualized activity in the fundic (proximal) and antral (distal) regions of the stomach, with care to

adjust the ROI to avoid activity from adjacent small bowel, if possible. A marker placed on the patient in a fixed position such as the iliac crest may be helpful for ensuring reproducibility in gastric positioning and ROI placement.

- b) All data must be corrected for radioactive decay.
- c) The final measurement of gastric emptying is based on the percentage of gastric retention at specific times after meal ingestion (e.g., at 2, 3, and 4 h). A time– activity curve obtained from the geometric mean of gastric counts displayed for all time points may be helpful.

15. ADVERSE REACTIONS FOLLOWING ADMINISTRATION OF Tc-LABELED MEALS

- a) None known

16. INTERNAL RADIATION DOSIMETRY

The estimated radiation doses to an average adult (70 Kg) from non-absorbable solid meal labeled with Tc-99m is shown in Table 1 below.

TABLE 1
Radiation Dosimetry: Adults

Radiopharmaceutical	Administered activity		Upper large intestine (organ receiving the largest radiation dose)		Effective dose	
	MBq	mCi	mGy/MBq	rad/mCi	mSv/MBq	rem/mCi
Nonabsorbable solid labeled with ^{99m} Tc	18.5–37	0.5–1.0	0.11	0.41	0.024	0.089

Data are from *Radiation Dose to Patients from Radiopharmaceuticals*. London, U.K.: ICRP;1988:226. ICRP Publication 53.

17. INTERFERING MEDICATIONS

- a) Medications that delay gastric emptying, such as opiates or antispasmodic agents, should generally also be stopped 2 d before testing. Some other medications that may have an effect on the rate of gastric emptying include atropine, nifedipine, progesterone, octreotide, theophylline, benzodiazepine, and phentolamine.

- b) Drugs called prokinetic agents that speed up the motility of the GI tract. Some of these are metoclopramide (Reglan), erythromycin, tegaserod (Zelnorm), and domperidone (Motilium).
- c) Drugs called anticholinergic antispasmodic agents that slow down the motility of the GI tract. Some of these are Bentyl, Donnatal, Levsin, Robinul, and Hyosyne.
- d) Pain medicines called opiate analgesics. Some of these are codeine, demerol, Percocet (Oxycodone), Tylenol #3, Tylox, Oxycontin, Percodan, Fentanyl patch, Morphine, Methadone, Vicodin (Hydrocodone), and Ultram (Tramadol).
- e) Marijuana.
- f) No laxatives the day before or any time during the test.

18. POTENTIAL SOURCES OF ERROR

- a) Vomiting after meal ingestion
- b) Poor labeling
- c) A nonstandard meal
- d) A marked variation in the environment, such as noise, lighting, or temperature, during imaging
- e) Emotional fluctuations, such as fear of the medical environment, anxieties about results, anger after a long wait for the study to begin
- f) Nausea caused by a meal that may be unfamiliar to the patient
- g) A patient who has eaten just before the study
- h) Slow movement of the ingested meal from the mouth or esophagus into the stomach
- i) Gastroesophageal reflux
- j) Overlap of small-bowel activity with the stomach ROI
- k) A prolonged time for the patient to ingest the meal
- l) Lack of attenuation correction, particularly in obese patients
- m) Failure to recognize that the patient has not eaten the entire meal
- n) Lack of decay correction for the tracer used
- o) Failure of the patient to ingest the entire meal

19. Gastric emptying scans in children

- a) Gastroparesis symptoms in children are similar to those seen in adults.
- b) The test for older children is identical to the test given to adults. If the child is a baby or infant, your child will receive the radioactive food in milk or formula in an exam known as a milk study or liquid study. In this case, you may be instructed to bring your own formula or milk from home to make sure your child doesn't have an allergic reaction.
- c) The radioactive substance is as safe for a child as it is for an adult. The test usually takes about three hours for children. For a liquid meal study, the camera takes continuous images for about an hour.
- d) It's important that the child remain still throughout the test.