ACR–ACNM–SNMMI–SPR PRACTICE PARAMETER FOR THE PERFORMANCE OF GASTROINTESTINAL TRACT, HEPATIC, AND SPLENIC SCINTIGRAPHY

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question. The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner considering all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by variables such as the condition of the patient, limitations of available resources, or advances in knowledge or technology after publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document may consider documenting in the patient record information sufficient to explain the approach taken.

The practice of medicine involves the science, and the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The purpose of this document is to assist practitioners in achieving this objective.

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1 *Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the "ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures (Revised 2008)" sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.*

I. INTRODUCTION

This practice parameter was revised collaboratively by the American College of Radiology (ACR), the American College of Nuclear Medicine (ACNM), the Society of Nuclear Medicine and Molecular Imaging (SNMMI), and the Society for Pediatric Radiology (SPR).

This practice parameter is intended to guide physicians performing and interpreting gastrointestinal tract, hepatic, and splenic scintigraphy in adult and pediatric patients. Gastrointestinal scintigraphy involves the intravenous (IV), oral, transcatheter (to include enteric tubes), or intraperitoneal administration of a radiopharmaceutical that localizes in or transits the salivary glands, gastrointestinal tract, or peritoneal cavity. Hepatic and splenic scintigraphy involves IV administration of radiopharmaceuticals that localize in the reticuloendothelial system (RES) or blood pool of the liver and/or spleen. Imaging is performed with a gamma camera and may also include additional hybrid scintigraphic and anatomical imaging such as single-photon emission computed tomography (SPECT) with or without computed tomography (CT) imaging which assists with further localization of an abnormality [1]. As with all scintigraphic studies, correlation of findings with the results of other imaging and nonimaging procedures, as well as clinical information, is necessary to achieve maximum diagnostic yield.

Imaging of the hepatobiliary system is discussed separately in the ACR–ACNM–SNMMI–SPR Practice Parameter for the Performance of Hepatobiliary Scintigraphy [2]. Imaging of radiopharmaceuticals delivered via the hepatic artery in preparation for yttrium-90 (^{90}Y) radioembolization of primary and metastatic liver tumors is discussed separately in the ACR–ABS–ACNM–ARS–SIR–SNMMI Practice Parameter for Selective Internal Radiation Therapy (SIRT) or Radioembolization for Treatment of Liver Malignancies [3].

Application of this practice parameter should be in accordance with the ACR-ACNM-SNMMI-SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures [4].

II. INDICATIONS

Clinical indications are varied and include, but are not limited to, the following:

A. Gastrointestinal Tract

1. Salivary Gland
   a. Demonstration of salivary gland function and/or tumors
2. Gastrointestinal Transit
   a. Verification of suspected aspiration
   b. Evaluation and quantification of esophageal motility
   c. Evaluation of gastroesophageal and enterogastric reflux
   d. Evaluation and quantification of gastric emptying of solid and/or liquid meals
   e. Demonstration of intestinal transit
3. Gastrointestinal Bleeding
   a. Demonstration of the presence and site of acute gastrointestinal bleeding
   b. Detection of ectopic functioning gastric mucosa (eg, Meckel's diverticulum)
4. Peritoneum
   a. Assessment of peritoneovenous shunt patency
   b. Detection of congenital or acquired perforation of the diaphragm (pleuroperitoneal fistula)
   c. Detection of peritoneal loculations before intraperitoneal chemotherapy or radiopharmaceutical therapy

B. Liver and Spleen

1. Assessment of the size, shape, and position of the liver and/or spleen
2. Detection of hepatic or splenic hemangiomas
3. Characterization of focal hepatic lesions ,(eg, focal nodular hyperplasia)
4. Evaluation for residual or ectopic functioning splenic tissue and suspected functional asplenia
5. Detection of functioning hepatic tissue

For information on radiation risks to the fetus, see the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation [5].

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR-ACNM-SNMMI-SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures [4].

IV. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for gastrointestinal, hepatic, and splenic scintigraphy should provide sufficient information to demonstrate the medical necessity of the examination and allow for the proper performance and interpretation of the examination.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). The provision of additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state scope of practice requirements. (ACR Resolution 35 adopted in 2006 – revised in 2016, Resolution 12-b)

IV. SPECIFICATIONS OF THE EXAMINATION

A. Radiopharmaceuticals

Several radiopharmaceuticals are currently available. The radiopharmaceutical used should be chosen based on the clinical indications and circumstances. Administered activity for children should be based on body weight and should be as low as reasonably achievable (ALARA) for diagnostic image quality as outlined in the latest *Update of the North American Consensus Guidelines for Pediatric Administered Radiopharmaceutical Activities*. The latest Nuclear Regulatory Commission (NRC) Advisory Committee on the Medical Uses of Isotopes guidelines should be followed for breastfeeding patients. In the United States, technetium-99m (Tc-99m) sulfur colloid (SC) is the only FDA-approved agent for oral administration, and the additional radiopharmaceuticals mentioned below for oral administration may require specific radioactive licensing amendments [6].

1. Indium-111 (In-111) diethylenetriamine-penta-acetic acid (DTPA)
   Given orally, In-111 DTPA with an administered activity of 5.55–18.5 MBq (0.15–0.50 mCi), may be used to evaluate liquid gastric emptying when a concomitant solid meal labeled with Tc-99m SC is used. When In-111 DTPA is not available, a liquid study with 0.1 –1.15 mCi of Tc-99m SC followed by a solid study with 1.0 –1.5 mCi Tc-99m SC may be used as an alternative. The administration of Tc-99m SC at 1/10th or lower for the liquid gastric emptying study is unlikely to affect the interpretation of the solid gastric emptying study. For a liquid-only gastric examination, Tc-99m SC should be used instead of In-111 DTPA to reduce radiation exposure. Because of the longer half-life of In-111 DTPA (physical half-life: 67.3 hours), additional imaging of the abdomen is possible up to 72 hours for measurement of small-bowel or colon transit. The administered activity of In-111 DTPA in water for colon transit is 3.7–37 MBq (0.1–1.0 mCi) [7-9].

2. Tc-99m (Stannous; Sn) DTPA
   Given orally, Tc-99m DTPA may be used for liquid gastric emptying evaluation or for small-bowel transit when only a single liquid meal transit examination is performed. It shoud not be used simultaneously for a combined liquid- and solid-phase gastric emptying examination when a Tc-99m solid-phase radiopharmaceutical is also used. Tc-99m DTPA in water can also be used for esophageal transit time evaluation. The administered activity for Tc-99m DTPA is 18.5–37 MBq (0.5-1.0 mCi) for adults. The administered activity of the radiopharmaceutical and the volume to be fed to the pediatric patient should be based on factors such as age, body weight, and the usual feeding volume [10].

3. Tc-99m Macroaggregated Albumin (MAA)
   Given intraperitoneally, Tc-99m MAA is not absorbed and is used as a qualitative marker of the movement of ascitic fluid through peritoneovenous shunt devices or congenital/traumatic diaphragmatic fenestrations. The usual adult-administered activity is 18.5–185 MBq (0.5–5.0 mCi) in 3–5 mL of 0.9% saline [10].

4. Tc-99m Red Blood Cells (autologous RBCs)
   Autologous Tc-99m RBCs remain intravascular and are commonly used for detecting and localizing the source of an active gastrointestinal bleed. The usual adult IV-administered activity for gastrointestinal blood loss detection is 555–1,100 MBq (15-30 mCi) [11]. For pediatric patients, the recommended administered activity is
   11.8 MBq/kg (0.32 mCi/kg) with a minimum administered activity of 74 MBq (2.0 mCi) and a maximum administered activity of 740 MBq (20.0 mCi). The highest RBC-labeling efficiency is achieved with the in vitro method (>;97%) which is recommended and widely used [12]. See the ACR-ACNM-SNMMI-SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures for handling of radiolabeled cells [4].

The usual IV-administered activity of Tc-99m–labeled autologous RBCs for hepatic hemangioma evaluation ranges from 740–925 MBq (20–25 mCi).

5. Heat-damaged Tc-99m RBCs
   Autologous RBCs are radiolabeled, preferably by the in vitro method, with an activity of 37 to 222 MBq (1-6 mCi) for planar imaging or 555–1,110 MBq (15-20 mCi) for SPECT or SPECT/CT imaging and heated for 15 minutes in a preheated water bath between 49.0°C and 50.0°C. After cooling to at least body temperature, the heat-damaged RBCs are administered IV with imaging performed 20–30 minutes after injection. The heat-damaged RBCs will be preferentially sequestered by splenic tissue. See the ACR-ACNM-SNMMI-SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures [4] for handling of radiolabeled cells.

6. Tc-99m Sodium Pertechnetate
   During the first 1 or 2 minutes after IV administration, Tc-99m sodium pertechnetate may be used as a blood flow marker. Within minutes after injection, this radiopharmaceutical begins to concentrate normally in the salivary glands and in mucin-producing cells of the gastric mucosa making it suitable for evaluation of salivary gland function and for detection of ectopic gastric mucosa. The usual adult IV-administered activity is 296–444 MBq (8–12 mCi). For pediatric patients, 1.85 MBq/kg (0.05 mCi/kg) is recommended with a minimum administered activity of 9.25 MBq (0.25 mCi) and maximum administered activity of 296 MBq (8 mCi). Physiologic renal excretion results in visualization of the kidneys and bladder. Rapid absorption by the stomach and peritoneum makes Tc-99m sodium pertechnetate unsuitable for oral or intraperitoneal administration [12].

7. Tc-99m SC
   Tc-99m SC, when administered orally, is not absorbed and is an excellent radiopharmaceutical for imaging and quantification of swallowing and gastrointestinal motility and transit. A small volume (up to 1 mL) of Tc-99m SC containing no more than 18.5 MBq (0.5 mCi) can be used for imaging gastropharyngeal aspiration. In adults, 10–30 mL of water containing 3.7–11.1 MBq (0.1–0.3 mCi) of Tc-99m SC or Tc-99m DTPA can be given for esophageal transit studies [13]. For gastric emptying, an administered activity of 18.5–74 MBq (0.5-2 mCi) is generally used as a radiolabel for liquid and solid meals in adults. The affinity of this radiopharmaceutical for the protein matrix of egg whites facilitates the egg white labeling as the solid phase component of the meal [14]. The egg white is mixed with the radiopharmaceutical and preferrentially cooked over a hotplate to prevent splatter that can occur in a microwave for approximately 2 minutes, until the egg achieves a firm consistency. Ideally, the temperature of the egg is documented immediately after cooking (>145 degree F). For liquid gastric emptying in infants, Tc-99m SC labeled milk or milk-based formula is used in the child's typical feeding volume [15]. There is no weight-based dosage for children, but 9.25–37 MBq (0-0.25–1.0 mCi) can be used to label a liquid meal and 9.25–18.5 MBq (0.25–0.5 mCi) for a solid meal.

   When administered IV, Tc-99m SC is also used for functional imaging of the RES of the liver, spleen, and bone marrow. Tc-99m SC consists of particles composed of Tc-99m sulfide stabilized with gelatin. These particles range in size from 0.1–1.0 µm. Given IV, they are phagocytized by the RES cells of the liver, spleen, and bone marrow in proportion to relative blood flow, functional capacity of the phagocytic cells, and particle size. The maximum concentration in the liver and spleen occurs within 10–20 minutes, and the rate of biological clearance from the RES is very slow. The usual administered activity is 111–222 MBq (3–6 mCi) for planar imaging in adults and up to 370 MBq (10 mCi) for SPECT imaging.

   If administered intraperitoneally, Tc-99m SC is not absorbed and becomes a qualitative marker of movement of ascitic fluid through congenital or traumatic diaphragmatic fenestrations and peritoneovenous shunts. It can be used to assess free flow or loculation of ascitic fluid. The administered activity of 18.5 to 185 MBq (0.5-5.0 mCi) Tc-99m SC is used [10].

   Although less superior to Tc-99m RBCs (autologous), Tc-99m SC can also be used to identify a gastrointestinal bleed. This is only useful in very brisk bleeds as most of the radiotracer clears the blood stream in less than 10 minutes.

IV. SPECIFICATIONS OF THE EXAMINATION

B. Imaging and Patient Preparation

1. Salivary Gland Imaging

Salivary gland imaging may help in the differential diagnosis of salivary gland disorders and certain masses. A sialagogue, such as lemon juice, may be given to stimulate salivary gland clearance in cases of salivary duct obstruction or ligation, sialadenitis, or suspected Warthin's tumor. The collimator surface should be protected from contamination by using a plastic-backed pad or other similar material. The patient should lie supine in a Water's position in front of a gamma camera (chin and nose touching the collimator). During the IV administration of Tc-99m sodium pertechnetate, a 1-to-2-minute radionuclide angiogram of the face (3-5 seconds/frame) is followed by serial dynamic imaging for 20 to 30 minutes (2-3 minutes/frame). Additional planar views may also be obtained in the oblique and lateral projections as needed [16]. The position of palpable nodules should be identified using a radioactive source marker. Computer-generated regions of interest can be drawn over the salivary glands to produce time-activity curves to demonstrate the pattern of accumulation and clearance over time. Quantitative analysis can be applied to the time-activity curves [13, 17].

IV. SPECIFICATIONS OF THE EXAMINATION

B. Imaging and Patient Preparation

2. Gastrointestinal Transit

a. Aspiration (Gastric or Pharyngeal Contents)

These examinations are usually limited to pediatric patients or as a preoperative evaluation before lung transplantation. The patient should have nothing by mouth or by tube feeding before the study. The length of time that the patient should refrain from intake depends on age and clinical circumstances, but in most cases, 4 hours should be sufficient. The patient should be in the supine position, and images should include the mouth and stomach in the field of view (FOV). Radioactive source markers are placed for anatomic reference (eg, shoulder markers as reference of the relative location of the lungs). An alternative for pediatric patients is the administration of a radiolabeled liquid meal at bedtime with imaging performed the following morning [18].

i. Aspiration of pharyngeal contents
A small volume of activity of Tc-99m SC is placed on the dorsal surface of the posterior portion of the tongue or in the buccal fossa. Images are obtained in the posterior projection over the course of 30–60 minutes. Delayed images can also be acquired for up to 24 hours. Radioactivity detected in the bronchi or lungs confirms aspiration.

ii. Aspiration of gastric contents
An appropriate amount of Tc-99m SC is placed in a small amount of the normal meal and administered orally or by tubing (nasogastric, gastrostomy) depending on the clinical situation and in consultation with the referring provider. If the material is administered orally, once the feeding is completed, an additional nonradioactive liquid feeding is given to clear any remaining radioactivity from the esophagus. Images are obtained immediately after ingestion (baseline) and serially for 60 minutes thereafter. Additional planar imaging at 4 hours or 24 hours may be helpful. In infants and children, evaluation for aspiration of gastric contents is included as a routine component of nuclear gastric emptying and gastroesophageal reflux examinations. Radioactivity seen in the lungs confirms the diagnosis of aspiration. Imaging is terminated after radioactivity has cleared the stomach.

b. Esophageal Transit

Scintigraphy of esophageal transit may yield unique and useful physiologic information about esophageal motility in conditions that cause impaired transit of esophageal contents from the pharynx to the stomach (eg, scleroderma, stricture, achalasia) or following therapy for these conditions [19]. This can be a qualitative or quantitative, global or regional (dividing the esophagus into thirds), esophageal evaluation. The patient should have nothing by mouth or by tube feeding before the examination. The length of time that the patient should refrain from intake depends on the age and the clinical circumstances, but in most cases, 4 to 6 hours is sufficient. The study is typically done with the patient in the supine position, and data are collected in the anterior projection to include the entire esophagus and proximal stomach in the FOV. As with barium esophagography, the use of multiple (up to 6) swallows can increase the sensitivity of the examination in detecting an abnormal swallow. Tc-99m SC is administered in water or a semisolid as a bolus. The initial rapid bolus transit should be recorded in a dynamic mode of 0.25–0.5 seconds per frame up to 30 seconds [20] and reviewed using a cinematic (movie) display to evaluate the bolus transit. Additional data acquisition for up to 10 minutes is also helpful, during which time serial dry swallows are used to measure clearance from the esophagus and to look for possible gastroesophageal reflux. Comparison of at least one upright and one supine swallow can be helpful to differentiate disorders such as achalasia from scleroderma. Time-activity curves may be generated regionally for the proximal, middle, and distal portions of the esophagus, but visual inspection of the entire cine bolus transit is more important for differentiating the various primary esophageal motor disorders. Esophageal transit time is the time from initial bolus entry into the esophagus until clearance of 90% of peak activity [21]. The normal value for esophageal transit time is generally under 14 seconds [13], although each facility should validate its own normal range for its specific technique or closely follow a validated technique and normal range from the literature. No significant activity should be in the esophagus after 10 minutes [20, 21].

c. Gastroesophageal Reflux

Scintigraphy for gastroesophageal reflux may yield unique and useful physiologic information when history, signs, or symptoms suggest possible incompetence of the gastroesophageal sphincter associated with acute or chronic reflux of gastric contents into the esophagus [19]. Observation of gastroesophageal reflux during an esophageal transit examination can also suggest the cause of reflux esophagitis. In infants and children, a gastroesophageal reflux examination (also called "milk scan") is often combined with a liquid gastric emptying examination. The patient should have nothing by mouth or by tube feeding before the examination. The length of fasting depends on age and the clinical circumstances, but in most cases, 4–6 hours is sufficient. A liquid consisting of formula, milk, or orange juice containing an appropriate amount of Tc-99m SC is administered orally or by tubing (nasogastric, gastrostomy). When the liquid is introduced via an orogastric or nasogastric tube, the tube should be removed before image acquisition, if possible. The patient is then positioned supine in a left anterior oblique position beneath the gamma camera, and dynamic images (5-10 seconds per frame) of the esophagus and stomach are obtained for 60 minutes [22]. Further delayed images can also be obtained for gastric emptying and evaluation of aspiration. It is often appropriate to image small children in a supine position with the gamma camera under the imaging table. In adults, a Valsalva maneuver or an abdominal binder may be of benefit. The use of an abdominal binder is contraindicated in children. The number of recorded reflux events detected during the recording session should include the duration and the proximal extent of reflux. Gastroesophageal reflux greater than 4% is considered abnormal. This is determined by dividing the maximum counts in the esophagus by total counts in the stomach and esophagus [13]. The examination may be repeated to assess the effectiveness of medical therapy.

d. Gastric Emptying

The evaluation of gastric motility using a radiolabeled solid meal or liquid provides functional information that is indispensable in the management of patients presenting with various upper gastrointestinal signs and symptoms [23]. The current standard of care is for a patient to have both a solid and a liquid gastric emptying study. However, there are cases in which a liquid- or solid-only study may be performed. The liquid phase is preferred in infants and in neurologically impaired children Liquid phase studies are also commonly used in patients on tube feeds and in adults in combination with solid phase gastric emptying studies. When the standard solid meal cannot be used secondary to dietary intolerance, liquid meals may also be used. In addition, liquids may detect abnormal gastric emptying when solid gastric emptying scintigraphy is normal. Solid phase studies using a standardized radiolabeled meal are commonly used in patients with postprandial symptoms of rapid or delayed gastric emptying (eg, nausea/vomiting, early satiety, heartburn, bloating, etc). In preparation for these studies, the patient should have nothing by mouth or by tube feeding at least 4 to 6 hours before the examination. This is most conveniently done by starting the study in the morning with instructions to take nothing by mouth after midnight. If necessary, sips of water can be taken with medications. At the time of the study, the glucose level should be below 200 mg/dL because hyperglycemia can delay gastric emptying. Patients with insulin-dependent diabetes should monitor their glucose level before the start of the examination and adjust their insulin dose as needed. As a general rule, half of the usual insulin dose may be administered with the intake of the radiolabeled meal. It is optional to monitor the glucose levels during the examination. On the other hand, fasting can lead to hypoglycemia. Precautions are necessary if patients develop symptoms, as they may need treatment, and the examination should not be performed under these conditions. Prokinetics and other medications that alter gastric emptying must be discontinued 2 days before the examination [24]. It is a good general practice to cover the camera detectors with protective wrap to prevent contamination. After a solid meal or liquid is ingested, a large FOV camera is used to obtain anterior and posterior images that include the distal esophagus, entire stomach, and proximal small bowel. A region of interest is drawn around the stomach (anterior and posterior), and the counts are decay-corrected. The geometric mean of counts is calculated. The gastric emptying time-activity curve, gastric retention, and half-time of gastric emptying and/or percent of emptying are provided. Posterior projecting imaging only may be sufficient in children . [25-27].

The percentage remaining at each time point is compared with established normal ranges. Details on consensus guidelines (which ACR also supports) can be found in the appendix and is entitled: Consensus Recommendations for Gastric Emptying Scintigraphy: a Joint Report of the American Neurogastroenterology and Motility Society and the Society of Nuclear Medicine [28]. Normal values reported in the literature elsewhere may also be used as a guide [26, 27]. Note that standardized meals, imaging protocols, and reference values are not well-established for the pediatric population, and there are no age-related normal values for children [29]. In addition, there are no established normal references for patients after gastric surgeries/procedures due to the altered anatomy and innervation of the stomach.

i. Solid-phase meal gastric emptying in adults and children
The standardized solid radiolabeled meal consists of Tc-99m SC mixed and cooked in 120 g of scrambled liquid egg whites, which is ingested along with 2 slices of white toast with 30 g of strawberry jelly and 120 mL of water (Tougas meal) [30]. It is preferred for the eggs to be cooked over a hotplate to prevent splatter that can occur in a microwave. Solid phase meal administration and ingestion should occur within 10 minutes in an effort to start imaging during the stomach's lag phase, which occurs before emptying into the duodenum (15-30 minutes). Static 1- to 5-minute images are acquired over 4 hours (time 0 and at 1, 2, 3, and 4 hours) with the patient in an upright or supine position. A dual-head gamma camera can be used to obtain simultaneous anterior and posterior projections [14, 24]. . Other alternative meals may be used in patients with egg allergy, egg intolerance, or gluten hypersensitivity. Oatmeal and liquid nutrient supplements such as Ensure Plus (Abbott Laboratories) may be used in these circumstances [31, 32]. Their respective normal references should be used. A solid gastric emptying study may not be suitable for young children. However, it is a valid option in older patients, particularly adolescents, and normal adult references may be used [27, 31, 32].

ii. Liquid-phase gastric emptying in adults and children
The liquid-phase study can be performed on a separate day and immediately before or concurrently with a solid-phase study. Tc-99m SC (alternatively, Tc-99m DTPA or In-111 DTPA) is mixed with an appropriate volume of a liquid carrier and introduced into the stomach by swallowing or tubing (nasogastric, orogastric, or gastric depending on the clinical situation) and in consultation with the referring clinician. In adults, the liquid meal typically consists of the radiopharmaceutical mixed in 200300 mL of water. Imaging with a single-head gamma camera in the left anterior oblique or

anterior-only projection is performed over the course of 30–60 minutes dynamically minutes (30 second frames). If obtained as a dual-phase study (eg, liquid and solid simultaneously), the geometric mean should also be calculated for the liquid study that is obtained in anterior/posterior projections [24]. For a liquid-only study, the activity distributes quickly throughout the stomach; therefore, imaging in a single left anterior oblique or anterior-only projection is usually adequate. In adult patients, the liquid usually exits from the stomach rapidly in a monoexponential fashion. For normal values, details can be found in a 2008 publication by Ziessman et al [25]. The patient should be positioned upright or semirecumbent in front of the camera and imaging started as the liquid is being ingested. In children, imaging is usually performed during the first hour, and the percentage of emptying is obtained at 60 minutes (or later, if indicated).

iii. Liquid-phase gastric emptying in infants

Liquid-phase gastric emptying may be combined with the evaluation of esophageal motility, gastroesophageal reflux, and aspiration. The radiopharmaceutical esophagram may be performed initially or following the completion of the gastric emptying portion of the examination. For the esophagram, the patient is placed in the supine position with the gamma camera posteriorly positioned. Dynamic images of the esophagus at 5 seconds per frame for 2–3 minutes are obtained for evaluation of esophageal motility, reflux, and signs of aspiration in the lungs. If the patient is normally fed by mouth, this may be accomplished as the initial part of the gastric emptying procedure that is then followed by continuous imaging of the chest and abdomen for 60 minutes for evaluation of the presence and severity of gastroesophageal reflux. Gastric emptying at 60 minutes and at 2 or 3 hours after completion of feeding is calculated. An additional delayed posterior image of the chest at the same time point can be acquired to detect delayed aspiration of the radiolabeled liquid. If the patient is not orally fed, the esophagram can be performed at the end of the gastric emptying examination using a small volume of radiolabeled sterile water or saline.

iv. Combined liquid- and solid-phase gastric emptying (liquid-solid or dual-phase gastric emptying)

For this purpose, In-111 DTPA should be used for the liquid and Tc-99m SC for the solid portion, which are ingested at the same time [18, 33]. On anterior and posterior imaging, both In-111 and Tc-99m gamma emission are acquired simultaneously [18, 33]. When In-111 DTPA is not available, a liquid study with Tc-99m SC followed by a solid study with Tc-99m SC may be performed as an alternative.

e. Intestinal Transit (Small and/or Large Bowel)

Although small- and/or large-bowel transit can be performed separately or in conjunction with gastric emptying scintigraphy, they are most commonly combined with a radiolabeled solid-liquid gastric emptying examination. Medications that may affect transit should be discontinued before the examination. No change in diet is necessary. These scans are not commonly performed in pediatric patients. The imaging FOV should include the entire area of interest if possible.

i. Small-bowel transit

This study is performed to evaluate for possible dysmotility of the small bowel. Tc-99m SC or Tc-99m DTPA in water can be used for a single-isotope study. Imaging occurs over 6 hours and is considered normal if more than 40%-50% of the radiolabeled liquid has progressed into the terminal ileum reservoir and/or progressed beyond the terminal ileum into the cecum and colon [21, 34].

ii. Large-bowel transit

This study is most commonly used for the evaluation of constipation or for the effectiveness of prokinetic medications. In-111 DTPA is the preferred radiopharmaceutical for this purpose. Images may be acquired at 6, 24, 48, and 72 hours. At each time point, anterior and posterior abdominal images are obtained for 4 minutes. The geometric center technique is the most widely used to determine regional transit through the colon. The colon is divided into either 5 or 7 segments, and each is given a numeric value. A geometric center, as a weighted average of the counts in each of these segments, is determined to determine the progression of the radioactivity in the colon. Higher values indicate activity is mostly in the left colon, and lower values indicate activity is closer to the cecum. Refer to published technique details and normal reference values [9, 35][8, 21].

iii. Whole-gut transit

An advantage provided by this technique includes the ability to measure solid/liquid gastric emptying in addition to measurement of small-bowel and colon transit resulting in evaluation of the entire gut [8]. A Tc-99m SC–labeled solid meal is given with an In-111 DTPA-labeled liquid meal (water). Gastric emptying and small-bowel transit imaging occurs on day 1, and large-bowel transit typically occurs at 6, 24, 48, and 72 hours. The longer half-life of In-111 DTPA allows for transit evaluation through the colon [21, 34, 36].

IV. SPECIFICATIONS OF THE EXAMINATION

B. Imaging and Patient Preparation

3. Gastrointestinal Bleeding

a. Acute Gastrointestinal Bleeding

Diagnosis and localization of a bleeding site requires active bleeding and imaging while the radiopharmaceutical is in the blood pool. Although this procedure is generally used for gastrointestinal bleeding, it can be useful for other sites of active bleeding. The use of Tc-99m RBCs (autologous) is the recommended method because they remain intravascular and permit a longer imaging time. The clinical detection rate for a gastrointestinal bleed with Tc-99m RBCs can be as low as 0.1 mL/min in clinical studies - 0.04 mL/min in experimental animal models [[11, 25]. 99m SC is an alternative radiopharmaceutical but is less superior to Tc-99m RBCs for this purpose, and if used, imaging is usually performed for 20–30 minutes because of the rapid clearance of SC from the intravascular space. No patient preparation is required. The patient should void immediately before imaging. The radiolabeled cells are injected IV and dynamic imaging of the anterior abdomen is then performed to first include a blood flow/angiographic phase (rate of 1 frame per 1-3 seconds for 60 seconds) and then for another 60–120 minutes (preferably 1 frame per 10-20 seconds) [11, 37]. Oblique, lateral, or delayed static abdominal images may be obtained to supplement the basic examination. If the examination is negative, continued imaging is appropriate for up to 24 hours. SPECT/CT, although not routinely performed, can be of value to more definitively localize the site of bleeding. If gastric activity is noted, further static images of the head and neck can be acquired to assess for possible thyroid and salivary gland uptake to help differentiate between gastric bleeding and the presence of free pertechnetate[38].

b. Ectopic Gastric Mucosa (Meckel's Scan)

Pharmacologic enhancement before radiopharmaceutical administration with H2 blockers (cimetidine, famotidine, or ranitidine) or proton pump inhibitors (omeprazole) to enhance free pertechnetate retention and/or glucagon to decrease gastrointestinal peristalsis can be used. Although not required, the patient should fast for 3 to 4 hours before imaging to increase sensitivity for the detection of ectopic gastric mucosa. The radiopharmaceutical Tc-99m pertechnetate is given IV, and then dynamic imaging of the abdomen is performed. A rapid sequence of images (blood flow/angiographic phase) taken at 1–3 seconds per frame over 60 seconds is obtained in the anterior projection to evaluate the presence of hypervascular abdominal lesions that could be mistaken for ectopic gastric mucosa. Subsequent imaging for 30–60 minutes is then acquired as serial static views or continuous dynamic imaging (30–60 seconds per image). Continuous dynamic imaging is preferred to better visually discriminate normal physiologic activity (such as renal activity) from ectopic gastric mucosa. A lateral view can be useful to distinguish renal activity and identify retrovesical ectopic gastric mucosa. Additional SPECT/CT imaging may help localization. Prone or right anterior oblique positioning can be used to delay gastric emptying into the small bowel if the patient has not been pretreated with H2 blockers. In patients who cannot void, a urinary catheter with or without the administration of 1 mg/kg of IV furosemide may be needed to help clear activity from the ureters and bladder [37, 39]. A false-negative scan occurs when there is a small amount or no ectopic gastric mucosa within the Meckel diverticulum, impaired vascular supply, localized bowel irritation with rapid washout of Tc-99m pertechnetate, which can also occur with active bleeding, previous imaging with barium, and poor patient positioning [39].

IV. SPECIFICATIONS OF THE EXAMINATION

B. Imaging and Patient Preparation

4. Peritoneal Fluid Imaging

No specific pre-procedure patient preparation is required. A local anesthetic may be administered before injection of the radiopharmaceutical.

a. Evaluation of patency of peritoneovenous shunt

Tc-99m SC or Tc-99m MAA is directly administered into the peritoneal cavity using an aseptic technique. An immediate image of the abdomen may be helpful to determine whether the radiopharmaceutical is free in the peritoneum and not loculated. The patient may need to roll from side to side to mix the radioactivity within the ascites. In addition, normal saline (50-200 mL) can be infused intraperitoneally to facilitate distribution. Static anterior images are typically acquired at 10, 30, 60, and 120 minutes. If the shunt is functioning correctly, activity will eventually appear in the liver and spleen (with Tc-99m SC) or lungs (with Tc-99m MAA) over 1 to 2 hours. Activity in the shunt tubing may or may not be visualized [10, 40].

b. Detection of congenital fenestrations or traumatic perforations of the diaphragm

Tc-99m SC or Tc-99m MAA is administered intraperitoneally. The radiopharmaceutical can also be instilled with up to 500 mL of sterile normal saline to facilitate the movement of the radiopharmaceutical into the pleural cavity. If activity appears in the pleural space, the diagnosis of fenestrated or perforated diaphragm is confirmed [41-43].

c. Demonstration of peritoneal loculation of fluid

Tc-99m SC or Tc-99m MAA is administered intraperitoneally. Immediate and delayed static images over the abdomen will reveal the pattern of distribution of the radiopharmaceutical in the peritoneal cavity.

IV. SPECIFICATIONS OF THE EXAMINATION

C. Liver and Spleen Imaging

1. Assess the size, shape, and/or position of the liver and/or spleen

Tc-99m SC can be used to identify the size and location of functional hepatic and splenic tissue. Approximately 10 to 20 minutes after IV administration of Tc-99m SC, static planar images of the liver and spleen are obtained. Anterior, posterior, right anterior oblique (RAO), left anterior oblique (LAO), right posterior oblique (RPO), and right lateral images should be acquired. Additional views (left posterior oblique and left lateral) may be indicated for more comprehensive evaluation of the spleen. Another anterior image may also be acquired with a lead marker of known length to help determine organ sizes. SPECT/CT will better localize any focal abnormality seen on planar imaging. The normal distribution of Tc-99m SC in the RES is approximately 85% to the liver, 10% to the spleen, and 5% to the bone marrow. A shift away from the normal biodistribution can be seen in severe liver dysfunction and is termed "colloid shift" in which there is greater splenic and marrow uptake [44].

2. Hepatic or splenic hemangiomas or venous malformations

Hepatic or splenic hemangiomas are conspicuous with Tc-99m RBC imaging because of their relatively greater blood volume than that of the surrounding parenchyma. They are typically identified when the radiolabeled RBCs reach equilibrium within the intravascular space of the hemangioma, which may take between 30 and 120 minutes postinjection or longer (may require up to 24 hours or more for larger hemangiomas [10]). Following IV administration of Tc-99m RBCs (autologous), immediate angiographic images (1-2 seconds/frame for 60 seconds) may yield useful information on the vascularity of particular lesions. Hemangiomas show typical low flow in the arterial phase with late "filling in" on delayed images. This is followed by blood pool imaging (eg, delayed imaging). SPECT or SPECT/CT imaging is particularly helpful in identifying lesions smaller than 3 cm.

Depending upon whether there are functioning or nonfunctioning Kupffer cells, the uptake pattern with Tc-99m SC can help differentiate between different types of mass lesions in the spleen and liver. Types of photopenic lesions include infarcts, cysts, hepatic adenoma, etc. FNH typically exhibits similar or increased uptake relative to the liver background [13, 45]. However, up to 30% FNH will be photopenic on a liver scan. SPECT/CT imaging is highly recommended for improved lesion detection and characterization.

3. Evaluating for residual or ectopic functioning splenic tissue and suspected functional asplenia

   Autologous heat-damaged Tc-99m RBCs are administered IV (preparation technique in Welch et al [46]). Imaging of the abdomen may commence 30 to 120 minutes later. Planar and SPECT or SPECT/CT imaging parameters are similar to those for liver and spleen imaging. If the test is being performed to identify residual or ectopic splenic tissue, the abdomen and pelvis should be imaged. If the patient has had prior trauma that might have ruptured the diaphragm, the chest should be imaged as well. Alternatively, Tc-99m SC can be utilized instead, but it is less sensitive and specific [10, 47-49].

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [50].

As with all nuclear medicine studies, the physician's report should include the radiopharmaceutical, the administered activity, and the route of administration. Any other administered pharmaceuticals or food/liquid, including dose/amount and route of administration should be recorded. For gastric emptying studies, parameters around meal composition, amount ingested, ingestion time, and confounding medications should be mentioned. Any alterations to standard protocols can also be reported, with clinical reasoning included.

VI. EQUIPMENT SPECIFICATIONS

Equipment performance monitoring should be in accordance with the ACR–AAPM Technical Standard for Nuclear Medical Physics Performance Monitoring of Gamma Cameras [51].

A gamma camera with a low-energy all purpose or high-resolution collimator is used for Tc-99m–labeled radiopharmaceuticals. A medium-energy collimator is needed for In-111 and Ga-67. SPECT or SPECT/CT may also be useful in select cases.

VII. RADIATION SAFETY

Radiologists, medical physicists, non-physician radiology providers**,** radiologic technologists, and all supervising physicians have a responsibility for safety in the workplace by keeping radiation exposure to staff, and to society as a whole, "as low as reasonably achievable" (ALARA) and to assure that radiation doses to individual patients are appropriate, taking into account the possible risk from radiation exposure and the diagnostic image quality necessary to achieve the clinical objective. All personnel who work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection, application of dose constraints and limits) and the principles of proper management of radiation dose to patients (justification, optimization including the use of dose reference levels). https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1775_web.pdf

Facilities and their responsible staff should consult with the radiation safety officer to ensure that there are policies and procedures for the safe handling and administration of radiopharmaceuticals in accordance with ALARA principles. These policies and procedures must comply with all applicable radiation safety regulations and conditions of licensure imposed by the Nuclear Regulatory Commission (NRC) and by applicable state, local, or other relevant regulatory agencies and accrediting bodies, as appropriate. Quantities of radiopharmaceuticals should be tailored to the individual patient by prescription or protocol, using body habitus or other customized method when such guidance is available.

Nationally developed guidelines, such as the ACR's Appropriateness Criteria®, should be used to help choose the most appropriate imaging procedures to prevent unnecessary radiation exposure.

Additional information regarding patient radiation safety in imaging is available from the following websites – Image Gently® for children (www.imagegently.org) and Image Wisely® for adults (www.imagewisely.org). These advocacy and awareness campaigns provide free educational materials for all stakeholders involved in imaging (patients, technologists, referring providers, medical physicists, and radiologists).

Radiation exposures or other dose indices should be periodically measured by a Qualified Medical Physicist in accordance with the applicable ACR Technical Standards. Monitoring or regular review of dose indices from patient imaging should be performed by comparing the facility's dose information with national benchmarks, such as the ACR Dose Index Registry and relevant publications relying on its data, applicable ACR Practice Parameters, NCRP Report No. 172, Reference Levels and Achievable Doses in Medical and Dental Imaging: Recommendations for the United States or the Conference of Radiation Control Program Director's National Evaluation of X-ray Trends; 2006, 2009, amended 2013, revised 2023 (Res. 2d).

VIII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR policy on Quality Control Improvement, Safety, Infection Control, and Patient Education appearing under the heading *ACR Position Statement on Quality Control and Improvement, Safety, Infection Control and Patient Education* on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

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