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SNMMI and EANM Practice Guideline for Meckel Diverticulum Scintigraphy 2.0

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PREAMBLE

The Society of Nuclear Medicine and Molecular Imaging (SNMMI) is an international scientific and professional organization founded in 1954 to promote the science, technology, and practical application of nuclear medicine. Its 18,000 members are physicians, technologists, and scientists specializing in the research and practice of nuclear medicine. In addition to publishing journals, newsletters, and books, the SNMMI also sponsors international meetings and workshops designed to increase the competencies of nuclear medicine practitioners and to promote new advances in the science of nuclear medicine. The European Association of Nuclear Medicine (EANM) is a professional nonprofit medical association that facilitates communication worldwide between individuals pursuing clinical and research excellence in nuclear medicine. The EANM was founded in 1985.

The SNMMI/EANM will periodically define new guidelines for nuclear medicine practice to help advance the science of nuclear medicine and to improve the quality of service to patients. Existing practice guidelines will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each practice guideline, representing a policy statement by the SNMMI/EANM, has undergone a thorough consensus process in which it has been subjected to extensive review. The SNMMI/EANM recognizes that the safe and effective use of diagnostic nuclear medicine imaging requires specific training, skills, and techniques, as described in each document.

The EANM and SNMMI have written and approved these guidelines to promote the use of nuclear medicine procedures with high quality. These guidelines are intended to assist practitioners in providing appropriate nuclear medicine care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the SNMMI/EANM cautions against the use of these guidelines 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 medical professionals taking into account the unique circumstances of each case. Thus, there is no implication that an approach differing from the guidelines, standing alone, is below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of the guidelines.

The practice of medicine involves not only the science but also 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 these guidelines will not ensure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable

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course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these guidelines is to assist practitioners in achieving this objective.

I. INTRODUCTION

Gastrointestinal bleeding is common in children and is often self-limited and benign; however, bleeding may have severe consequences if left untreated and should therefore be investigated (*1*). A complete history and physical examination can usually identify a presumptive bleeding source in children and facilitate the diagnosis and treatment (*1*). A guaiac test should be performed for stool content, which may become black after ingestion of iron, grape juice, spinach, and blueberries. A positive test result does not always indicate the presence of human blood because many foods, such as undercooked meat, raw fruits, and vegetables, can cause occult blood testing to be false-positive, especially in stool (*1*).

The clinical presentation in children with gastrointestinal bleeding ranges from asymptomatic microcytic anemia to hypovolemic shock, depending on the rate and extent of bleeding, but often clinical findings for gastrointestinal bleeding are unreliable and obscure (*1*). Acute upper gastrointestinal bleeding usually presents with hematemesis (vomiting of gross blood or coffee-ground material) or melena, which can be dark maroon, or production of tarry stools that contain digested blood. Occasionally, hematochezia can occur even if the source of bleeding is proximal to the ligament of Treitz—in the case of rapid transit of blood through the digestive tract. Bright red blood per rectum more commonly signifies bleeding distal to the ligament of Treitz (*1*).

Once the signs or symptoms of gastrointestinal bleeding in children are recognized or suspected, careful evaluation of each child is imperative. This must also include assessment of the cardiorespiratory system, along with other diagnostic studies that can be useful for determining the cause of bleeding. The primary cause of gastrointestinal bleeding varies with age, whereas the rate and extent of bleeding vary with cause (*2*).

Meckel diverticulum is the most common cause of lower gastrointestinal hemorrhage in previously healthy infants. More than 50% of these patients present with bleeding by the age of 2 y (*3*).

Meckel diverticulum is the vestigial remnant of the omphalomesenteric duct and represents the most common congenital anomaly of the gastrointestinal tract, with an incidence of 1%–3% in the general population (*3*). It is normally located on the antimesenteric border of the terminal ileum within 80–100 cm of the ileocecal valve and is on average 2 cm in length.

Approximately 57% of Meckel diverticula contain ectopic gastric mucosa (*4*), which actively secretes the hydrochloric acid responsible for mucosal ulcerations within the diverticulum and unprotected wall of the adjacent ileum (*4–6*). The most common sign of Meckel diverticulum is gross rectal bleeding, which may or may not be associated with abdominal symptoms. Almost all diverticula of children with symptoms of lower gastrointestinal bleeding contain ectopic gastric mucosa (*7*).

^{99m}Tc-pertechnetate is taken up by the mucin-producing cells of gastric mucosa and is then secreted into the gut lumen. The excretion of ^{99m}Tc-pertechnetate is not dependent on the presence of parietal (acid-producing) cells (*8–10*). Avid accumulation of ^{99m}Tc-pertechnetate in gastric mucosa makes scintigraphy with ^{99m}Tc-pertechnetate the study of choice for identifying ectopic gastric mucosa in a Meckel diverticulum. Properly performed ^{99m}Tc-pertechnetate scintigraphy in the appropriate clinical setting is an effective method for the detection of Meckel diverticulum containing functioning gastric mucosa, with overall sensitivity of 85%, specificity of 95%, and accuracy of 90% (*5*).

II. GOALS

The purpose of this guideline is to provide basic information to assist the nuclear medicine technologist and physician in understanding, recommending, performing, interpreting, and reporting the results of Meckel diverticulum (ectopic gastric mucosa) scintigraphy, which may identify the site and etiology of gastrointestinal bleeding.

III. DEFINITIONS

See the SNMMI Guideline for General Imaging.

IV. COMMON CLINICAL INDICATIONS

The indication for Meckel scintigraphy is to localize ectopic gastric mucosa in a Meckel diverticulum as the source of unexplained gastrointestinal bleeding. Bleeding Meckel diverticula usually occur in young children.

Meckel scintigraphy should be used when the patient is not actively bleeding. Even in young children, active bleeding is best studied by radiolabeled red blood cell (RBC) scintigraphy (*2*).

V. QUALIFICATIONS AND RESPONSIBILITES OF PERSONNEL (IN THE UNITED STATES)

See the SNMMI Guideline for General Imaging.

VI. PROCEDURE/SPECIFICATIONS OF THE EXAMINATION

See also the SNMMI Guideline for General Imaging.

A. Patient preparation

Preexamination fasting of 3–4 h may reduce the size of the gastric silhouette and improve sensitivity for the detection of ectopic gastric mucosa (*1*). However, fasting is not required for the examination and may not always be possible. The use of all drugs or procedures that may irritate the gastrointestinal tract should be stopped for 2–3 d before the study if possible.

It is important to determine whether the patient has undergone recent in vivo RBC labeling in which all circulating RBCs were treated with stannous ion via intravenous administration of a cold pyrophosphate kit. If so, the Meckel scan may be compromised, since intravenous ^{99m}Tc-pertechnetate will label RBCs rather than concentrate in ectopic gastric mucosa. This may occur for days after the administration of stannous

pyrophosphate and is not a problem with in vitro labeling. Recent administration of perchlorate may reduce the sensitivity of the test by decreasing uptake of ^{99m}Tc-pertechnetate in normal and ectopic gastric mucosa. Pretreatment options include the following:

1. Histamine H_2 blockers

Histamine H_2 blockers (cimetidine, ranitidine, famotidine) inhibit acid secretion by the parietal cells, thus limiting release of ^{99m}Tc-pertechnetate by the mucosal cells (*11–13*) and improving the sensitivity of the Meckel scan (*3,4*). (Dose recommendations are provided in Appendix A.)

2. Proton pump inhibitors

Proton pump inhibitors are used in the pediatric population to control acid secretion, and they may be more practical than H_2-antagonists even for short-term use (*14*).

3. Glucagon

Glucagon relaxes the smooth muscles of the gastrointestinal tract, slightly suppressing peristalsis and transit of any secreted ^{99m}Tc-pertechnetate through the small bowel. This movement of tracer may decrease the sensitivity of the study and the localization of ectopic gastric mucosa (*4–6,9,15*).

Glucagon should not be administered to diabetic patients. (Dose recommendations are provided in Appendix A.)

Pharmacologic pretreatment is not considered necessary for a high-quality Meckel scan. Any medication administered to children should be scaled according to weight and route of administration (Appendix A).

B. Information pertinent to performing the procedure

Are there signs of active bleeding? (If so, a gastrointestinal bleeding scan may be more helpful than a Meckel scan.) Is there a history of past bleeding episodes? What are the results of prior studies to localize the bleeding site? Has in vivo RBC labeling recently been done? Previous in vivo–labeled RBC scintigraphy with ^{99m}Tc-pertechnetate and stannous pyrophosphate may give an indeterminate result.

C. Precautions

The vital signs of children suspected of having acute gastrointestinal bleeding should be constantly monitored on their arrival at the nuclear medicine clinic. The patient should have a large-bore intravenous catheter in place (if necessary), so that hypotension can be rapidly treated.

D. Radiopharmaceuticals

See also the SNMMI Guideline for the Use of Radiopharmaceuticals.

^{99m}Tc-pertechnetate is eluted from a molybdenum–technetium parent–daughter generator with physiologic saline and injected intravenously. The administered activity should be calculated according to the recommendation of the 2012 North American consensus guidelines for pediatric radiopharmaceutical administered doses (*16*), the new EANM pediatric dosage card (*17*), and European Union directive 97/43/EURATOM: The European Directive on Health Protection of Individuals against the Dangers of Ionising Radiation in Relation to Medical Exposures (*18*).

Administered doses should be in the context of good practice of nuclear medicine and local regulations. The recommended administered activity for children from the 2010 North American consensus guidelines (*16*) is 1.85 MBq/kg (0.05 mCi/kg), with a minimum of 9.25 MBq (0.25 mCi). The EANM pediatric dose card (2007 version) (*17*) may also be used. A harmonization of the North American and European pediatric dosages is under way and will be published in 2014 (*19*). The usual administered activity for adults in the United States is 296–444 MBq (8–12 mCi) intravenously.

E. Image acquisition

1. Equipment

Images are acquired on a large-field-of-view camera, using a low-energy, high-resolution parallel collimator. The photopeak has a 20% window centered on 140 keV. The computer is used in planar mode, with a 128×128 matrix, 1- or 2-byte mode, and a zoom appropriate for patient size. SPECT is performed using 3° per step, 30 s per frame, a 360° rotation, a 64×64 or 128×128 matrix, and a zoom appropriate for patient size.

2. Acquisition protocol

The patient is positioned supine, and the imaging field is the abdomen and pelvis (to include stomach and bladder). In infants and small children (up to 2 y of age), the thorax should be included in the field of view, to assess for possible bronchopulmonary foregut malformation with ectopic mucosa.

Anterior abdominal dynamic flow images (1–5 s/frame for up to 1 min) are obtained to identify any focus of vascular blood pool that may be confused with ectopic gastric mucosa.

Anterior abdominal dynamic images are obtained at a frame rate of 1 image every 30–60 s for at least 30 min. Imaging up to 60 min may be performed and is especially advisable when early images are negative despite a high clinical suspicion. Imaging beyond 60 min may compromise study interpretation due to passage of activity from the stomach to the intestine.

Additional static images (anterior, anterior oblique, lateral, and posterior projection views) are recommended at the end of the dynamic acquisition. Lateral views may be useful to localize renal pelvic activity. Postvoiding images may be helpful to detect activity in a Meckel diverticulum obscured by the urinary bladder.

3. Other considerations

SPECT imaging may improve the detection of a small diverticulum, or a diverticulum obscured by the urinary bladder, when the clinical suspicion for a Meckel diverticulum is high and the planar images have negative or equivocal findings.

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SPECT imaging coregistered with a simultaneously acquired low-dose CT scan on a hybrid system may be helpful for localization of a Meckel diverticulum (*20–22*). For SPECT, see the SNMMI Guideline for General Imaging.

SPECT/CT fusion adds a small amount of additional radiation exposure. The CT dose should be tailored to patient size and age (*23*). See the SNMMI Guideline for SPECT/CT.

F. Interventions

A urinary catheter to drain the bladder of activity can be helpful if the Meckel diverticulum is adjacent to the bladder and if the patient is unable to voluntarily void. Alternatively, decubitus or upright views may be helpful by causing the Meckel diverticulum to fall away from the bladder.

Furosemide (1 mg/kg intravenously) can be administered in some settings to eliminate radiopharmaceutical pooling in a dilated ureter; this may be helpful when there are time constraints for delayed imaging.

G. Processing

For SPECT, see the SNMMI Guideline for General Imaging. The field of view should be maximized for the patient's size.

H. Interpretation criteria

Normal structures seen on the flow phase after injection of ^{99m}Tc-pertechnetate include the heart, lungs (not typically included in the field of view), major arteries and veins, and vascular organs such as the spleen, liver, and kidneys. Stomach activity appears early on dynamic scintigraphy and is most prominent after 10–15 min. Radiopharmaceutical activity is often present in the kidneys, ureters, and bladder.

Ectopic gastric mucosa is visible as a focal, localized area of uptake that appears at the same time as the activity in the normal gastric mucosa. As the stomach activity accumulates, so does diverticular activity. The intensity of the tracer accumulation may be less in the diverticulum than within the stomach, depending on the amount of mucosa present within the diverticulum and its secretory activity. Meckel diverticula are typically located in the right lower quadrant but may also be found elsewhere in the abdomen. They may change position during the study, especially after the body position has been changed. False-positive studies can occur if excreted tracer activity in the proximal small bowel, kidneys, ureter, or bladder is mistaken for ectopic gastric mucosa. Activity in the urinary tract usually appears after activity is seen in the normal gastric mucosa. A small Meckel diverticulum may appear somewhat later than the stomach.

A lateral view at the end of the study usually allows activity in the kidney and ureters, which is in the posterior part of the abdomen, to be differentiated from activity in the diverticulum, which is usually anterior (*24*).

^{99m}Tc-pertechnetate that is secreted by the gastric mucosa will gradually accumulate in the small bowel. This activity can be distinguished from a Meckel diverticulum by its delayed appearance and by its appearance as an area of mildly, ill-defined increased activity.

Viewing the dynamic image as a cine loop on a computer display that also permits adjustment of image contrast is recommended to help distinguish small-bowel or urinary tract activity from ectopic gastric mucosa.

I. Pitfalls

False-positive radiopharmaceutical activity suggestive of Meckel diverticula can result from the following conditions: duplication cyst with ectopic gastric mucosa, bowel inflammation (*25*), intussusception or small-bowel obstruction (*26*), peptic ulcer (*27*), and vascular lesions with increased blood pool (e.g., hemangioma or arteriovenous malformation) (*27*).

False-negative findings usually result from anatomic or physiologic causes (see "Sources of Errors"). Other pathologic conditions that may result in a false-negative scan include gastrointestinal bleeding unrelated to ectopic gastric mucosa (e.g., pancreatic mucosa) (*28*). A negative Meckel scan in a patient with significant recent gastrointestinal bleeding where no other etiology for bleeding is discovered over several weeks' time may warrant a repeated study—optimally using pretreatment with an H_2 blocker or proton pump inhibitor.

J. Reporting

Aside from patient demographics, the report should include the following information: the indication for the study; the type of procedure; the radiopharmaceutical, dose, and route of administration (intravenous); the duration of the acquisition (e.g., 30 min vs. 1 h); the frame rate (e.g., 60 s/frame); the number of projections acquired (e.g., anterior, laterals); the field of view (e.g., stomach to the bladder); the type of display (e.g., static vs. cine); the findings; any study limitations or confounding factors; and the interpretation (e.g., positive, negative, or indeterminate).

The reported findings should include the time of appearance of the gastric mucosa, the time of appearance of ectopic activity (e.g., early vs. late, correspondence with gastric activity), the location of ectopic activity, and the characteristics of ectopic activity, such as size and shape (e.g., focal, round, oblong, or diffuse) and movement (if any).

K. Quality control

Quality controls for the γ camera, computer system, and image display are as enumerated by the SNMMI Guideline for General Imaging.

L. Sources of errors

1. Procedures that may cause interference

A false-negative result may occur if the patient underwent prior barium fluoroscopy examination (*25*) or prior

TABLE 1
Radiation Dosimetry in Adults

Radiopharmaceutical	Administered activity (intravenous)		Upper large intestine (organ receiving largest radiation dose)		Effective dose		Upper large intestine (organ receiving largest radiation dose)		Effective dose	
	MBq	mCi	mGy/MBq	rad/mCi	mSv/MBq	rem/mCi	mGy	rad	mSv	rem
^{99m}Tc-pertechnetate	296–444	8–12	0.057	0.21	0.013	0.048	17–25	1.7–2.5	3.8–5.7	0.38–0.57

Data are from ICRP publication 53, page 199, no blocking agent (*34*).

administration of perchlorate (*29*), and a false-positive result may occur if there was a prior cleansing enema or laxatives causing bowel irritation (*30*).

2. Anatomic or physiologic causes of errors

A false-positive result may occur if there is focal pooling of tracer in the urinary tract (hydronephrosis, extrarenal pelvis, ectopic kidney, hydroureter, vesicourethral reflux, bladder diverticulum) or if there is a uterine blush (*30*). A false-negative result may occur if the image is obscured by brisk gastrointestinal bleeding during circulation of the tracer or by the urinary bladder or dilated ureter (*25*), if a focus of ectopic mucosa is small (<1.8 cm ^{2}) (*31*), and if there is movement of the diverticulum (*25*).

M. Issues requiring further clarification

The role of pharmacologic interventions requires further clarification. Studies are needed to determine whether any of the specific H_2 blockers, any of the proton pump inhibitors, or any dose alterations of these agents have an advantage over the others for pharmacologic augmentation.

The role of SPECT and SPECT/CT to improve the accuracy of Meckel diverticulum scintigraphy also requires further clarification.

VII. DOCUMENTATION/REPORTING

See the SNMMI Guideline for General Imaging.

VIII. EQUIPMENT SPECIFICATION

A large-field-of-view γ camera is recommended. A high-resolution collimator is preferred. The photopeak is typically a 20% window centered at 140 keV.

IX. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION CONCERNS

See the SNMMI Guideline for General Imaging.

X. RADIATION SAFETY IN IMAGING

See also the SNMMI Guideline for General Imaging.

It is the position of the SNMMI that exposure to ionizing radiation should be at the minimum level consistent with obtaining a diagnostic examination. Radiation exposure may be reduced by administering less radiopharmaceutical when the technique or equipment used for imaging can support such an action. Each procedure is unique, and the methodology to achieve minimum exposure while maintaining diagnostic accuracy needs to be viewed in this light. Radiopharmaceutical dose ranges outlined in this document should be considered as a guide. Dose reduction techniques should be used when appropriate. The same principles should be applied when CT is used in a hybrid imaging procedure. CT acquisition protocols should be optimized to provide the information needed while minimizing radiation exposure. Minimizing radiation dose is especially important

TABLE 2
Radiation Dosimetry in Children (5 Years Old)

Radiopharmaceutical	Administered activity (intravenous)		Upper large intestine (organ receiving largest radiation dose)		Effective dose		Upper large intestine (organ receiving largest radiation dose)		Effective dose	
	MBq	mCi	mGy/MBq	rad/mCi	mSv/MBq	rem/mCi	mGy	rad	mSv	rem
^{99m}Tc-pertechnetate	37 (1.85 MBq/kg*)	1 (0.05 mCi/kg*)	0.20	0. 74	0.040	0.16	7.4	0.74	1.6	0.16

*20-kg body mass assumed.

Data are from ICRP publication 80, page 73, no blocking agent (*35*). Pediatric radiopharmaceutical administered dose is from 2010 North American consensus guidelines (*16*). EANM pediatric dose card (2007 version) may also be used (*17*).

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TABLE 3
Radiation Dosimetry in the Fetus

Stage of gestation	Fetal dose	
	mGy/MBq	rad/mCi
Early	0.011	0.041
3 mo	0.022	0.081
6 mo	0.014	0.052
9 mo	0.0093	0.034

Data are from Russell et al. (*32*)

[**Table 1**] in children. Tables 1 and 2 provide radiation dosimetry data [**Table 2**] in adults and 5-y-old children, respectively.

A. Radiation dosimetry in fetus/embryo: ^{99m}Tc-pertechnetate

Dose estimates to the fetus are provided by Russell et al. (*32*). Information about possible placental crossover of this compound was available and was used in estimating fetal doses. Table 3 provides radiation dosimetry data in the fetus. [**Table 3**]

B. The breast-feeding patient

International Commission on Radiological Protection (ICRP) publication 106, Appendix D (*33*), recommends interruption of breast feeding for 12 h after administration of ^{99m}Tc-pertechnetate.

XI. APPENDIX A: PHARMACOLOGIC PRETREATMENT IN CHILDREN REFERRED FOR MECKEL SCAN

A. Cimetidine

1. Oral administration

Neonates: 10–20 mg/kg/d by mouth; infants and older children: 20 mg/kg/d × 2 d by mouth; adults: 300 mg 4 times per day × 2 d by mouth.

2. Intravenous administration

Three hundred milligrams in 100 mL of 5% dextrose intravenously over 20 min, with imaging starting 1 h later.

B. Ranitidine

1. Oral administration

Children: 2 mg/kg by mouth; adults:150 mg/kg by mouth.

2. Intravenous administration

Infants, children, and adults: 1 mg/kg intravenously (maximum, 50 mg) over 20 min, with imaging starting 1 h later.

C. Famotidine

1. Oral administration

Children: 0.5 mg/kg/d by mouth; adults: 20 mg by mouth.

2. Intravenous administration

Children: 0.5 mg/kg/d intravenously; adults: 20 mg intravenously

or

0.25 mg/kg intravenously 1 h before the scanning procedure.

D. Glucagon

Intravenous administration: 50 μg/kg intravenously, to a maximum of 1 mg, diluted to a volume of 10 mL with sterile water, infused slowly over 2 min immediately before injection of the ^{99m}Tc-pertechnetate. Flush intravenously with sterile water immediately before and after the infusion of glucagon. Do not give glucagon to a diabetic patient. It is important to reconstitute the glucagon with sterile water, not normal saline. The patient should be observed carefully for signs of nausea or vomiting. (The primary reason for administering glucagon before the radiotracer is to reduce the likelihood of vomiting and possible aspiration during the study.)

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XIII. ACKNOWLEDGMENTS

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XIV. APPROVAL

This practice guideline (version 2.0) was approved by the Board of Directors of the SNMMI on June 5, 2014, and by the EANM Board on March 26, 2014. Version 1.0 was approved on February 7, 1999.