Society of Nuclear Medicine (SNM) is an international scientific and professional organization founded in 1954 to promote the science, technology and practical application of nuclear medicine. Its 16,000 members are physicians, technologists and scientists specializing in the research and practice of nuclear medicine. In addition to publishing journals, newsletters and books, the Society 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 SNM will periodically define new procedure guidelines for nuclear medicine practice to help advance the science of nuclear medicine and to improve the quality of service to patients throughout the United States. Existing procedure guidelines will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each procedure guideline, representing a policy statement by the Society, has undergone a thorough consensus process in which it has been subjected to extensive review, requiring the approval of the Committee on SNM Guidelines, Health Policy and Practice Commission, and SNM Board of Directors. The SNM recognizes that the safe and effective use of diagnostic nuclear medicine imaging requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published procedure guideline by those entities not providing these services is not authorized.

THE SNM PRACTICE GUIDELINE FOR LUNG SCINTIGRAPHY

DRAFT V3.4

PREAMBLE

These guidelines are an educational tool designed 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 Society of Nuclear Medicine 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 the physician or medical physicist in light of all the circumstances presented. Thus, an approach that differs from the guidelines, 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 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 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 sole purpose of these guidelines is to assist practitioners in achieving this objective.
I. INTRODUCTION

This guideline describes the technique of performing and interpreting ventilation and perfusion scintigraphy.

II. GOALS

The purpose of this guideline is to assist nuclear medicine practitioners in recommending, performing, interpreting, and reporting the results of ventilation and perfusion lung scintigraphy.

III. DEFINITIONS

A. Lung Scintigraphy

A diagnostic imaging procedure that utilizes ventilation scintigraphy, perfusion scintigraphy or both to evaluate cardiovascular and pulmonary disorders.

B. Aerosol Ventilation Scintigraphy

A diagnostic imaging test that records the bronchopulmonary distribution of an inhaled radioactive aerosol within the lungs.

C. Gas Ventilation Scintigraphy

A diagnostic imaging test that records the pulmonary distribution of a radioactive gas during breathing.

D. Pulmonary Perfusion Scintigraphy

A diagnostic imaging test that records the distribution of pulmonary arterial blood flow.

E. Radiographic Pulmonary Evaluation

Chest radiograph or CT used to evaluate pulmonary parenchyma.

IV. COMMON CLINICAL INDICATIONS

Indications for Lung Scintigraphy include, but are not limited to:

A. The most common clinical indication for lung scintigraphy is to determine the likelihood of pulmonary embolism.

B. Less common clinical indications are:

1. Document the degree of resolution of pulmonary embolism.
2. Quantify differential pulmonary function before pulmonary surgery for lung cancer (1-3).

3. Evaluate lung transplants (4-5).

4. Evaluate congenital heart or lung disease such as cardiac shunts, pulmonary arterial stenoses, and arteriovenous fistulae and their treatment (6).

5. Confirm the presence of bronchopleural fistula (7-8).

6. Evaluate chronic pulmonary parenchymal disorders such as cystic fibrosis (9-10).

7. Evaluate the cause of pulmonary hypertension (11).

V. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

Refer to Section V of the SNM Procedure Guideline for General Imaging

VI. PROCEDURE/SPECIFICATIONS OF THE EXAMINATION

A. Nuclear Medicine study request

1. In women of childbearing age, pregnancy and lactation status should be noted and the procedure performed in a manner to minimize radiation exposure.

2. The referring physician’s estimate of the prior probability of pulmonary embolism may be helpful. Use of validated tools such as the Wells (12) score is preferred.

3. Results of D-dimer test, if obtained.

4. History of prior deep venous thrombosis or pulmonary embolism should be elicited.

5. Review of prior lung scintigraphy. Defects from prior pulmonary emboli do not always resolve completely.

6. Pertinent chest radiographic findings include, but are not limited to: a) consolidation; b) atelectasis; c) effusions; d) masses; e) cardiomegaly; and f) decreased pulmonary vasculature. The chest radiograph may be normal in patients with pulmonary embolism.

7. Treatment with anticoagulant or thrombolytic therapy should be noted.

8. Results of tests for deep venous thrombosis, e.g. compression ultrasonography, should be noted.
B. Patient Preparation and Precautions

1. A standard chest radiograph in both posterior-anterior and lateral projections is preferred. A CT scan can substitute for the chest radiograph. A portable anterior-posterior chest radiograph is acceptable only if the patient cannot tolerate a routine chest radiographic examination. In patients who have no changes in signs or symptoms, a chest radiograph within a few days may be adequate.

2. A CT scan can substitute for the chest radiography.

C. Radiopharmaceuticals

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>$T_1/2$</th>
<th>Photopeak (keV)</th>
<th>Decay</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{99m}$Tc</td>
<td>6 hour</td>
<td>140</td>
<td>IT</td>
</tr>
<tr>
<td>$^{133}$Xe</td>
<td>5.2 days</td>
<td>81</td>
<td>Beta</td>
</tr>
<tr>
<td>$^{81m}$Kr</td>
<td>13 seconds</td>
<td>190</td>
<td>IT</td>
</tr>
</tbody>
</table>

IT = Isomeric Transition

1. Aerosols

a. $^{99m}$Tc diethylenetriamine-pentaacetic acid (DTPA) is the preferred radiopharmaceutical.

b. The usual dispensed activity of $^{99m}$Tc DTPA is 900–1300 MBq (25–35 mCi) in the nebulizer, from which the patient receives approximately 20–40 MBq (0.5–1.0 mCi) to the lungs.

c. $^{99m}$Tc labeled ultrafine carbon suspension has more uniform distribution in the lungs than $^{99m}$Tc DTPA aerosol, but is currently not available in the United States.

d. Aerosol imaging is usually performed before perfusion imaging because it is more difficult to deliver a larger dose of the $^{99m}$Tc aerosol than it is to deliver a larger dose of $^{99m}$Tc macroaggregated albumin (MAA). Because both agents are labeled with $^{99m}$Tc, it is extremely important that the count rate of the second study is at least three to four times the count rate of the first study.

2. Krypton-81m

a. $^{81m}$Kr is obtained from an $^{81}$Rb/$^{81m}$Kr generator.

b. $^{81m}$Kr is administered by continuous inhalation of approximately 40–400 MBq (1–10 mCi).
3. Xenon-133
   a. The usual administered activity is 200–750 MBq (5–20 mCi). The usual
dose for children is 10–12 MBq/kg (0.3 mCi/kg) with a minimum of 100–
120 MBq (3 mCi).
   b. $^{133}$Xe should be used in room that is at negative pressure with respect to
the surroundings.

4. Perfusion
   a. Before intravenous administration of the pulmonary perfusion
radiopharmaceutical, the patient should be instructed to cough and to take
several deep breaths. The patient should be in the supine position during
injection, or in the case of a patient with orthopnea, as close to supine as
possible.
   b. The radiopharmaceutical used for perfusion imaging is $^{99m}$Tc MAA.
   c. The biological half-life of the macroaggregated albumin in the lungs
varies (usually 1.5 to 3 hr).
   d. The usual adult administered activity is 40–150 MBq (1–4 mCi). The
usual pediatric administered activity is 0.5–2.0 MBq/kg (0.02-0.08
mCi/kg) with a minimum of 7–8 MBq (0.2 mCi).
   e. The number of particles should be in the range of 200,000–700,000. For
children, the number of particles is a function of age (13).
   f. Freshly prepared $^{99m}$Tc MAA with reduced numbers of particles should be
considered for patients with pulmonary hypertension or right-to-left
shunting, and in infants and children. In adults, the number may be
reduced to 100,000–200,000 particles without altering the quality of the
images for detection of perfusion defects. Inhomogeneous distribution of
activity may result from a reduction of the number of particles below
100,000 in adults.
   g. Labeled MAA particles will settle in the vial with time. Vials
should be agitated prior to withdrawing a dose, and the syringe should be
inverted prior to injection.

D. Protocol/Image Acquisition

1. Sequence of Imaging
a. A chest radiograph should be obtained and reviewed before lung scintigraphy.

b. Ventilation scintigraphy using $^{133}$Xe is usually performed before perfusion scintigraphy. Alternately, perfusion scintigraphy can be performed first and ventilation scintigraphy omitted if not needed.

c. The disadvantages of performing perfusion imaging before ventilation imaging with $^{133}$Xe:
   
   i. The perfusion image contributes background activity to the ventilation image.
   
   ii. A decision to perform or not to perform the ventilation study must be made in a timely manner.

d. The advantages of performing perfusion imaging before ventilation imaging with $^{133}$Xe:
   
   i. If the perfusion study is normal or matches the chest radiographic findings, the ventilation study can be omitted.
   
   ii. For single-projection ventilation studies, the projection that best shows the defect can be obtained.

e. Because of the higher energy of the gamma emissions and the short half-life of $^{81m}$Kr, images obtained with this gas can be alternated with those obtained with $^{99m}$Tc MAA.

f. When $^{99m}$Tc labeled aerosol imaging is performed before $^{99m}$Tc MAA perfusion imaging, smaller amounts (20-40 MBq [0.5-1.0 mCi]) of $^{99m}$Tc labeled aerosol should be administered to the lungs.

2. Processing

None.

3. Aerosol Ventilation Imaging

a. The aerosol is administered through a mouthpiece with the nose occluded while the patient is tidal breathing.

b. An advantage of aerosol imaging is that images can be obtained in multiple projections or with single-photon emission computed tomograph (SPECT) to match those obtained for perfusion imaging.
c. It is preferable to have the patient inhale the aerosol in the upright position, but the supine position can be used if necessary.

d. Aerosol ventilation imaging can be performed at the bedside.

e. A disadvantage of aerosol imaging is that aerosol deposition is altered by turbulent flow, and central deposition can result in a suboptimal study.

f. SPECT can be used to obtain a three-dimensional evaluation of ventilation.

4. Xenon-133 Ventilation Imaging

a. An advantage of $^{133}$Xe ventilation is that single-breath, wash-in and/or equilibrium and washout images can be obtained, thus providing a more complete characterization of ventilation and a more sensitive test for obstructive airway disease. Physiologic information about ventilation can best be obtained from $^{133}$Xe imaging.

b. The imaging room should provide appropriate exhaust for radioactive gas. Regulations for safe handling of radioactive gas should be followed.

c. The patient is positioned upright in front of the scintillation camera. If necessary, the patient can be positioned supine.

d. The projection that best shows the defect(s) on perfusion scintigraphy is used for the ventilation scintigraphy if performed after perfusion scintigraphy. Otherwise, the posterior projection is generally used. When possible, posterior oblique images should be obtained during the washout phase (and during wash-in phase if continuous imaging is performed during this phase).

e. If ventilation scintigraphy is performed after perfusion scintigraphy, a $^{99m}$Tc background image should be obtained using the $^{133}$Xe window.

f. A facemask or mouthpiece (with nose clip) should be connected via a bacterial filter to the xenon delivery system.

g. Single-breath, equilibrium and washout images are obtained.

h. Equilibrium is obtained by breathing in a closed xenon delivery system for 3–4 minutes as tolerated by the patient.

5. Krypton-81m Imaging
a. The advantage of $^{81m}$Kr is that images can be obtained in all views without interference from prior perfusion imaging. Alternating $^{99m}$Tc MAA and $^{81m}$Kr imaging allows ventilation and perfusion images to be obtained without patient repositioning between paired $^{99m}$Tc MAA and $^{81m}$Kr views.

b. The patient breathes continuously from the $^{81}$Rb/$^{81m}$Kr generator. Due to the short half-life of $^{81m}$Kr, the distribution of radioactivity approximates regional minute ventilation rate.

c. A collimator with low septal penetration at 190 keV should be used.

d. SPECT can be used to obtain a three-dimensional evaluation of ventilation.

e. A disadvantage of $^{81m}$Kr is that the short half-life of the parent radionuclide, $^{81}$Rb (4.57 h), decreases availability and increases cost of the generator.

6. Perfusion Imaging

a. After having the patient cough and take several deep breaths, $^{99m}$Tc MAA is injected slowly during 3–5 respiratory cycles with the patient in the supine position.

b. A well-flushed indwelling line can be used if venous access is difficult. Do not administer in the distal port of a Swan-Ganz catheter or any indwelling line or port that contains a filter, e.g. chemotherapy line.

c. Imaging is preferably performed in the upright position to increase chest cavity size and to minimize diaphragmatic motion. If necessary, images can be obtained in the supine or decubitus position.

d. Planar images should be obtained in multiple projections including anterior, posterior, both posterior oblique, both anterior oblique and both lateral projections. Either the anterior oblique or the lateral projections can be omitted. It may be possible to obtain only limited views in some patients.

e. SPECT can be used to obtain a three-dimensional evaluation of the perfusion.

f. Imaging of high blood flow systemic organs can be used to detect right-to-left shunting.
7. SPECT/Low-dose CT

a. Lung scintigraphy for pulmonary embolism may be performed using SPECT/low-dose CT. The low-dose CT portion of the study provides information for attenuation, and also provided improved anatomic information compared to a chest X-ray.

b. Ventilation imaging is practical using an agent that has a stable distribution, $^{99m}$Tc carbon micro-particles, $^{81m}$Kr, or $^{99m}$Tc aerosols.

c. The CT portion of the study should be performed as described in the Procedure Guideline for SPECT/CT Imaging.

E. Interpretation

1. Several diagnostic criteria (summarized in the Table 1 below) have been described as an aid in interpretation.

a. Modified PIOPED criteria: The modified PIOPED criteria were derived from a retrospective analysis of the PIOPED database (14, 15). The criteria were prospectively tested and shown to be more accurate than the original PIOPED criteria (16).

b. Modified PIOPED II criteria: In an attempt to reduce the number of non-diagnostic studies, the PIOPED II criteria were modified using fewer categories. The performance of the modified PIOPED II criteria was evaluated on the PIOPED II database (17).

c. Criteria using chest radiograph and perfusion scan: The modified PIOPED II and PISAPED criteria not using the information from ventilation scintigraphy have been shown to perform equivalently to those including ventilation scintigraphy with fewer indeterminate studies (18).
Table 1
Ventilation (V), Perfusion (Q), Radiographic (CXR) Interpretive Criteria for Pulmonary Embolism (PE)

<table>
<thead>
<tr>
<th>PIOPED</th>
<th>Modified PIOPED II</th>
<th>Perfusion Only Modified PIOPED II</th>
<th>Perfusion Only PISAPED</th>
</tr>
</thead>
<tbody>
<tr>
<td>High LR</td>
<td>High LR</td>
<td>PE Present</td>
<td>PE Present</td>
</tr>
<tr>
<td>&gt;2 large mismatched (V:Q) segmental defects*</td>
<td>≥2 large mismatched (V:Q) segmental defects*</td>
<td>≥2 large mismatched (Q:CXR) segmental defects*</td>
<td>≥1 wedge-shaped Q defects</td>
</tr>
<tr>
<td>Borderline High LR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 large mismatched (V:Q) segmental defects*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate LR</td>
<td>Non-diagnostic</td>
<td>Non-diagnostic</td>
<td>Non-diagnostic</td>
</tr>
<tr>
<td>2 moderate or 1 large mismatched (V:Q) defects*</td>
<td>All other findings</td>
<td>All other findings</td>
<td>Cannot classify as PE-present or PE-absent</td>
</tr>
<tr>
<td>Borderline Low LR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 matched (V:Q) defect, CXR-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low LR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonsegmental perfusion defects**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q defect substantially &lt; CXR defect</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matched (V:Q) defects, CXR-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any number of small Q defects*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>Very Low LR</td>
<td>PE Absent</td>
<td>PE Absent</td>
</tr>
<tr>
<td>No Q defects*****</td>
<td>Nonsegmental**</td>
<td>Very low Probability</td>
<td>Non-wedge-shaped Q defect</td>
</tr>
<tr>
<td></td>
<td>Q defect &lt; CXR lesion</td>
<td></td>
<td>Contour defect caused by enlarged heart, mediastinum, or diaphragm</td>
</tr>
<tr>
<td></td>
<td>1-3 small segmental* defects</td>
<td></td>
<td>Near normal Q</td>
</tr>
<tr>
<td></td>
<td>Solitary matched (V:Q:CXR) defect (≤ 1 segment) in mid or upper lung</td>
<td>Solitary matched (Q:CXR) defect (≤ 1 segment) in mid or upper lung</td>
<td>Normal Q</td>
</tr>
<tr>
<td></td>
<td>Stripe sign***</td>
<td>Stripe sign***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Solitary large pleural effusion****</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥2 matched (V:Q) defects, regionally normal CXR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Q defects*****</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

403 NR = likelihood ratio
404 * Or equivalent where a large segmental defect, >75% of a segment, equals 1 segmental equivalent; a moderate defect, 25-75% of a segment, equals 0.5 segmental equivalents; a small defect, <25%, is not counted.
405 ** For example, prominent hilum, cardiomegaly, elevated diaphragm, linear atelectasis, or costophrenic angle effusion with no other perfusion defect in either lung and no other radiographic lesion.
406 *** Peripheral perfusion in a defect (best seen on tangential view).
407 **** Pleural effusion in at least 1/3 of the pleural cavity, with no other perfusion defect in either lung.
408 ***** Perfusion defects exactly match shape of CXR.
409
2. Gestalt interpretation: The experienced nuclear medicine physician may be able to provide a more accurate interpretation of the ventilation-perfusion study than is provided by the criteria alone; however, his/her opinion is usually informed by
detailed knowledge of the various lung image interpretive criteria given in E.1 (16).

3. Further Interpretive Considerations (19)

a. Ventilation-perfusion mismatch can result from any cause of pulmonary arterial blood flow obstruction. Although there is a very long differential diagnosis for ventilation-perfusion mismatch, there are few common causes: 1) acute pulmonary embolism; 2) old pulmonary embolism; 3) obstruction of an artery by tumor; and 4) radiation therapy.

b. On perfusion scintigraphy, extrapulmonary activity (which may be seen at the edges of lung images in the thyroid or kidneys) may be either the result of right-to-left shunting, free $^{99m}$Tc pertechnetate, reduced $^{99m}$Tc compounds, or another recent nuclear medicine procedure. An image of the head can be used to differentiate free $^{99m}$Tc pertechnetate or reduced $^{99m}$Tc compounds from a right-to-left shunting.

c. The stripe sign (activity at the periphery of a perfusion defect) lowers the likelihood that a perfusion defect is due to pulmonary embolism.

4. Interpretation of Right-to-Left Shunt Studies

a. Presence of a right-to-left shunt is identified by activity in systemic vascular beds.

b. An image of the head provides the most accurate method to detect small shunts. Activity due to shunting of $^{99m}$Tc MAA particles will correspond to brain perfusion while other activity will be seen in the scalp.

c. The fraction of right-to-left shunting can be approximated by comparing the activity in the lungs to the activity in the rest of the body.

5. Interpretation of Preoperative Lung Scintigraphy

a. Each lung is generally divided into three equal rectangular regions-of-interest on anterior and posterior views – top, middle, and bottom.

b. The activity in the 6 regions-of-interest is reported for perfusion or for both ventilation and perfusion.

c. An anatomically based description of the perfusion should be provided.

d. Alternative methods of quantification with regions that correspond more closely to pulmonary anatomy are preferred by some experts.
6. Interpretation of Post-transplant Lung Scintigraphy

a. In the immediate post-transplantation setting, perfusion imaging documents the patency of the vascular anastomoses.

b. In single lung transplantation, the ratio of right-to-left lung perfusion and the change in ratio correlates with rejection.

c. Analysis of regional changes in ventilation and perfusion may also be useful. Development of matched ventilation perfusion abnormalities consistent with obstructive lung disease often reflect rejection (bronchiolitis obliterans).

7. Sources of Error

a. Perfusion images can show “hot spots” in the lung if clotting of blood occurs in the syringe during the injection, or if the injection is made through an indwelling catheter that is not well flushed.

b. Ventilation scintigraphy is obtained at a different point in time than the perfusion scintigraphy. In the intervening time, there can be changes in ventilation and perfusion. Similarly, ventilation scintigraphy may be obtained with the patient in an upright position and the radiopharmaceutical for perfusion scintigraphy typically is injected with the patient in the supine position. These changes in position may also affect the comparability of the two scintigrams.

c. Injection of $^{99m}$Tc MAA through a central line can result in inadequate mixing of activity in the pulmonary artery. This inadequate distribution of activity is especially true if the activity is injected through a pulmonary artery line.

d. A decubitus or oblique patient position can markedly affect the distribution of ventilation and perfusion. If the injection for perfusion scintigraphy or if ventilation scintigraphy is performed in the decubitus or oblique position, mismatched patterns can result. Accordingly, any nonstandard patient positioning should be recorded and considered during subsequent interpretation.

e. Activity in the thyroid is often used as an indicator of free $^{99m}$Tc pertechnetate in the radiopharmaceutical preparation. However, the thyroid is also a high flow organ and may be visualized in the case of a right-to-left shunt.
8. Issues Requiring Further Clarification

a. There is considerable literature on SPECT lung scintigraphy and there is emerging literature on SPECT/low-dose CT lung scintigraphy (20). However, there is currently no information about the comparison of these methods with planar imaging in a multi-institutional setting (21).

b. The criteria for interpretation of SPECT and SPECT/low-dose CT need to be established.

c. The utility of breathing maneuvers or gating in the context of SPECT and SPECT/low-dose CT need to be established.

d. The radiation absorbed dose that provides adequate diagnostic information for use in low-dose CT needs to be established.

e. The utility of adding ventilation imaging to anatomic and perfusion imaging needs further study (18, 20).

F. Interventions

1. In patients with acute obstructive lung disease, the use of bronchodilator therapy before lung scintigraphy may decrease ventilatory defects and improve the accuracy of the study. Because perfusion defects often change as acute obstruction resolves, patients are best imaged when bronchospasm has resolved.

2. In patients with congestive heart failure, improved specificity will be obtained if imaging can be delayed until therapy for heart failure has been instituted.

VII. DOCUMENTATION/REPORTING

A. Goals of a Nuclear Medicine Report

Refer to Section VII in the SNM Procedure Guideline for General Imaging

B. Direct Communication

Refer to Section VII of the SNM Procedure Guideline for General Imaging

C. Written Communication

Refer to Section VII of the SNM Procedure Guideline for General Imaging

D. Contents of the Nuclear Medicine Report

Refer to Section VII of the SNM Procedure Guideline for General Imaging
1. **Study identification**

2. **Clinical Information**

3. **Procedure description**

4. **Description of findings**

The report should include a description of the lung scintigraphy findings, diagnostic category and an overall assessment of the likelihood of pulmonary embolism based on the scintigraphic findings. Terms referring to test outcome, e.g. “likelihood ratio for pulmonary embolism,” are preferred over terms referring to posterior probability, e.g. “probability of pulmonary embolism.”

5. **Impression**

6. **Comments**

   a. The report may include an assessment of the post-test probability of pulmonary embolism based on the result of lung scintigraphy and an estimate of the prior probability of disease (22, 23).

   b. Many experts believe limiting reporting to three categories – pulmonary embolism present, pulmonary embolism absent, and nondiagnostic (intermediate likelihood ratio) – facilitates communication. Some believe more accurate categorization provides more information to referring physicians (24).

   c. The outcome of patients with low likelihood ratio lung scans is good (25, 26, 27).

VIII. **EQUIPMENT SPECIFICATION**

A. **Ventilation**

   1. An ultrafine dispersion of $^{99m}$Tc labeled carbon produced using a commercial system is not currently available in the United States.

   2. A xenon gas ventilation system should include capabilities for single breath, wash-in and/or equilibrium, and washout phases. A xenon trap should be available for exhausted gas.

   3. A disposable aerosolizer is needed for $^{99m}$Tc DTPA aerosol.

B. **Planar Imaging**

   *Refer to Section IV.D of the SNM Procedure Guideline for General Imaging.*
C. SPECT

Refer to Section IV.D of the SNM Procedure Guideline for General Imaging.

D. SPECT/CT

Refer to the SNM Procedure Guideline for SPECT/CT.

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

Refer also to Section IX of the SNM Procedure Guideline for General Imaging.

Radiochemical purity and particle size determination of $^{99m}$Tc MAA should be performed. Reconstituted MAA should be stored in a refrigerator and be used before expiration. Dose reduction in pediatric imaging is always desirable, as long as image quality is maintained (28).

X. RADIATION SAFETY IN IMAGING

Radiation Dosimetry – Adults (29)

<table>
<thead>
<tr>
<th>Radiopharmaceutical</th>
<th>Administered Activity MBq (mCi)</th>
<th>Organ Receiving the Largest Radiation Dose mGy/MBq (rad/mCi)</th>
<th>Effective Dose $^5$ mSv/MBq (rem/mCi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{99m}$Tc MAA$^1$</td>
<td>40-150</td>
<td>0.067 Lung (0.25)</td>
<td>0.011 (0.041)</td>
</tr>
<tr>
<td></td>
<td>(1.1-4.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{99m}$Tc DTPA$^2$</td>
<td>20-40</td>
<td>0.047 Bladder (0.17)</td>
<td>0.0061 (0.023)</td>
</tr>
<tr>
<td></td>
<td>(0.54-1.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{133}$Xe$^3$</td>
<td>200-750</td>
<td>0.0011 Lung (0.0041)</td>
<td>0.00071 (0.0026)</td>
</tr>
<tr>
<td></td>
<td>(5.4-20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{81}$Kr$^4$</td>
<td>40-400</td>
<td>0.00021 Lung (0.00078)</td>
<td>0.000027 (0.00001)</td>
</tr>
<tr>
<td></td>
<td>(1.1-11)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^1$ ICRP 53, page 224
$^2$ ICRP 53, page 218
$^3$ ICRP 53, page 345, rebreathing for 5 minutes
$^4$ ICRP 53, page 160
$^5$ ICRP Publication 80

Radiation Dosimetry in Children

(5 year old)
<table>
<thead>
<tr>
<th>Radiopharmaceutical</th>
<th>Administered Activity</th>
<th>Organ Receiving the Largest Radiation Dose</th>
<th>Effective Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MBq/kg (mCi/kg)</td>
<td>mGy/MBq (rad/mCi)</td>
<td>mSv/MBq (rem/mCi)</td>
</tr>
<tr>
<td>99mTc MAA(^1)</td>
<td>0.5-2 (0.014-0.054)</td>
<td>0.21 Lung (0.78)</td>
<td>0.038 (0.14)</td>
</tr>
<tr>
<td>99mTc DTPA(^2)</td>
<td>0.4-0.6 (0.011-0.016)</td>
<td>0.12 Bladder (0.44)</td>
<td>0.020 (0.074)</td>
</tr>
<tr>
<td>133Xe(^3)</td>
<td>10-12 (0.27-0.32)</td>
<td>0.0037 Lung (0.014)</td>
<td>0.0027 (0.010)</td>
</tr>
<tr>
<td>81mKr(^4)</td>
<td>0.5-5 (0.014-0.14)</td>
<td>0.00068 Lung (0.0025)</td>
<td>0.000088 (0.00033)</td>
</tr>
</tbody>
</table>

\(^1\) ICRP 53, page 224
\(^2\) ICRP, page 218
\(^3\) ICRP, page 345, rebreathing for 5 minutes
\(^4\) ICRP 53, page 160

99mTc MAA: Dose estimates to the fetus were provided by Russell et al. (30). No information about possible placental crossover of this compound was available for use in estimating fetal doses.

<table>
<thead>
<tr>
<th>Stage of Gestation</th>
<th>Fetal Dose</th>
<th>Fetal Dose*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mGy/MBq (rad/mCi)</td>
<td>mGy (rad)</td>
</tr>
<tr>
<td>Early</td>
<td>0.0028 (0.010)</td>
<td>0.11-0.42 (0.011-0.042)</td>
</tr>
<tr>
<td>3 months</td>
<td>0.0040 (0.015)</td>
<td>0.16-0.60 (0.016-0.060)</td>
</tr>
<tr>
<td>6 months</td>
<td>0.0050 (0.018)</td>
<td>0.20-0.75 (0.020-0.075)</td>
</tr>
<tr>
<td>9 months</td>
<td>0.0040 (0.015)</td>
<td>0.16-0.60 (0.016-0.060)</td>
</tr>
</tbody>
</table>

* Maternal administered activity 40-150 MBq (1.1-1.4 mCi).

99mTc DTPA aerosol: Dose estimates to the fetus were provided by Russell et al. (29). Information about possible placental crossover of this compound was available and was considered in estimates of fetal doses.

<table>
<thead>
<tr>
<th>Stage of Gestation</th>
<th>Fetal Dose</th>
<th>Fetal Dose*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mGy/MBq (rad/mCi)</td>
<td>mGy (rad)</td>
</tr>
<tr>
<td>Early</td>
<td>0.0058</td>
<td>0.12-0.23 (0.012-0.023)</td>
</tr>
</tbody>
</table>
### Table 1: Fetal Dose Estimates

<table>
<thead>
<tr>
<th>Stage of Gestation</th>
<th>Fetal Dose</th>
<th>Fetal Dose*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mGy/MBq</td>
<td>mGy</td>
</tr>
<tr>
<td></td>
<td>(rad/mCi)</td>
<td>(rad)</td>
</tr>
<tr>
<td>Early</td>
<td>0.00025</td>
<td>0.050-0.19</td>
</tr>
<tr>
<td></td>
<td>(0.00092)</td>
<td>(0.0050-0.199)</td>
</tr>
<tr>
<td>3 months</td>
<td>0.000029</td>
<td>0.0058-0.022</td>
</tr>
<tr>
<td></td>
<td>(0.00011)</td>
<td>(0.00058-0.0022)</td>
</tr>
<tr>
<td>6 months</td>
<td>0.000021</td>
<td>0.0042-0.016</td>
</tr>
<tr>
<td></td>
<td>(0.000078)</td>
<td>(0.00042-0.0016)</td>
</tr>
<tr>
<td>9 months</td>
<td>0.000016</td>
<td>0.0032-0.012</td>
</tr>
<tr>
<td></td>
<td>(0.000059)</td>
<td>(0.00032-0.0012)</td>
</tr>
</tbody>
</table>

* Maternal administered activity 200-750 MBq (5.4-20 mCi).

### Table 2: Fetal Dose Estimates

<table>
<thead>
<tr>
<th>Stage of Gestation</th>
<th>Fetal Dose</th>
<th>Fetal Dose*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mGy/MBq</td>
<td>mGy</td>
</tr>
<tr>
<td></td>
<td>(rad/mCi)</td>
<td>(rad)</td>
</tr>
<tr>
<td>Early</td>
<td>1.8x10^{-7}</td>
<td>7.2x10^{-6} - 7.2x10^{-5}</td>
</tr>
<tr>
<td></td>
<td>(6.7x10^{-7})</td>
<td>(7.2x10^{-5} - 7.2x10^{-6})</td>
</tr>
<tr>
<td>3 months</td>
<td>1.8x10^{-7}</td>
<td>7.2x10^{-6} - 7.2x10^{-5}</td>
</tr>
<tr>
<td></td>
<td>(6.7x10^{-7})</td>
<td>(7.2x10^{-5} - 7.2x10^{-6})</td>
</tr>
<tr>
<td>6 months</td>
<td>2.8x10^{-7}</td>
<td>1.1x10^{-5} - 1.1x10^{-4}</td>
</tr>
<tr>
<td></td>
<td>(1.0x10^{-6})</td>
<td>(1.1x10^{-6} - 1.1x10^{-5})</td>
</tr>
<tr>
<td>9 months</td>
<td>3.4x10^{-7}</td>
<td>1.4x10^{-4} - 1.4x10^{-3}</td>
</tr>
<tr>
<td></td>
<td>(1.3x10^{-6})</td>
<td>(1.4x10^{-6} - 1.4x10^{-5})</td>
</tr>
</tbody>
</table>

* Maternal administered activity 40-400 MBq (1.1-11 mCi).

#### The Breastfeeding Patient

ICRP Publication 106, Appendix D suggests a 12 hour interruption of breast feeding for subjects...
receiving 150 MBq (4.1 mCi) $^{99m}$Tc MAA; it does not provide a recommendation about interruption of breastfeeding for $^{99m}$Tc DTPA aerosols (but suggests that no interruption is needed for $^{99m}$Tc DTPA intravenously administered or $^{99m}$Tc technegas); the authors recommend that no interruption is needed for breastfeeding patients administered $^{133}$Xe or $^{81m}$Kr.

XI. ACKNOWLEDGEMENTS

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XII. BIBLIOGRAPHY/REFERENCES


XIII. BOARD OF DIRECTORS APPROVAL DATES:

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