

# Society of Nuclear Medicine Procedure Guideline for Lung Scintigraphy

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## I. Purpose

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

## II. Background Information and Definitions

- A. Aerosol Ventilation Scintigraphy  
A diagnostic imaging test that records the bronchopulmonary distribution of an inhaled radioactive aerosol within the lungs.
- B. Gas Ventilation Scintigraphy  
A diagnostic imaging test that records the pulmonary distribution of a radioactive gas during breathing maneuvers.
- C. Pulmonary Perfusion Scintigraphy  
A diagnostic imaging test that records the distribution of pulmonary arterial blood flow.
- D. Lung Scintigraphy for Pulmonary Embolism  
A diagnostic imaging test that assesses pulmonary perfusion and often includes ventilation scintigraphy.

## III. Examples of Clinical or Research Applications

- A. The most common indication for lung scintigraphy is to determine the likelihood of pulmonary embolism.
- B. Less common indications (e.g. evaluation of lung transplantation, preoperative evaluation, right-to-left shunt evaluation) will be included in future versions of this guideline.

## IV. Procedure

### A. Patient Preparation

1. A chest radiograph should be obtained before lung scintigraphy for pulmonary embolism. A routine chest radiograph obtained in both the posterior-anterior and lateral projections is preferred. 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

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The Society of Nuclear Medicine (SNM) has written and approved these guidelines as an educational tool designed to promote the cost-effective use of high-quality nuclear medicine procedures or in the conduct of research and to assist practitioners in providing appropriate care for patients. The guidelines should not be deemed inclusive of all proper procedures nor exclusive of other procedures reasonably directed to obtaining the same results. They are neither inflexible rules nor requirements of practice and are not intended nor should they be used to establish a legal standard of care. For these reasons, SNM cautions against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment about the propriety of any specific procedure or course of action must be made by the physician when considering the circumstances presented. Thus, an approach that differs from the guidelines is not necessarily below the standard of care. A conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in his or her reasonable judgment, such course of action is indicated by the condition of the patient, limitations on available resources, or advances in knowledge or technology subsequent to publication of the guidelines.

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.

Advances in medicine occur at a rapid rate. The date of a guideline should always be considered in determining its current applicability.

within 1 day of scintigraphy is adequate. A more recent chest radiograph (preferably within 1 hr) is necessary in patients whose signs and symptoms are changing.

2. 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. Information Pertinent to Performing the Procedure

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. Pertinent clinical history includes, but is not limited to: a) right-to-left shunt; b) severe pulmonary hypertension; c) chest pain; d) dyspnea; e) hemoptysis; f) syncope; g) symptoms of deep venous thrombosis; h) oral contraceptive use; i) recent surgery; j) prior pulmonary embolism; k) cancer; l) congestive heart failure; m) antecedent illness; n) smoking; and o) intravenous drug abuse.
3. Pertinent findings on physical examination include, but are not limited to: a) vital signs, particularly respiratory rate; b) chest examination; c) cardiac examination; and d) leg findings.
4. Review of prior lung scintigraphy. Defects from prior pulmonary emboli do not always resolve completely.
5. 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.
6. Treatment with anticoagulant or thrombolytic therapy should be noted.

7. Results of tests for deep venous thrombosis, (e.g., compression ultrasonography), should be noted.
8. The referring physician's estimate of the prior probability of pulmonary embolism may be helpful.

### C. Precautions

Reduced numbers of macroaggregated albumin (MAA) 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.

### D. Radiopharmaceuticals

1. Aerosols
  - a.  $^{99m}\text{Tc}$  diethylenetriamine-pentaacetic acid (DTPA) is the preferred radiopharmaceutical.
  - b. The usual administered activity of  $^{99m}\text{Tc}$  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. Aerosol imaging is usually performed before perfusion imaging because it is more difficult to deliver a larger dose of the  $^{99m}\text{Tc}$  aerosol than it is to deliver a larger dose of  $^{99m}\text{Tc}$  macroaggregated albumin (MAA). Because both agents are labeled with  $^{99m}\text{Tc}$ , 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.  $^{81m}\text{Kr}$  is obtained from an  $^{81}\text{Rb}/^{81m}\text{Kr}$  generator.
  - b. The usual administered activity of  $^{81m}\text{Kr}$  is 40–400 MBq (1–10 mCi).

## Physical Characteristics of Radionuclides

<i>Radionuclide</i>	<i>T1/2</i>	<i>Photopeak (keV)</i>	<i>Decay</i>
$^{99m}\text{Tc}$	6 hour	140	IT
$^{133}\text{Xe}$	5.2 days	81	Beta
$^{81m}\text{Kr}$	13 seconds	190	IT

IT = Isomeric Transition

### Radiation Dosimetry – Adults<sup>1</sup>

Radiopharmaceutical	Administered Activity	Organ Receiving the Largest Radiation Dose	Effective Dose
	MBq (mCi)	mGy/MBq (rad/mCi)	mSv/MBq (rem/mCi)
<sup>99m</sup> Tc MAA <sup>1</sup>	40–150 (1–4)	0.067 Lung (0.25)	0.012 (0.044)
<sup>99m</sup> Tc DTPA <sup>2</sup>	20–40 (0.5–1.0)	0.047 Bladder (0.17)	0.0070 (0.026)
<sup>133</sup> Xe <sup>3</sup>	200–750 (5–20)	0.0011 Lung (0.0041)	0.0008 (0.0030)
<sup>81m</sup> Kr <sup>4</sup>	40–400 (1–10)	0.0068 Lung (0.025)	0.00070 (0.0026)

<sup>1</sup> ICRP 53, page 224

<sup>2</sup> ICRP, page 218

<sup>3</sup> ICRP, page 345, rebreathing for 5 minutes

<sup>4</sup> Package insert (Mediphysics, Inc., October 1990), rebreathing for 1 minute; ICRP 53, page 160

### Radiation Dosimetry in Children (5 year old)

Radiopharmaceutical	Administered Activity	Organ Receiving the Largest Radiation Dose	Effective Dose
	MBq/kg (mCi/kg)	mGy/MBq (rad/mCi)	mSv/MBq (rem/mCi)
<sup>99m</sup> Tc MAA <sup>1</sup>	0.5–2 (0.02–0.08)	0.21 Lung (0.78)	0.038 (0.14)
<sup>99m</sup> Tc DTPA <sup>2</sup>	0.4–0.6 (0.01–0.02)	0.12 Bladder (0.44)	0.020 (0.074)
<sup>133</sup> Xe <sup>3</sup>	10–12 (0.2–0.3)	0.0037 Lung (0.014)	0.0027 (0.01)
<sup>81m</sup> Kr <sup>4</sup>	0.5–5 (0.015–0.15)	0.022 Lung (0.081)	0.0023 (0.0085)

<sup>1</sup> ICRP 53, page 224

<sup>2</sup> ICRP, page 218

<sup>3</sup> ICRP, page 345, rebreathing for 5 minutes

<sup>4</sup> Package insert (Mediphysics, Inc., October 1990), rebreathing for 1 minute; ICRP 53, page 160

3. Xenon-133  
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).
4. Perfusion
  - a. The radiopharmaceutical used most commonly for perfusion imaging is  $^{99m}\text{Tc}$  MAA.
  - b. The biological half-life of the macroaggregated albumin in the lungs varies (usually 1.5 to 3 hr).
  - c. 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).
  - d. 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 (see Table 11.2, Treves, ST. Pediatric Nuclear Medicine, 2nd ed. New York, NY: Springer-Verlag; 1995, p.168).
  - e. 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.

## E. Image Acquisition

1. Sequence of Imaging
    - a. A chest radiograph should be obtained and reviewed before lung scintigraphy.
    - b. Ventilation scintigraphy using  $^{133}\text{Xe}$  is usually performed before perfusion scintigraphy using  $^{99m}\text{Tc}$ . Alternately, perfusion scintigraphy can be performed first and ventilation scintigraphy omitted if not needed.
    - c. The disadvantages of performing perfusion imaging first are:
      - i. With  $^{133}\text{Xe}$  gas or  $^{99m}\text{Tc}$  aerosol imaging, 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 first are:
      - 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 Kr-81m, images obtained with this gas can be alternated with those obtained with  $^{99m}\text{Tc}$  MAA.
  - f. When  $^{99m}\text{Tc}$  labeled aerosol imaging is performed before  $^{99m}\text{Tc}$  MAA perfusion imaging, smaller amounts (40 MBq [1.0 mCi]) of activity should be administered to the lungs.
2. 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 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.
  3. Xenon-133 Ventilation Imaging
    - a. An advantage of  $^{133}\text{Xe}$  ventilation is that single-breath, equilibrium and washout images can be obtained, which provide a more complete characterization of ventilation and a more sensitive test for obstructive airway disease. Physiologic information about ventilation can best be obtained from  $^{133}\text{Xe}$  imaging.
    - b. The imaging room should be at negative pressure with 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 washout.
    - e. If ventilation scintigraphy is performed after perfusion scintigraphy, a  $^{99m}\text{Tc}$  background image should be obtained using the  $^{133}\text{Xe}$  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 3–6 minutes as tolerated by the patient.
4. Krypton-81m Imaging
    - a. The advantage of  $^{81\text{m}}\text{Kr}$  is that images can be obtained in all views without interference from prior perfusion imaging. Alternating  $^{99\text{m}}\text{Tc}$  MAA and Kr-81m imaging allows ventilation and perfusion images to be obtained without patient repositioning between paired MAA and Kr-81m views.
    - b. The patient breathes continuously from the  $^{81}\text{Rb}/^{81\text{m}}\text{Kr}$  generator. Due to the short half-life of  $^{81\text{m}}\text{Kr}$ , the distribution of radioactivity approximates single-breath gas distribution.
    - c. A medium-energy collimator is preferred to image the 190 keV photopeak of  $^{81\text{m}}\text{Kr}$ .
    - d. The disadvantage of  $^{81\text{m}}\text{Kr}$  is that the short half-life of the generator decreases availability and increases cost.
  5. Perfusion Imaging
    - a. After having the patient cough and take several deep breaths,  $^{99\text{m}}\text{Tc}$  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. Single photon emission computed tomography (SPECT) can be used to obtain a three dimensional evaluation of the perfusion.

#### 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.

#### G. Processing

None.

#### H. Interpretation Criteria

1. Modified PIOPED criteria: The following modified PIOPED criteria were derived from a retrospective analysis of the PIOPED database. The criteria were prospectively tested and shown to be more accurate than the original PIOPED criteria.
  - a. High Probability ( $\geq 80\%$ , in the absence of conditions known to mimic pulmonary embolism)
    - i.  $\geq 2$  large mismatched segmental perfusion defects or the arithmetic equivalent in moderate or large and moderate defects. (A large segmental defect,  $>75\%$  of a segment, equals 1 segmental equivalent; a moderate defect,  $25\text{--}75\%$  of a segment, equals 0.5 segmental equivalents; a small defect,  $<25\%$  of a segment, is not counted.)
    - ii. Two large mismatched segmental perfusion defects, or the arithmetic equivalent, are borderline for “high probability.” Individual readers may correctly interpret individual images with this pattern as “high probability.” In general, it is recommended that more than this degree of mismatch be present for the “high probability” category.
  - b. Intermediate Probability (20%–79%)
    - i. One moderate to two large mismatched perfusion defects or the arithmetic equivalent in moderate or large and moderate defects.
    - ii. Single-matched ventilation-perfusion defect with a clear chest radiograph is borderline for “low probability” and thus should be categorized as “intermediate” in most circumstances by most readers, although individual readers may correctly interpret individual scintigrams with this pattern as “low probability.”
    - iii. Difficult to categorize as low or high or not described as low or high.
  - c. Low Probability ( $<19\%$ )
    - i. Nonsegmental perfusion defects (e.g. cardiomegaly, enlarged aorta, enlarged hila, elevated diaphragm).
    - ii. Any perfusion defect with a substantially larger chest radiographic abnormality.

- iii. Perfusion defects matched by ventilation abnormality (see IV.H.1.b.ii) provided that there are: a) clear chest radiograph; and b) some areas of normal perfusion in the lungs.
  - iv. Any number of small perfusion defects with a normal chest radiograph.
- d. Normal
- No perfusion defects or perfusion exactly outlines the shape of the lung seen on the chest radiograph (note that hilar and aortic impressions may be seen and the chest radiograph and/or ventilation may be abnormal).
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.
  3. Further Interpretive Considerations
    - 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 due to either right-to-left shunt, to free Tc-99m pertechnetate or reduced technetium compounds, or to a recent nuclear medicine procedure. An image of the head can be used to differentiate free pertechnetate/reduced technetium from a right-to-left shunt.
    - c. Some authors have found that neural network evaluation of lung scintigrams findings assists the interpretive process.
    - d. The stripe sign (activity at the periphery of a perfusion defect) lowers the chance of pulmonary embolism in the zone of the perfusion defect that shows the stripe.
- I. Reporting**
1. 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”).

2. The report should 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.

#### **J. Quality Control**

Radiochemical purity and particle size determination of <sup>99m</sup>Tc MAA should be performed. Reconstituted MAA should be stored in a refrigerator and be used before expiration.

#### **K. Sources of Error**

1. 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.
2. 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 in an upright position and perfusion scintigraphy injected in the supine position. These changes in position may also affect the comparability of the two scintigrams.
3. Injection of <sup>99m</sup>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.
4. 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.

#### **V. Issues Requiring Further Clarification**

- A. The utility of SPECT compared with planar imaging.

#### **VI. Concise Bibliography**

- A. British Thoracic Society guidelines for the management of suspected acute pulmonary embolism. *Thorax* 2003;58:470–484.  
*Includes a discussion of the prior probability of pulmonary embolism.*
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*The PIOPED database was reviewed retrospectively and modified PIOPED criteria were developed.*

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*Patients without documented thromboembolic disease who have low likelihood results from their lung scintigraphy have little thromboembolic disease in follow-up.*

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*The PIOPED criteria for interpretation of lung scintigraphy (see IV.H.1) were tested prospectively.*

- H. Sostman HD, Coleman RE, DeLong DM, et al. Evaluation of revised criteria for ventilation-perfusion scintigraphy in patients with suspected pulmonary embolism. *Radiology* 1994;193:103–107.

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*Management of patients with suspected pulmonary embolism on the basis of pretest probability and results of ventilation-perfusion scanning.*