ACR–ACNM–SNMMI–SPR–STR PRACTICE PARAMETER FOR THE PERFORMANCE OF PULMONARY 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), the Society for Pediatric Radiology (SPR), and the Society of Thoracic Radiology (STR).

It is intended to guide physicians performing pulmonary scintigraphy in adult and pediatric patients. Properly performed ventilation and perfusion imaging are sensitive tools for detecting certain pulmonary abnormalities. A critical element is to discriminate between functional air space or vascular pathologies that contribute to the

patient's symptoms. The interpretation of pulmonary scintigraphy is optimized by incorporating clinical data and relevant correlative imaging, including but not limited to, current chest radiography and computed tomography (CT).

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 [1].

II. INDICATIONS AND CONTRAINDICATIONS

Clinical indications for pulmonary scintigraphy include, but are not limited to, the following:

A. Indications

1. Assessment of acute pulmonary thromboembolic disease and chronic thromboembolic disease as an etiology of pulmonary arterial hypertension [2-5]. It is an alternative examination or a follow-up examination to CT pulmonary angiography in various clinical settings, including detection pulmonary emboli in young patients, particularly if pregnant [5-8].
2. Quantification of differential or regional pulmonary function (eg, evaluation of regional perfusion in patients with pulmonary artery anomaly)
3. Evaluation of transplanted lungs
4. Evaluation of pulmonary or cardiac right-to-left shunts
5. Evaluation of the functional significance of structural abnormalities of the chest, such as pectus excavatum and congenital diaphragmatic hernia
6. Confirmation of the presence of bronchopleural fistulae

B. Contraindications

There are no absolute contraindications for pulmonary scintigraphy. Potential benefits must outweigh the minor risks of the procedure.

The ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation provides useful information on radiation risks to the fetus regardless of source. Information on managing pregnant or potentially pregnant patients undergoing nuclear medicine procedures is available from the International Commission on Radiological Protection [9-11].

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR–ACNM–SNMMI–SPR Practice Parameter for the Use of Radiopharmaceuticals in Diagnostic Procedures [1].

IV. SPECIFICATIONS OF THE EXAMINATION

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

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). 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's scope of practice requirements. (ACR Resolution 35 adopted in 2006 – revised in 2016, Resolution 12-b)

IV. SPECIFICATIONS OF THE EXAMINATION

A. Pulmonary Perfusion Imaging

1. Radiopharmaceutical—Technetium-99m–labeled macroaggregated albumin (MAA) [12,13]

a. Administered Activity—Perfusion After Ventilation

i. Adult: 111–222 MBq (3.0– 6.0mCi)
ii. Pediatric: 2.6 MBq/kg (0.07 mCi/kg)

- Minimum 14.8 MBq (0.4 mCi)
- Maximum 185 MBq (5.0 mCi)

IV. SPECIFICATIONS OF THE EXAMINATION

A. Pulmonary Perfusion Imaging

1. Radiopharmaceutical—Technetium-99m–labeled macroaggregated albumin (MAA) [12,13]

b. Administered Activity—Ventilation After Perfusion or Perfusion Only

i. Adult: 37–111 MBq (1.0–3.0 mCi)
ii. Pediatric: 1.11 MBq/kg (0.03 mCi/kg)

- Minimum 14.8 MBq (0.4 mCi)
- Maximum 111 MBq (3.0 mCi)

IV. SPECIFICATIONS OF THE EXAMINATION

A. Pulmonary Perfusion Imaging

1. Radiopharmaceutical—Technetium-99m–labeled macroaggregated albumin (MAA) [12,13]

c. MAA Particle Size and Administered Number of Particles

i. Adult Patients

For adult patients: The range of particle sizes should be between 10 and 90 micrometers (microns) in diameter and should not exceed 150 micrometers (microns) with between 200,000 and 700,000 particles being injected.

For adult patients with known pulmonary arterial hypertension, a right-to-left shunt, previous pneumonectomy, or pregnancy: The number of particles may be decreased to between 100,000 and 150,000 particles

ii. Pediatric Patients

General: In all pediatric patients, except in the conditions below, administered activity should optimally minimize the radiation dose for the appropriate clinical indication and for appropriate image quality. See the table below for the recommended number of administered particles [5,14,15].

In children with severe pulmonary hypertension, a reduced administered particle number is recommended and should be based on age and weight. This usually ranges from 10,000 up to the adult number of particles. See the table below for the recommended number of administered particles [5,14,15].

For the diagnosis and quantitation of right-to-left vascular shunts in infants and children, the number of particles administered should be approximately 10,000. This is to reduce systemic microembolization. Moreover, unlike in the detection of perfusion defects, for this indication high spatial resolution is not necessary.

TABLE – MODIFIED Usual administered doses of ^{99m}Tc–macroaggregated albumin (^{99m}Tc-MAA)					
Parameter	Newborn	1 Year	5 Years	10 Years	15 Years
Body weight (kg)	3.5	12.1	20.3	33.5	55.0
Administered dose (MBq/mCi)	7.4/0.2	18.5/0.5	37.0/1.0	55.5/1.5	92.5/2.5
Range of particles administered (×1000)	10-50	50-150	200-300	200-300	200-700

IV. SPECIFICATIONS OF THE EXAMINATION

A. Pulmonary Perfusion Imaging

1. Radiopharmaceutical—Technetium-99m–labeled macroaggregated albumin (MAA) [12,13]

d. Radiopharmaceutical Administration

The patient should be supine for 10 minutes, before the injection. To minimize settling and clumping of technetium-99m–labeled MAA, the vial should be agitated gently before the radiopharmaceutical is withdrawn into the syringe, and then the syringe should be agitated gently before intravenous administration of the radiopharmaceutical. A 22-gauge or larger bore needle is preferred to help reduce the chance of damage to the particles. During intravenous injection, extreme care must be taken not to draw blood back into the syringe to avoid formation of clots, which may produce focal areas of increased radiopharmaceutical activity ("hot spots") on the lung perfusion images. When possible, the injection should be directly intravenous, avoiding intravenous tubing and use of indwelling catheters. The patient should remain supine for injection, and infusion should be slow (10–15 seconds). If possible, the patient should cough or take several deep breaths before and during the injection. If the perfusion examination is performed after an aerosol ventilation study, then the technologist should verify a 3- to 4-fold increase in the perfusion count rate when compared with the ventilation count rate.

IV. SPECIFICATIONS OF THE EXAMINATION

A. Pulmonary Perfusion Imaging

1. Radiopharmaceutical—Technetium-99m–labeled macroaggregated albumin (MAA) [12,13]

e. Imaging

Imaging with single-detector systems should be performed with the patient in the upright (sitting) position, if possible, because doing so provides improved visualization of the costophrenic angles. With dual-detector systems, both the injection and imaging are performed with the patient in the supine position. Imaging may begin immediately after the radiopharmaceutical has been administered. Preferably eight views (anterior, posterior, bilateral posterior oblique, bilateral anterior oblique, and both lateral images) should be obtained for 500,000–1,000,000 counts per image. Counts per image may be reduced in infants and small children. For critically ill patients undergoing pulmonary perfusion scintigraphy, a minimum of anterior, posterior, bilateral posterior oblique, and bilateral anterior oblique views is an alternative to the usual eight views.

For the diagnosis of pulmonary embolism, single photon emission CT (SPECT) or SPECT-CT may be used as a supplemental or alternative examination that can aid diagnosis [7,12,13,16-21]. Typical acquisition parameters would be low-energy, high-resolution collimator, a 360-degree orbit with 120 projections (3 degrees intervals), and 15 seconds per projection for perfusion imaging. SPECT-CT provides anatomic information that can aid diagnosis.

IV. SPECIFICATIONS OF THE EXAMINATION

B. Pulmonary Ventilation Imaging

1. Radiopharmaceutical—Technetium-99m-labeled diethylene-triamine pentacetic acid (DTPA) aerosol

DTPA is most often used because of favorable characteristics that include a relatively fast clearance and rapid renal excretion, which lowers patient radiation exposure.

a. Administered Activity—Perfusion After Ventilation

i. 1,110–1,850 MBq (30–50 mCi) is placed in a nebulizer and agitated with oxygen.
ii. Patient inhales to a count rate of 1,000–1,600 counts per second, which deposits approximately 37 MBq (1 mCi) in the lungs.

b. Administered Activity—Perfusion before Ventilation
i. 1,110–1,850 MBq (30–50 mCi) is placed in a nebulizer and agitated with oxygen
ii. Patient inhales to a count rate of 3–4 times that of the perfusion scan count rate.

c. Radiopharmaceutical Administration
The flow rate should be adjusted to deliver the aerosol droplet size at or below about 1 micrometer (micron) in diameter. Patient cooperation is required for success of the examination. Care should be exercised to prevent spillage of the aerosol into the environment.

d. Imaging

Ventilation images should be acquired in the same projections and with the same collimator used for the perfusion examination.

If SPECT or SPECT-CT is used for perfusion imaging, ventilation imaging would use acquisition parameters similar to perfusion imaging, but the time per projection should be at least 20 seconds to account for the lower count rate.

IV. SPECIFICATIONS OF THE EXAMINATION

B. Pulmonary Ventilation Imaging

2. Radiopharmaceutical—Xenon-133

Xenon-133, a radioactive gas, is administered by mask and requires a delivery and trapping system or external exhaust system.

IV. SPECIFICATIONS OF THE EXAMINATION

B. Pulmonary Ventilation Imaging

2. Radiopharmaceutical—Xenon-133

a. Administered activity

i. Adults: 370–1,110 MBq (10–30 mCi)
ii. Pediatrics: 11.1 MBq/kg (0.3 mCi/kg)
- Minimum: 111 MBq (3.0 mCi)

A room with negative pressure ventilation is desirable and is also dependent on the individual state regulatory requirements. Patient cooperation is very important for success of the examination. Care should be exercised to prevent leakage of the radiopharmaceutical into the environment; a xenon trap should be used. Patients who are severely dyspneic or who are on ventilator support may not be able to undergo xenon-133 ventilation imaging. Special adapters may be available to administer xenon-133 through an endotracheal tube. If available, aerosol ventilation imaging may be an alternative for these patients. In pediatric patients of any age and in adults who cannot cooperate, an effective and simpler method was described by Treves et al [22].

IV. SPECIFICATIONS OF THE EXAMINATION

B. Pulmonary Ventilation Imaging

2. Radiopharmaceutical—Xenon-133

b. Imaging

The ventilation phase is usually performed before the perfusion phase. Three sets of images are usually obtained, nearly always in the posterior projection with the same collimator used for the perfusion examination. These may be performed as three separate image acquisitions or may be acquired as parts of a single dynamic image acquisition. The first is a breath-holding view of the first deep breath after introduction of the radiopharmaceutical ("single breath image") for 10 seconds. The second is an "equilibrium" phase, during which the patient rebreathes the xenon-133 and oxygen, usually for 2 to 3 minutes, after which two static images at 90 seconds are acquired. The third is the "wash-out phase," during which the patient inhales room air, possibly mixed with oxygen, but exhales into the xenon-133 trap. Serial images are obtained at 15- to 60-second intervals for 3 to 5 minutes or until wash-out is complete, whichever comes first. Right and left posterior oblique equilibrium images may also be obtained early in the "equilibrium phase" and/or during wash-out (typically obtained during the third and fourth minutes of wash-out) to provide additional information about the location of ventilation abnormalities.

IV. SPECIFICATIONS OF THE EXAMINATION

C. Other Considerations

For patients being studied for acute pulmonary embolic disease, current chest radiographs, preferably posteroanterior and lateral, should be obtained and inspected by the interpreting physician to ascertain whether confounding conditions (eg, pneumonias, tumors, congestive heart failure, pleural effusions, pneumothoraces) are present. Optimally, chest radiographs should be obtained immediately before or after scintigraphy or, after any change in cardiopulmonary status, usually within 24 hours of the scintigraphic examination.

If available, prior pulmonary scintigrams, chest CT images, or abdominal CT images (if the abdominal CT examination includes the lower lungs) should be reviewed to evaluate for chronic unresolved pulmonary emboli or other persistent abnormalities. To help in correlation with tomographic studies, it is best to include SPECT or SPECT-CT imaging in the scintigraphic examination. In this context, SPECT allows for one-to-one correlation without the pitfall of overlapping structures such as the overlap between basilar posterior and basilar medial segments in the lower lobes.

Quantitative measures of split function or regional lung perfusion (comparing lungs or dividing each lung into halves or thirds and calculating the percentage of total counts in each region) may be useful in assessment of pulmonary artery anomaly or evaluation of post–lung transplant. Perfusion-only scan can be used to assess regional perfusion in children with congenital pulmonary artery anomaly.

Quantitation of lobar perfusion and ventilation may also be used in patients with lung lesions, such as cancer, to estimate residual lung function following planned total or partial pneumonectomy. Regions of interest (ROIs) are drawn to approximate counts in each lung zone. Recent chest CT should be reviewed to define anatomic abnormalities or previously resected lobes before drawing ROIs.

If a patient with an abnormal lung scan is diagnosed as having pulmonary emboli, a follow-up perfusion lung scan should be considered to establish a baseline for continued evaluation, particularly in patients with comorbid cardiopulmonary disease and/or a large initial perfusion deficit. Preferably, this follow-up examination should be performed 3–4 months following the initial thromboembolic episode.

The use of ventilation imaging may be modified in the setting of lung infection [23].

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [24].
The report should include the radiopharmaceutical, administered activity, and route of administration, as well as any other pharmaceuticals administered, also with dosage and route of administration.

The image interpretation should include a statement of the scan-based probability for pulmonary embolus using accepted criteria such as modified Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED II) in the case of ventilation/perfusion imaging or such as Prospective Investigative Study of Acute Pulmonary Embolism diagnosis (PISA-PED) if only perfusion imaging is done. If SPECT ventilation perfusion imaging is done, the

interpretation should be categorized into three possible outcomes: 1) consistent with pulmonary embolus, 2) inconclusive examination, or 3) not consistent with pulmonary embolus.

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 [25].

A single or multidetector planar or SPECT gamma camera may be used. Low-energy all-purpose/general-purpose (LEAP/GAP) or high-resolution parallel hole collimators may be used. Optionally, a SPECT/CT camera may be used

VII. RADIATION SAFETY IMAGING

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 and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *Position Statement on QC & 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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*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

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