# ACR–SPR–STR PRACTICE PARAMETER FOR THE PERFORMANCE OF HIGH-RESOLUTION COMPUTED TOMOGRAPHY (HRCT) OF THE LUNGS



## 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

High-resolution computed tomography (HRCT) imaging of the lungs is well established for diagnosing and managing many pulmonary diseases but is primarily intended for the evaluation of known or suspected interstitial lung disease [1-8]. Optimal methods of acquisition and interpretation of HRCT images require knowledge of anatomy and pathophysiology [9] as well as familiarity with the basic physics and techniques of CT. This practice parameter outlines the principles for high-quality HRCT images of the lungs.

The main objective of HRCT is to detect, characterize, and determine the extent of diseases that involve the lung parenchyma, providing diagnosis of the pathologies using standard nomenclature [10, 11].

HRCT is the use of thin-section CT images (≤1.5 mm, preferably 1 mm or less slice thickness) with a high spatial frequency reconstruction algorithm to detect and characterize diseases that affect the pulmonary parenchyma and small airways [12]. Images are generally acquired without the administration of intravenous (IV) contrast, although IV contrast may be appropriate in select circumstances such as co-existing pulmonary vascular disease. Following the development and widespread availability of multidetector CT (MDCT) scanners capable of acquiring near-isotropic data throughout the entire thorax in a single breath-hold, HRCT has been performed using MDCT for the last decade [13-17]. The acquisition of volumetric single breath-hold CT data, allows spaced, contiguous, and/or overlapping HRCT images to be reconstructed based on protocol selected. The volumetric data can be postprocessed to construct multiplanar (MPR) images [15]enhance select structures as in maximum intensity projection (MIP), and minimum intensity projections (minIP). Quantitative CT assessment is emerging as an important technique for determining the extent of fibrotic and obstructive lung diseases and requires specific standardized protocols that will not be addressed here [18]. The older approach to HRCT used noncontiguous inspiratory thin-section images acquired at 10–20mm intervals through the lungs. Although this method substantially reduces the radiation dose, its diagnostic value is more limited and is not generally recommended in the modern era of alternative lower dose techniques.

HRCT images are routinely acquired at suspended full inspiration with patients in the supine position. Additional options, useful in many cases, include obtaining inspiratory prone images to differentiate posterior lung disease from dependent atelectasis and end-expiratory images to evaluate for air trapping [19]. Coronal and sagittal reconstructions are also routinely acquired and can help in determining the distribution of the abnormality.

Pediatric patients deserve special consideration, as pathologies and scan techniques often differ from those of adults. Although low and ultralow-dose CT are generally favored and achievable with newly introduced CT scanner technology and reconstruction methods, slightly higher doses may be appropriate to reduce image noise and increase diagnostic confidence in such settings as childhood interstitial lung disease [20]. Patients under the age of 4 to 6 months can generally be immobilized by a feed and swaddle technique but will not be able to breath hold for an inspiratory or expiratory scan. Toddlers and young children (less than 7 years [21, 22] ) will also not have the ability to follow commands and may require sedation or extra coaching and support to remain still and attempt a breath hold. Unsedated free-breathing acquisitions are often adequate for many pediatric indications, further facilitated by newer techniques such as high-pitch helical acquisition [20]. However, dedicated inspiratory or expiratory imaging may be required for accurate evaluation of some diffuse lung pathologies [22]. The options for sedation must be carefully considered when necessary. The less invasive method is to sedate a child and use face-mask ventilation with induced transient respiratory pauses. In case this is not deemed sufficient, then endotracheal intubation is performed, which comes with its inherent risk of atelectasis that may impair interpretation. In such cases, lung recruitment techniques and controlled ventilation may be needed in children to obtain adequate quality images [23]. Effective communication among radiologists, imaging technologists, nurses and other members of the imaging team is of paramount importance to prospectively clarify requirements for each scan with the anesthesia/sedation team and develop an appropriate plan.

## II. INDICATIONS AND CONTRAINDICATIONS

A. Indications

The indications for the use of HRCT of the lungs include, but are not limited to, the following [2, 9, 24-32]:

1. Evaluation of known or clinically suspected diffuse lung disease - obstructive and restrictive and/or interstitial lung disease
2. Evaluation of small airway disease
3. Visual or quantitative estimation of the extent of diffuse lung disease and presence of fibrosis for evaluating effectiveness of treatment
4. Guidance in the selection of the most appropriate site for biopsy of diffuse lung disease
5. Pneumoconiosis [33]

B. Contraindications
There are no absolute contraindications to HRCT of the lungs. As with any imaging procedure, the benefits and risks should be considered before the thoracic CT performance.

For the pregnant or potentially pregnant patient, see the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation [34].

For imaging of diffuse lung disease in the pediatric patient, please refer to the ACR–ASER–SABI-SPR Practice Parameter for the Performance of Pediatric Computed Tomography (CT) [35].

## III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR-SPR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) [36].

The physician is responsible for reviewing all indications for the examination, specifying the precise technical factors to be used for the HRCT study, generating a final report, and monitoring and maintaining the quality of images and interpretation.

The physician should be thoroughly acquainted with the many anatomic and physiologic manifestations of thoracic disease. Radiologists interpreting HRCT should have specific familiarity with the diagnosis of interstitial lung diseases. Additionally, supervising physicians should have appropriate knowledge of alternative modalities for the imaging of the thorax, including chest radiography and standard thoracic CT as well as angiography, ultrasonography, magnetic resonance imaging (MRI), and nuclear medicine studies.

The CT technologist must be familiar with optimal techniques for acquiring an HRCT examination, and in particular, need to communicate breathing instructions with the patient to ensure high-quality, motion-free inspiratory and expiratory images.

## IV. SPECIFICATIONS AND PERFORMANCE OF THE EXAMINATION

### A. Written Request for the Examination

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

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

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient’s clinical problem or question and consistent with the state scope of practice requirements. (ACR Resolution 17 adopted in 2006 – revised in 2009, 2013, Resolution 52)

## IV. SPECIFICATIONS AND PERFORMANCE OF THE EXAMINATION

### B. Technical Parameters

Although many of the operations of a CT scanner are automated, many technical parameters remain operator dependent. Because these factors can significantly affect the diagnostic value of the HRCT examination [1, 37-39], it is necessary for the supervising physician to be familiar with the following:

1. Radiation exposure factors (Milliampere-Seconds, Kilovoltage peak)
2. Collimation
3. Table increment or pitch and gantry rotation time and table speed
4. Matrix size, and reconstruction field of view
5. Window settings (width and center)
6. Reconstruction algorithm (kernel) and reconstruction techniques
7. Display section thickness for multidetector systems and image reconstruction interval or increment
8. Detector configuration for multidetector systems
9. Automatic exposure control (angular and longitudinal tube current modulation) and image quality reference parameter
10. Reformatted images (MPR, MIP, and minIP) and image plane (axial, coronal, sagittal)
11. Axial or helical acquisition mode
12. Radiation dose indices report

## IV. SPECIFICATIONS AND PERFORMANCE OF THE EXAMINATION

### C. Optimal HRCT Protocol

Optimization of the CT examination requires the supervising physician to develop an appropriate HRCT protocol based on careful review of relevant patient history and clinical indications as well as all previously available imaging studies that are relevant.

1. Protocols should be prepared according to the specific medical indication. Techniques that provide image quality consistent with the diagnostic needs of the examination at acceptably low radiation dose levels to the patient should be selected. When volumetric HRCT data are acquired, utilization of MPR capabilities is encouraged to facilitate assessment of disease distribution and morphology. For each indication, the protocol should include at least the following:
   a. Tube potential and tube current appropriate to patient size. For the lowest radiation exposure to provide diagnostic quality, see the ACR–AAPM–SPR Practice Parameter for Diagnostic Reference Levels and Achievable Doses in Medical X-Ray Imaging [40]. Using similar technical parameters for each study facilitates direct comparison between studies and is of value if quantitative CT measurements are employed.
   b. Techniques available to minimize radiation exposure (eg, tube current modulation) should be used. Imaging using lower radiation settings is subject to image noise, which can be offset with iterative reconstruction techniques [41]. However, special caution should be taken when using iterative techniques because high degrees of iterative reconstruction weighting may obscure subtle interstitial pulmonary findings and lead to an inaccurate characterization of the patient's underlying lung disease.
   c. Proper supine and/or prone patient positioning with optimal breathing instructions.
   d. State of respiration (inspiration and/or expiration) with appropriate breathing instructions; it is critical to obtain inspiratory scans on full inspiration. Expiratory images are typically acquired at end-maximal expiration.

      Uncooperative children may require use of anesthesia with controlled ventilation. However, use of anesthesia is discouraged unless truly necessary for accurate diagnosis due to inherent risks of anesthesia and the potential for related atelectasis obscuring findings. Depending on the indication, adequate studies on children can often be obtained with rapid free breathing images without inspiratory or expiratory breath-holds.

e. Table speed for volumetric HRCT to enable single breath-hold acquisition, when possible.
f. Axial (incremental HRCT) or helical (volumetric HRCT) modes of data acquisition. As mentioned above, helical, volumetric acquisition is generally recommended for the inspiratory acquisition. For expiratory and prone acquisitions, depending on institutional preference, one may choose either direct axial acquisition with nonirradiated increments of 10 –20 mm or low-dose volumetric acquisition . However, if using a wide-detector array scanner, the entire chest of an infant or child up to 3 years can be scanned using the nonhelical axial mode in a single subsecond gantry rotation and would be preferred over the helical mode of the same scanner to minimize motion artifact in this setting.
g. Gantry rotation: =1 s.
h. Reconstructed image thickness (0.5 -1mm for axial CT, ≤1.5-mm nominal slice thickness for helical CT).
i. Moderately high spatial-frequency reconstruction algorithm, such as a bone algorithm for lung images. Avoid use of an overly sharp reconstruction algorithm, which would create excessive image noise and high degrees of iterative reconstruction, which can decrease spatial resolution [41, 42].
j. Proper patient positioning at isocenter to minimize radiation dose and optimize image quality
k. Superior and inferior extent of the region of interest to be imaged, typically from the lung apices to the costophrenic sulci. For prone acquisition, a limited z-axis is recommended from the carina to the lung bases to decrease radiation exposure. For expiratory imaging, a full z-axis coverage of the lungs is recommended.
l. Plane, thickness, and interval for reconstructions or reformats (eg, coronal, sagittal, oblique MPRs and MIPs) sent to the PACS.
m. Retention of the radiation exposure report in the radiological record, in alignment with the ACR–SABI–SPR Practice Parameter for the Performance of Thoracic Computed Tomography (CT) [43].

2. Attention should be directed toward the following:
   a. Radiation exposure based on the parameters indicated in the ACR–SABI–SPR Practice Parameter for the Performance of Thoracic Computed Tomography (CT) [43], considering factors influencing radiation dose, particularly for small adults, and techniques such as increasing pitch, lowering tube current or kilovoltage, and limiting the z-axis coverage to the region of clinical question. Other factors that can decrease radiation dose are the use of sequential acquisition and larger interscan gap, which can be employed when expiratory and prone HRCT imaging is performed to supplement an inspiratory examination. The appropriateness of prone imaging should be determined in all patients, particularly on subsequent HRCT scans; omitting unnecessary sequences provides an opportunity to reduce dose.
   b. Producing motion-free images at the appropriate inspiratory and expiratory level

3. IV iodinated contrast should generally not be used when performing an HRCT to exclusively evaluate the lung parenchyma and small airways. In addition, IV contrast adds little value to the interpretation of diffuse lung disease yet exposes patients to the risks associated with the administration of iodinated contrast.

**V. DOCUMENTATION**

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [10, 44][-3197621].

**VI. EQUIPMENT SPECIFICATIONS**

Equipment performance monitoring should be in accordance with the ACR–AAPM Technical Standard for

Diagnostic Medical Physics Performance Monitoring of Computed Tomography (CT) Equipment [45].

To achieve acceptable clinical HRCT scans of the lungs, a CT scanner should meet or exceed the following capabilities as specified in the ACR–SABI–SPR Practice Parameter for the Performance of Thoracic Computed Tomography (CT) [43]:

1. Scan times: a scan time of <1 s per image may apply to direct axial acquisition but may not apply to helical CT acquisition of HRCT images
2. Image thickness: <;;;=1.5mm
3. Algorithm available: bone or moderately high spatial frequency
4. Axial mode available on CT scanner

Review capability of a PACS workstation should be available to the radiologist; authorized health care providers should be able to review images remotely. A method for digitally transmitting the image data should be available.

## VII. RADIATION SAFETY IN 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

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.

Facilities should have and adhere to policies and procedures that require ionizing radiation examination protocols (radiography, fluoroscopy, interventional radiology, CT) to vary according to diagnostic requirements and patient body habitus to optimize the relationship between appropriate radiation dose and adequate image quality. Automated dose reduction technologies available on imaging equipment should be used, except when inappropriate for a specific exam. If such technology is not available, appropriate manual techniques should be used.

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

A Qualified Medical Physicist should perform an annual survey of the CT unit. More frequent QC tests should be performed by a trained CT technologist. These QC tests and their frequencies should be under the supervision of the QMP.

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 *ACR Position Statement on Quality Control and Improvement, Safety, Infection Control and Patient Education* on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).


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