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

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 in light of 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 the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

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 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 sole 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, ___ N.W.2d ___ (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 [1-7]. Optimal methods of acquisition and interpretation of HRCT images require knowledge of anatomy and pathophysiology [8], as well as familiarity with the basic physics and techniques of computed tomography. This parameter outlines the principles for performing high-quality HRCT of the lungs.

II. DEFINITIONS

HRCT is the use of thin-section CT images (0.625-mm to 1.5-mm slice thickness) with a high spatial frequency reconstruction algorithm, to detect and characterize diseases that affect the pulmonary parenchyma and small airways [9]. 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, 2 general approaches are available for acquiring HRCT images [10-14]. The first and more traditional method entails obtaining axial HRCT images spaced at 10-mm to 20-mm intervals throughout the lungs. The second method uses the ability of MDCT scanners to provide volumetric single breath-hold datasets allowing spaced, contiguous, and/or overlapping HRCT images to be reconstructed. With MDCT, the volumetric data enables multiplanar thin-section HRCT reconstruction, which facilitates evaluation of the distribution of diffuse lung disease [15,16] and the application of postprocessing techniques such as maximum intensity projection (MIP), minimum intensity projection (minIP), and software that uses volumetric data for quantification of features in the lungs and airways [14,17-19].

Optimal performance of HRCT studies requires familiarity with the advantages and disadvantages of each HRCT method, with the choice between these approaches reflecting available equipment, clinical indication(s), and radiation dose considerations.

With both methods, image data 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 [20-23].

III. GOAL

The main objective of HRCT is to detect, characterize, and determine the extent of diseases that involve the lung parenchyma and airways.

IV. PATIENT INDICATIONS AND CONTRAINDICATIONS

A. Indications

The indications for the use of HRCT of the lungs include, but are not limited to, the following [2,7,8,24-31]:

1. Evaluation of known or clinically suspected diffuse lung disease that is incompletely evaluated on standard chest CT or chest x-ray or that which is chest x-ray occult
2. Evaluation of suspected small airway disease
3. Quantification of the extent of diffuse lung disease for evaluating effectiveness of treatment
4. Guidance in selection of the most appropriate site for biopsy of diffuse lung disease

B. Contraindications

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

For the pregnant or potentially pregnant patient, see the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation [32].

For imaging of diffuse lung disease in the pediatric patient, please refer to the ACR-ASER-SCBT-MR-SPR Practice Parameter for the Performance of Pediatric Computed Tomography (CT) [33].

V.   QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) [34].

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. Additionally, supervising physicians should have appropriate knowledge of alternative modalities for imaging of the thorax, including chest radiography and standard thoracic CT, as well as angiography, ultrasonography, magnetic resonance imaging, and nuclear medicine studies.

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

VI.   SPECIFICATIONS AND PERFORMANCE OF THE EXAMINATION

A. Written Request for the Examination

The written or electronic request for a HRCT of the lungs 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 scope of practice requirements. (ACR Resolution 35, adopted in 2006)

B. Technical Parameters

Although many of the operations of a CT scanner are automated, a number of technical parameters remain operator-dependent. As these factors can significantly affect the diagnostic value of the HRCT examination [4,23,35,36], it is necessary for the supervising physician to be familiar with the following:

1. Radiation exposure factors (mAs, KvP)
2. Collimation
3. Display section thickness for multidetector systems
4. Table increment or pitch and gantry rotation time and table speed
5. Matrix size, scan field of view, and reconstruction field of view
6. Window settings (width and center)
7. Reconstruction algorithm, filter or kernel
8. Image reconstruction interval or increment

9. Detector configuration for multidetector systems
10. Automatic exposure control (angular and longitudinal tube current modulation) and image quality reference parameter
11. Radiation dose report
12. Reformatted images (multiplanar (MPR), curvilinear, MIP, and minIP) and 3-D surface or volume-rendered (VR) and image plane (axial, coronal, sagittal)
13. Reconstruction techniques such as filtered back projection or iterative reconstruction
14. Axial or helical mode of the CT scanner

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 prior available imaging studies that are relevant.

1. Protocols should be prepared according to the specific medical indication. Technique should be selected that provide image quality consistent with the diagnostic needs of the examination at acceptably low radiation dose levels to the patient. When volumetric HRCT data are acquired, utilization of the multiplanar 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. Typically this entails use of 120 (kVp) and approximately ≤240 mAs. Use of lower tube potentials (eg, 100 kVp) and tube-current settings is encouraged, especially for younger patients or those who may need serial imaging. In this case, using similar technical parameters for each study facilitates direct comparison between studies and is of particular value if quantitative CT measurements are employed.
   b. Utilization of techniques available to minimize dose (eg, tube current modulation) is encouraged.
   c. Proper supine and/or prone patient positioning with optimal breathing instructions
   d. State of respiration (inspiration and/or expiration), with appropriate breathing instructions; Expiratory images are typically acquired at end-expiration.
   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. Acquiring exploratory and/or prone sequence images in a helical fashion is discouraged. For those sequences, axial acquisition with nonirradiated increments of 10–20 mm or more is preferable.
   g. Gantry rotation: ≤1 second
   h. Reconstructed image thickness (≤ 1.5 mm 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
   j. Proper patient positioning (positioning the patient 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 additional series such as prone or expiratory HRCT imaging, shorter z-axis coverage and/or greater increment between imaging locations is encouraged to decrease patient radiation exposure.
   l. When possible, scan field of view should be selected appropriate to patient size at time of image.
   m. Reconstructed field of view limited to the lungs adjusted for small, medium, and large patients to optimize spatial resolution for each patient
   n. Plane, thickness, and interval for reconstructions or reformats (eg, coronal, sagittal, oblique MPRs and MIPs) from volumetric HRCT data to be sent to the picture archiving and communications system (PACS) or reconstruction directly at the PACS workstation.
   o. Retention of the radiation dose report in the radiological record, in alignment with the ACR-SCBT-MR-SPR Practice Parameter for the Performance of Thoracic Computed Tomography [37].

2. Attention should be directed toward the following:
    a. Radiation dose to the degree indicated in the [ACR-SCBT-MR-SPR Practice Parameter for the Performance of Thoracic Computed Tomography](#) [37], considering factors influencing radiation dose, particularly for small adults. Techniques such as increasing pitch, lowering tube current or kV, 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 necessity of prone imaging should be considered in all patients, particularly on subsequent HRCT scans; omitting unnecessary sequences provides an opportunity to reduce dose. Alternatives to breast shielding need to be carefully considered and utilized. Please refer to the AAPM Position Statement on the Use of Bismuth Shielding for the Purpose of Dose Reduction in CT Scanning at (http://www.aapm.org/publicgeneral/BismuthShielding.pdf).
    b. Producing motion-free images at the appropriate inspiratory and expiratory level

3. Use of intravenous (IV) iodinated contrast should not be used when performing an HRCT to evaluate the lung parenchyma and small airways primarily, as subtle pulmonary findings may be obscured by intrapulmonary contrast. In addition, IV contrast adds little value to the interpretation of diffuse lung disease while exposing patients to the risks associated with the administration of iodinated contrast.

4. Periodic update and review of the HRCT protocol

VII.   DOCUMENTATION

Reporting should be in accordance with the [ACR Practice Parameter for Communication of Diagnostic Imaging Findings](#) [38,39].

VIII.   EQUIPMENT SPECIFICATIONS

To achieve acceptable clinical HRCT scans of the lungs, a CT scanner should meet or exceed the following capabilities as specified in the [ACR-SCBT-MR-SPR Practice Parameter for the Performance of Thoracic Computed Tomography](#) [37]:

1. Scan times: ≤1 second per image; A scan time of <1 second per image may apply to direct axial acquisition but may not apply to helical CT acquisition of HRCT images.
2. Image thickness: ≤ 1.5 mm
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.

IX.   RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, registered radiologist assistants, 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 that work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection and application of dose limits) and the principles of proper management of radiation dose to patients (justification, optimization and the use of dose reference levels) http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578_web-57265295.pdf.

Nationally developed guidelines, such as the ACR's Appropriateness Criteria®, should be used to help choose the most appropriate imaging procedures to prevent unwarranted radiation exposure.

Facilities should have and adhere to policies and procedures that require varying ionizing radiation examination protocols (plain radiography, fluoroscopy, interventional radiology, CT) to take into account patient body habitus (such as patient dimensions, weight, or body mass index) to optimize the relationship between minimal radiation dose and adequate image quality. Automated dose reduction technologies available on imaging equipment should be used whenever appropriate. If such technology is not available, appropriate manual techniques should be used.

Additional information regarding patient radiation safety in imaging is available at the Image Gently® for children (www.imagegently.org) and Image Wisely® for adults (www.imagewisely.org) websites. 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 measured and patient radiation dose estimated for representative examinations and types of patients by a Qualified Medical Physicist in accordance with the applicable ACR technical standards. Regular auditing of patient dose indices should be performed by comparing the facility's dose information with national benchmarks, such as the ACR Dose Index Registry, the 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. (ACR Resolution 17 adopted in 2006 – revised in 2009, 2013, Resolution 52).

X.   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 (http://www.acr.org/guidelines).

Equipment performance monitoring should be in accordance with the ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Computed Tomography (CT) Equipment [40].

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