ACR–SABI–SPR–STR PRACTICE PARAMETER FOR THE PERFORMANCE OF THORACIC COMPUTED TOMOGRAPHY (CT)

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 Society of Advanced Body Imaging (SABI), the Society for Pediatric Radiology (SPR), and the Society of Thoracic Radiology (STR).

Computed tomography (CT) is a frequently used imaging modality for the diagnosis and evaluation of many thoracic diseases. Optimal performance of thoracic CT requires knowledge of normal anatomy, anatomic variants, pathophysiology, CT techniques, and the associated risks. This practice parameter outlines the principles for performing high-quality thoracic CT in adults and children.

The goal of thoracic CT is to demonstrate normal and pathologic anatomy and physiology within the chest.

II. INDICATIONS AND CONTRAINDICATIONS

A. Thoracic CT may be a complementary examination to other imaging studies such as chest radiography (see the ACR–SPR–STR Practice Parameter for the Performance of Chest Radiography) or a stand-alone procedure. Indications for the use of thoracic CT include, but are not limited to [1]:

1. Evaluation of abnormalities discovered on other imaging modalities, including chest radiography [2]
2. Screening for lung cancer [3]
3. Staging and follow-up of lung cancer and other primary thoracic malignancies and detection and evaluation of metastatic disease [4-7]
4. Evaluation of cardiothoracic manifestations of known extrathoracic diseases [8-11]
5. Evaluation of known or suspected thoracic cardiovascular abnormalities (congenital or acquired), including aortic stenosis, aortic aneurysms, and dissection [12-14]
6. Evaluation of suspected pulmonary emboli, pulmonary hypertension, pulmonary vascular malformations, and pulmonary venous abnormalities [15-24]
7. Evaluation and follow-up of pulmonary parenchymal and airway disease [26-33]
8. Evaluation of blunt and penetrating trauma [34,35]
9. Performance of CT-guided interventional procedures [36-39]
10. Evaluation of the chest wall [40-42]
11. Evaluation of pleural disease [43,44]
12. Evaluation of the mediastinum
13. Treatment planning for surgical or radiation therapy [45,46]
14. Response to therapies including chemotherapy, immunotherapy, and ablative therapies
15. Evaluation of medical complications in the intensive care unit or other settings [47,48]
16. Evaluation of postoperative patients and surgical complications [49-51]
17. Identification and location of devices within the lungs and cardiovascular system
18. Evaluation of patients with suspected complicated pneumonia, suspected pneumonia in immunocompromised patients, or fever of unknown origin

B. For more details regarding the use of low-dose CT in screening for lung cancer, see the ACR–STR Practice Parameter for the Performance and Reporting of Lung Cancer Screening Thoracic Computed Tomography (CT) [53].

C. For more details regarding the use of CT in assessing a variety of pulmonary diseases, see the ACR–STR Practice Parameter for the Performance of High-Resolution Computed Tomography (HRCT) of the Lungs in Adults [54].

D. There are no absolute contraindications to thoracic CT. As with all procedures, the relative benefits and risks of the procedure should be evaluated before the performance of thoracic CT, with or without the administration of intravenous iodinated contrast or oral contrast media. See the ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media and the ACR Manual on Contrast Media [55,56].) Appropriate precautions should be taken to minimize patient risks, including radiation exposure [57,58].

Iterative reconstruction algorithms and automatic exposure control techniques including tube current modulation and automatic kV selection, if available, are valuable for this purpose [59-61].

For the pregnant or potentially pregnant patient, see the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation [58].

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) [64].

IV. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for a thoracic CT examination 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 – revised in 2016, Resolution 12-b)

A. A typical CT of the thorax should include axial images from the lung apices to the posterior costophrenic sulci usually reconstructed at = 5–3 mm slice thickness with both soft tissue and a high spatial frequency (lung or bone) reconstruction algorithm. =1.2 mm slice thickness is preferable unless volumetric reconstructions are also routinely created. Volumetric images can be reconstructed using <1.25 mm slice thickness with a high spatial frequency reconstruction algorithm. Sagittal and coronal reconstructions at axial image matched thickness are recommended. Contiguous or overlapping transverse maximum intensity projection (MIP) images with 5–10 mm slab thickness can help in the detection of lung nodules (along with thin slices). Minimum intensity projection (MinIP) images with <10 mm slab thickness can help assess emphysema and air trapping. MIP, MinIP, and volume rendered images should be generated with soft tissue reconstruction kernel. Computer-aided diagnosis software can help assess lung nodules, airways, emphysema, coronary artery calcification, and/or pulmonary emboli.

B. During most examinations, scans should be obtained at suspended full inspiration. There are a few exceptions:
   1. Breath hold at full inspiration can lead to interruption of injection contrast bolus and suboptimal pulmonary artery enhancement in CT pulmonary angiography (CTPA). For CTPA, patients must be instructed to suspend breathing at a comfortable tidal inspiratory volume for the scan duration instead of holding a breath in full inspiration.
   2. In neonates and infants, imaging during quiet free-breathing may be preferable to breath-hold under anesthesia, if rapid (eg, <1 second) acquisition is possible. Faster scanners (scan acquisition time <1 second) may allow adequate images with free breathing without the need for sedation or anesthesia [62-66].
   3. Free-breathing CT may be preferred in patients (both children and adults) who cannot hold their breath for the duration of chest CT. This may provide sufficiently "motion-free" images, particularly on scanners with faster gantry rotation times (<0.5 seconds), wide area detectors (8-16 cm detector width along the longitudinal axis), and/or high nonoverlapping pitch (>1.5:1) [67,68].
   4. There are two ways of acquiring expiratory An end-expiratory breath-hold scan is sufficient for assessing air trapping. For suspected tracheobronchomalacia, a scan acquired during, forceful (continuous dynamic) expiration is more sensitive than expiratory breath-hold CT [71]. . Cine imaging

may be appropriate for evaluating certain disease states such as tracheomalacia [69,70].

5. Respiratory-gated CT may be helpful in certain applications such as radiation therapy planning. Electrocardiographic (ECG) synchronizing is valuable for aortic and cardiac imaging.

C. Imaging should be obtained through the entire area of interest [72]. For low-dose chest CT, such as for lung nodule follow-up and lung cancer screening, the area of interest should be limited to the entire lungs; extending scan length to cover the adrenal glands is not recommended.

D. The field of view should be optimized for each patient. Scout topogram images should be transmitted to the PACS for review. A "full field of view" reconstruction may reveal abnormalities (eg, skin) not visible on other series. For thin-section CT reconstructed with high spatial frequency reconstruction algorithm, in order to maximize spatial resolution, field of view should be limited to rib cage (rib-to-rib) rather than skin-to-skin coverage. This is especially important for high-resolution chest CT protocols for diffuse lung diseases.

E. The examination may be conducted with and/or without intravenous iodinated contrast media as clinically indicated. In children, one scan (single phase) is sufficient except in a minority of CT angiography procedures (see section VIII, Image Gently®). The exam may be conducted after administration of water-soluble oral contrast to evaluate for esophageal perforation.

F. Anatomically appropriate window and level settings should be used to view the lung parenchyma, mediastinum, vasculature, chest wall, skeletal structures, any visible portions of the lower neck and upper abdomen, and implanted metallic devices. Review on a PACS (picture archiving and communication system) workstation facilitates evaluation of many studies, particularly those with large data sets. Multiplanar viewing is encouraged to facilitate the display of anatomy and pathology [73,74]. 3-D visualization and/or measurement software may be helpful in certain circumstances.

G. Although many of the operations of a CT scanner are automated, a number of technical parameters remain operator-dependent. Because these parameters can significantly affect the diagnostic quality of a CT examination, the supervising physician must be familiar with the following:

1. Radiation exposure factors (mAs, kVp, specifically weight-based suggested parameters for children) [75,76]
2. Dual-energy and spectral CT techniques (if these features are present/in use in the facility's CT units)
3. Automatic exposure control (angular and longitudinal tube current modulation) and image quality reference parameter
4. Automatic tube potential selection technique and reference parameter
5. Beam collimation and detector configuration
6. Table increment and pitch
7. Acquisition mode, eg, sequential, spiral, or single-shot
8. Reconstructed section thickness
9. Image reconstruction interval or increment
10. Reconstruction techniques such as filtered back projection or iterative reconstruction
11. Reconstruction algorithm, filter, or kernel
12. Acquisition and reconstruction field of view
13. Reconstruction matrix (512, 768, 1024, and 2048) [77,78]
14. Window settings (width and center)
15. Radiation dose information page, dose report, and dose descriptors including CT dose index volume (CTDIvol) and dose length product
16. Reformatted images (MPR, curvilinear, MIP, MinIP, and 3-D surface or volume rendered)
17. Prospective ECG-triggering or retrospective ECG-gating, which is helpful to reduce cardiac or aortic motion artifacts and to visualize cardiovascular structures
18. Intravenous contrast media use and injection techniques including the use of timing or test bolus as well as mono- versus polyphasic contrast injection techniques

H. Optimizing CT examination technique requires the supervising physician to select an appropriate CT protocol based on careful review of the patient history (including risk factors that might increase the likelihood of adverse reactions to contrast media) and clinical indications, as well as relevant prior imaging studies when available. This optimization process includes determining if the thoracic CT examination is clinically appropriate or if another imaging modality would be more appropriate for answering the clinical question.

I. Protocols may be prepared according to region of interest and clinical indication. Techniques should be selected that provide image quality consistent with the diagnostic needs of the examination at optimal radiation dose levels to answer the clinical question(s) posed. For each area of interest or indication, the protocol should indicate the following:

1. If gastrointestinal contrast material is used, the volume, type, route of administration (oral or via nasogastric or other tube), and the time intervals during which it should be delivered.
2. If intravenous contrast material is used, the type, volume, rate of administration, and time delay between administration and scan initiation. Bolus tracking or a timing bolus should be used whenever indicated to optimize results.
3. Detector configuration
4. Pitch (table increment and feed)
5. Reconstructed section thickness
6. Reconstruction interval or increment
7. Reconstruction matrix (>512 matrix images can help improve spatial resolution for evaluation of lung parenchyma and small airways)
8. Reconstruction technique and kernel, algorithm, or filter
9. kVp and effective mAs per section as appropriate for adult or pediatric patients. With tube current modulation, a prescribed image quality with maximum and minimum mAs as appropriate for adult or pediatric patients.
10. Noise index, noise standard deviation, quality reference mAs, or reference image (image quality reference parameter for automatic tube current modulation), type of reconstruction (filtered back projection versus iterative reconstruction), and percentage of reconstruction type ("strength”) used for presentation images.
11. With automatic tube potential (kVp) selection techniques, users should be familiar with reference tube potential values, and specific examination type (such as noncontrast, contrast-enhanced, and CT angiography)
12. Use of dual-energy and spectral scanning mode requires familiarity with monoenergetic and material decomposition images. Users must be familiar with their vendor-specific dual-energy or spectral CT requirements to ensure appropriate use and radiation dose.
13. Superior and inferior extent of the region of interest to be imaged
14. Field of view
15. Protocols for sending images to PACS (eg, section thickness and plane of reformations such as coronal, sagittal, and other oblique projections), and the Medical Image Processing System as needed.
16. 2-D and 3-D reconstructions and measurements where appropriate to further delineate known or suspected abnormalities.
17. For every CT examination, the information in the radiation dose report (containing CTDI, dose length product, and other information) should be retained in the radiological record (such as the PACS, in a radiation dose monitoring software tool, and/or the radiology report) for reference.

    These protocols should be reviewed and updated annually, and dated copies should be available to appropriate physicians, radiologic technologists, medical physicists, and administrative personnel at the facility.

J. For all patients, particularly pediatric patients and small adults, efforts should be directed to:

1. Minimize radiation dose when diagnostically feasible by using automatic exposure control techniques that adjust for patient size or by using low mA or kV settings as well as using iterative or

deep learning reconstruction algorithms and tightly restricting the scan range to the body region of clinical concern. X-ray tube current modulation should be used if available .

Although bismuth shields have been shown to reduce radiation doses in some limited studies, there are several disadvantages associated with their use, especially when used with automatic exposure control (tube current modulation). Other techniques exist that can provide the same level of anterior dose reduction at equivalent or superior image quality without these disadvantages. The American Association of Physicists in Medicine (AAPM) recommends that these alternatives to bismuth shielding be carefully considered and implemented when possible (see the AAPM Position Statement on the Use of Bismuth Shielding for the Purpose of Dose Reduction in CT Scanning at https://www.aapm.org/org/policies/details.asp?id=431&type=PP and the policy rationale at https://www.aapm.org/publicgeneral/BismuthShielding.pdf [79]).

2. Minimize motion artifact with short scan times (balanced against any changes in mA in order to maintain appropriate mAs) and, when necessary, using appropriate sedation.

3. When sedation is used, it should be administered in accordance with the ACR–SIR Practice Parameter for Mild and/or Moderate Sedation/Analgesia [80].

4. The use of dual-energy technique to perform thoracic CT may be valuable in certain instances, including assessment of acute and chronic pulmonary emboli, other vascular disorders, lung malignancy, and parenchymal disease [81].

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [82].

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 [83].

A. Performance Guidelines

To achieve acceptable clinical CT scans of the thorax, a CT scanner should meet or exceed the following capabilities:

1. Type of scanner: multiple detector rows, helical capability
2. Single breath hold acquisition
3. Gantry rotation time: =1 sec
4. Acquired slice thickness: =5 mm
5. Reconstructed scan width: =5 mm
6. Beam pitch: no greater than 2:1.
7. Limiting spatial resolution: =8 lp/cm for =32-cm display field of view (DFOV) and =10 lp/cm for <24-cm DFOV
8. Tube heat capacity to allow for study completion
9. Dose reduction techniques, such as tube-current modulation, variable tube potential, and advanced reconstruction (eg, iterative or deep learning) should be used to reduce exposure to patients.
10. Radiation monitoring software
11. Capable of performing a low-dose lung CT of CTDIvol =3 mGy for a standard size patient.

B. Patient monitoring equipment, medications, and facilities for cardiopulmonary resuscitation, including vital signs monitoring, support equipment, and an emergency crash cart, should be immediately available.

Radiologists, technologists, and staff members should be able to assist with procedures, patient monitoring, and patient support. A written policy should be in place for dealing with emergency situations such as cardiopulmonary arrest.

C. Images should be available on a PACS workstation for review by the radiologist. Remote viewing of images with approved software and viewing stations should also be available to authorized health care providers. Equipment should be capable of providing a digital means of conveying the data set. Regular quality assurance checks should be performed.

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).

A Qualified Medical Physicist and radiologist together should verify that any dose reduction devices or utilities maintain acceptable image quality while actually reducing radiation dose.

Dose estimates for typical examinations should be compared to reference levels described in the ACR–AAPM Practice Parameter for Diagnostic Reference Levels in Medical X-Ray Imaging [84].

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).

The quality control program for CT equipment should be designed to minimize patient, personnel, and public radiation risks and to maximize the quality of the diagnostic information. The program should be supervised by a Qualified Medical Physicist. Each imaging facility should have documented policies and procedures that include:

1. A list of tests to be performed and the frequency of performance.
2. A list identifying which individual or group will perform the tests.
3. A written description of the procedure that will be used for each test, including the technique factors to be employed, the equipment to be used for testing, the acceptability limits of each test, and sample records from each test.
4. Periodic tests for CT technologists to ensure that they understand CT principles and are complying with dose reduction protocols for multidetector CT imaging.

For specific issues regarding CT quality control, see the ACR Practice Parameter for Performing and Interpreting Computed Tomography (CT) [64].

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