ACR–ASER–SCBT-MR–SPR PRACTICE PARAMETER FOR THE PERFORMANCE OF PEDIATRIC COMPUTED TOMOGRAPHY (CT)

Revised 2019 (Resolution 6)

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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 developed collaboratively by the American College of Radiology (ACR), the American Society of Emergency Radiology (ASER), the Society of Computed Body Tomography and Magnetic Resonance (SCBT-MR), and the Society for Pediatric Radiology (SPR).

Computed tomography (CT) is a radiologic modality that provides clinical information in the detection, differentiation, and demarcation of disease. It is the primary diagnostic modality for a variety of presenting problems and is widely accepted as a supplement to other imaging techniques. In selected cases, CT is used for guidance of interventional procedures.

CT is a form of medical imaging that involves the exposure of patients to ionizing radiation. It should only be performed under the supervision of a physician with the necessary training in radiation protection to optimize examination safety. Medical physicists and trained technical staff must be available to evaluate the equipment and perform the examination.

CT examinations should be performed only for a valid medical reason and with the minimum exposure that provides the image quality necessary for adequate diagnostic information.

Because children are more sensitive than adults to the effects of ionizing radiation, it is particularly important to tailor CT examinations to minimize exposure while providing diagnostic-quality examinations [1]. Protocols should include CT scan parameters, contrast administration, and anatomical coverage. CT scan parameters (eg, rotation time, pitch, peak kilovoltage (kVp), milliampere-seconds (mAs), tube current modulation, beam collimation) should be tailored to the child's body size. If contrast is used, the type of contrast, volume, method of administration (intravenous [IV], oral, rectal, intravesical), scan delay time, and rate of contrast injection should be specified [2-6].

Nonionizing imaging studies, such as ultrasound (US) and magnetic resonance imaging (MRI) should be considered in some cases as an alternative to CT when appropriate. Reasons to consider using CT over MRI include the availability of CT, higher spatial resolution, shorter examination, less need for sedation, and the presence of contraindications for MRI.

II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) [7].

III. INDICATIONS

A. Chest

CT is the preferred cross-sectional imaging modality for detailed evaluation of anatomy and pathology of the lung and tracheobronchial tree. In addition to US and MRI, CT may also be used for evaluation of certain thoracic bony, mediastinal, and cardiac abnormalities.

Primary indications for CT include, but are not limited to, the following:

1. Chest wall abnormalities [8-15]
    a. Extent of chest wall developmental deformities, such as pectus excavatum, pectus carinatum, and thoracic insufficiency syndrome secondary to scoliosis or rib anomalies. CT scan for some chest wall deformities (eg, pectus excavatum) may be limited to the area of deformity using very low dose technique, although MRI is increasingly being used in these instances [16].
    b. Chest wall injury, including penetrating trauma and injuries that are not adequately addressed by radiography, such as sternal fractures, sternoclavicular dislocation, and occult rib fractures.
    c. Chest wall mass and mass-like conditions that include inflammatory/infectious processes. This also includes evaluation of posttreatment complications and residual or recurrent mass.
2. Extracardiac vascular disorder [17-23]

a. Congenital and syndromic vascular abnormalities, such as vascular rings, pulmonary slings, pulmonary vein abnormalities (eg, anomalous course), systemic-to-pulmonary collateral vessels, coarctation of the aorta, or other congenital lesions with anomalous blood supply (eg, bronchopulmonary sequestration)
b. Acquired disorders of the great vessels (eg, medium- or large-vessel vasculitides, aneurysms, stenoses, infectious or other inflammatory conditions) and posttraumatic evaluation. Assessment includes aortic dissection, transection, and pulmonary embolism.

3. Cardiac disease. See the ACR–NASCI–SPR Practice Parameter for the Performance and Interpretation of Cardiac Computed Tomography (CT) [7].

4. Tracheobronchial abnormalities, including tracheal rings; tracheobronchial narrowing secondary to vascular anomaly, mass, inflammatory/infectious process, suspected foreign body, or congenital anomaly; postoperative complications of lung transplant [23-28]; and dynamic evaluation of the airway for the assessment of congenital or acquired tracheobronchomalacia [29].

5. Mediastinal congenital abnormalities and masses [30-32].
   a. Neoplasms—These include, but are not restricted to, germ cell tumors, lymphoma, or thymic tumors. Posterior mediastinal neurogenic tumors can also be imaged by CT, although MRI is often more useful to depict chest wall, vertebral, neural foraminal, or intraspinal involvement.
   b. Congenital abnormalities, such as ectopic thymic tissue and bronchopulmonary foregut malformations that affect the mediastinum. The latter include bronchogenic cyst, esophageal duplication cyst, and neuroenteric cyst. Congenital abnormalities in a paraspinal location may be better evaluated with MRI to assess for potential chest wall, vertebral, neural foraminal, or intraspinal disease.
   c. Infectious or inflammatory processes affecting the mediastinum, such as lymphadenitis, mediastinitis, abscess, or sternal osteomyelitis.
   d. Trauma that is not adequately assessed by radiography. CT angiography can be considered for evaluation of suspected major thoracic vascular injury.

6. Lung—CT is the primary cross-sectional imaging modality to evaluate the lung parenchyma [33-51].

   a. Infection/pneumonia complicated by involvement of the pleural space (such as parapneumonic effusion, empyema, or bronchopleural fistula), the lung (such as cavitation/necrosis or abscess), or the pericardium (such as purulent pericarditis). For evaluation of parapneumonic effusion and empyema, US should be considered as the first and primary imaging modality, with CT reserved for evaluation of aerated portions of the lung and more complicated cases with parenchymal complications. In patients with persistent or recurrent pneumonias or whose plain radiography is atypical for pneumonia, CT is used to assess for possible underlying congenital lesion or mass. CT is also used to assess the sequelae of respiratory infections (such as bronchiectasis and bronchiolitis obliterans). In immunocompromised patients, CT can be used in the absence of definite plain-radiography abnormality to detect early manifestations of opportunistic infections.
   b. Diffuse/interstitial lung disease, either primary or related to systemic processes, such as collagen vascular, connective tissue, or autoimmune diseases. These studies may include inspiratory and expiratory scans. Additional limited imaging in a prone or decubitus position may help differentiate between dependent atelectasis and lung parenchymal abnormality. Some patients with cystic fibrosis may be followed with limited reduced-dose high-resolution CT.
   c. Congenital pulmonary abnormalities that include bronchopulmonary foregut malformation, congenital pulmonary airway malformations (CPAM), congenital lung hyperinflation, pulmonary sequestration, bronchial atresia, tracheal diverticula, tracheal bronchus, pulmonary agenesis or hypoplasia, and related conditions, such as horseshoe lung and pulmonary arteriovenous malformation.
   d. Malignancy, including patients with underlying extrapulmonary primary malignancy that may metastasize to lung and primary lung neoplasms, including inflammatory myofibroblastic tumor (plasma cell granuloma), pleuropulmonary blastoma, bronchial carcinoid, and mucoepidermoid

carcinoma. In immunocompromised patients, CT is used in the evaluation for lymphoproliferative disease or smooth-muscle (spindle cell) tumors.

e. Traumatic injuries not adequately assessed by radiography, such as pulmonary contusions and lacerations.

III. INDICATIONS

B. Abdomen and Pelvis

CT of the abdomen and pelvis is the preferred cross-sectional imaging for evaluation of abdominal and pelvic trauma. MRI may be used as an alternative method for many abdominopelvic indications. CT can be used as an alternative study to MRI in evaluation of solid viscus and bowel. CT is often used as an adjunct or follow-up to US when findings are equivocal or when there is a need for additional anatomic detail or other information (eg, nephrolithiasis, solid viscus, bowel, and vascular pathology).

1. Hollow viscera [52-67]
    a. Inflammatory or infectious processes affecting the gastrointestinal (GI) tract, including the gastroesophageal junction, stomach, small intestine, colon, or appendix. These processes include, but are not limited to, appendicitis, infectious enteritis, inflammatory bowel disease, neutropenic colitis, or radiation enteritis, although MRI may also be used in some of these instances [68].
    b. Congenital abnormalities, including gastrointestinal duplication cysts, and complications of omphalomesenteric duct remnants, such as Meckel diverticulitis.
    c. Benign and malignant neoplasms, including, but not limited to, lymphoma (particularly Burkitt lymphoma), gastrointestinal stromal tumor (GIST), lipoma, and large polyps.
    d. Trauma, blunt or penetrating abdominal trauma, to demonstrate bowel injury including intramural hematoma and perforation.
    e. Bowel obstruction.

2. Liver and gallbladder [69-76]
    a. Primary or secondary hepatic neoplasms, including, but not limited to, hepatoblastoma and hepatocellular carcinoma, as well as liver metastases to evaluate for the presence and extent of tumor in the liver
    b. Blunt or penetrating trauma, including nonaccidental trauma, to assess the extent of parenchymal and hepatic vascular injury.
    c. Hepatic infection, including pyogenic or amebic liver abscesses.
    d. Congenital abnormalities of the liver and biliary tree, including heterotaxy and associated anomalies.
    e. Gallbladder and biliary tract disorders are typically best evaluated with US, MRI, and nuclear medicine studies. CT may be used in selected cases to supplement US in the evaluation of gallbladder and biliary tract disorders.

3. Pancreas [77-82]
    a. Complications of pancreatitis, including pancreatic hemorrhage or necrosis, peripancreatic vascular thrombosis, pseudocyst formation, secondary inflammation of hollow visceral structures, or duct abnormalities, including stones or dilation.
    b. Pancreatic tumors to further characterize the extent of lesion, staging, and involvement of adjacent structures.
    c. Blunt or penetrating abdominal trauma to evaluate the integrity of the gland, the extent of pancreatic injury, including fracture or pancreatic ductal injury, and injury to adjacent solid or hollow visceral structures.

4. Kidneys [83-92]
    a. Urinary tract stones in children with hematuria. CT may be used when US and radiographs do not provide enough information for optimal management.
    b. Renal or ureteral trauma. Additional delayed imaging may be useful if injury to the collecting system is suspected. Split-dose IV contrast in suspected renal trauma can demonstrate both parenchymal

and collecting system injury with one imaging acquisition.
c. Detection and staging of renal tumors (benign and malignant), including vascular invasion.
d. Congenital anomalies of the genitourinary tract.
e. Obstruction of the urinary tract secondary, but not limited to, nephrolithiasis, mass, infection/inflammation, or trauma.
f. Complications of infection of the urinary tract (eg, acute pyelonephritis), including renal/perirenal abscess.
g. Renovascular evaluation in the setting of traumatic injury, renal donor transplant evaluation, or regional masses. CT angiography can also be used in selected patients to evaluate for renovascular hypertension

5. Adrenal gland [93-97]
   a. Evaluation of blunt or penetrating trauma with suspected adrenal hemorrhage.
   b. Adrenal neoplasms, such as neuroblastoma, ganglioneuroma, ganglioneuroblastoma, and adrenocortical neoplasms (adenoma and carcinoma).

6. Spleen [98-104]
   a. Splenic injury in the setting of blunt or penetrating trauma.
   b. Primary cystic or solid lesions of the spleen.
   c. Other conditions, such as infarction, sequestration (sickle cell disease), granulomatous disease, wandering spleen/torsion.

7. Pelvis [105-107]
   a. Mass or mass-like conditions of the pelvic organs, including inflammatory/infectious processes, vascular malformations, and evaluation of lymph nodes.
   b. Anomalies of the genital tract not adequately assessed by US or genitogram, or where MRI is contraindicated or not available.
   c. Bladder rupture after trauma or bladder surgery. Dedicated CT cystography techniques can be performed as indicated.

8. Mesentery/omentum/peritoneum/retroperitoneum/vascular/abdominal wall/diaphragm [108-112]
   a. Inflammatory or infectious processes affecting the mesentery, peritoneum, or omentum, such as an abscess and generalized peritonitis.
   b. Peritoneal fluid characterization and quantification, when appropriate.
   c.
   d. Cystic malformations, including mesenteric/omental cyst and lymphatic malformation.
   e. Benign or malignant neoplastic processes, including teratoma, sarcoma, and spread of disease to the peritoneum and/or retroperitoneum.
   f. Omental infarction.
   g. Posttraumatic abnormalities of the mesentery, abdominal wall, or diaphragm.
   h. Congenital abnormalities of the abdominal wall or diaphragm.
   i. Arterial and venous abnormalities, such as vasculitis, thrombosis, narrowing, aneurysm, dissection, and varices.

III. INDICATIONS

C. Extremities/Musculoskeletal

CT may supplement plain radiography for characterization and evaluation of extent of bone lesions and fractures, evaluation of orthopedic implant complications, and assessment of alignment deformities. CT is better than MRI in assessment of cortical and trabecular bone abnormalities. CT has lower contrast resolution and less sensitivity compared with MRI in evaluation of bone marrow and soft-tissues pathology, but CT can be used in selected cases where MRI is contraindicated or not readily available.

1. General indications [113-138]

a. Bone abnormality not adequately assessed by radiographs
b. Congenital bone malformations
c. Inflammatory conditions, such as osteomyelitis and myositis, when MRI is contraindicated or unavailable
d. Fractures and follow-up of fracture complications (such as premature growth plate fusion and intra-articular loose bodies)
e. Tumors of the bone or soft tissues
f. Osteochondral lesions, when MRI is contraindicated or unavailable
g. Foreign bodies

2. Shoulder [123-125]

Evaluation of glenoid morphology, glenoid dysplasia, and acquired glenohumeral deformity related to perinatal brachial plexus injury, although MRI is being increasingly used in these instances.

3. Pelvis, hip, and thigh [126-131]
   a. Congenital malformations not adequately assessed by radiographs or sonography, including postoperative assessment of reduction of developmental dysplasia of the hip
   b. Measurement of femoral and acetabular version
   c. Deformity related to epiphyseal osteonecrosis (including Legg-Calve-Perthes)
   d. Femoral head impingement syndrome
   e. Sacroiliitis
   f. Apophysitis

4. Knee and leg [132-134]
   a. Kinematic assessment of patellofemoral joint
   b. Preoperative tibial tuberosity trochlear groove assessment in patients with patellar tracking abnormalities
   c. Tibial torsion

III. INDICATIONS

D. Foot and ankle [135-138]

1. Fractures in the foot or ankle not optimally assessed by radiographs, including, but not limited to, Tillaux and triplane fractures of the ankle or other fractures involving the tibial plafond
2. Tarsal coalition, diagnosis, and follow-up after surgery

III. INDICATIONS

E. Head and spine

See the ACR–ASNR–SPR Practice Parameter for the Performance of Computed Tomography (CT) of the Brain [139] and the ACR–ASNR–ASSR–SPR Practice Parameter for the Performance of Computed Tomography (CT) of the Spine [140].

IV. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for pediatric CT 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 and/or 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 35, adopted in 2006 – revised in 2016, Resolution 12-b)

Images should be labeled with the following: (a) patient identification, (b) facility identification, (c) examination date, and (d) the side (right or left) of the anatomic site imaged.

Additionally, an attempt should be made to obtain and review prior studies.

IV. SPECIFICATIONS OF THE EXAMINATION

A. General Considerations [2-6]

Pediatric CT may require different examination preparation and performance than in adults. Preparation includes ensuring appropriate NPO status if moderate sedation or general anesthesia is potentially necessary.

With the advent of faster CT scanner technology, general anesthesia or sedation can be avoided in many children. Patient/parent preparation, well-trained technologists, child life specialists, and distraction techniques/equipment are helpful in this regard. Additionally, reduced use of IV contrast when appropriate (eg, follow-up of lung metastatic disease) may allow for easier performance and greater acceptance of nonsedated CT scans.

Certain indications require administration of IV contrast media. IV contrast enhancement should be performed using appropriate injection protocols and in accordance with the institution's policy on IV contrast utilization. (See the ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media [141] and the ACR Manual on Contrast Media [142].)

For scan performance, single-phase scanning is the standard rather than the exception. Only the necessary scan coverage should be obtained, and scan parameters including beam collimation, tube current, gantry cycle time, pitch, and kVp—should be adjusted for the size of the child, the region scanned, and the clinical indications.

The physician responsible for the examination must supervise patient selection and preparation and be available for consultation. All personnel who inject intravascular contrast media (ICM) should be prepared to (1) recognize the variety of adverse events that may occur following ICM administration and (2) institute appropriate measures to manage the reaction. These measures include notifying the supervising radiologist (or his/her designee), monitoring the patient, administering certain medications, and/or calling for additional assistance (emergency service providers, "code team," etc). (See the ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media [141] and the ACR Manual on Contrast Media [142].)

Appropriate emergency equipment and medications must be immediately available for consultation or to treat adverse reactions associated with administered medications. See Table 6 of the ACR Manual on Contrast Media [142].

IV. SPECIFICATIONS OF THE EXAMINATION

B. Examination Technique [2-6,143-163]

General Observations:

Scanning parameters should be optimized to obtain diagnostic image quality while adhering to the as low as reasonably achievable (ALARA) principle. The scan area should be restricted according to the clinical indication, with areas not involved in the clinical problem excluded from the scan. The scanning parameters, including kVp and exposure time product (mAs), should be changed according to body size, regions of interest, and clinical indication. This can be achieved by using weight-based or cross-sectional size tables and by using automatic exposure control (see www.imagegently.org). In addition, mAs should be further reduced if noncontrast scans are performed only to evaluate calcifications or for cases in which only gross bony relationships are being evaluated,

such as scans done for preoperative pectus excavatum evaluation. Noise-reducing reconstruction technique (eg, iterative reconstruction), if available, can be used to improve image quality and allow use of decrease dose [143].

IV. SPECIFICATIONS OF THE EXAMINATION

B. Examination Technique [2-6,143-163]

1. Chest [2-6,152-159]

a. Use of cutting-edge technologies for reducing exposure, such as dose modulation and iterative reconstruction, are preferred, if available [164,165]. The use of bismuth shields is controversial. Shielding can reduce dose to anterior organs, such as breast, lens of the eye, and thyroid in CT scanning. There are disadvantages associated with the use of bismuth shields. Bismuth shields may induce image artifacts and increased image noise, which limits measurements of attenuation. If used, the shield needs to be elevated from the anterior chest wall (eg, by laying it on several towels or a sponge), and it should be flat without internal bends to decrease artifacts. In order to avoid increased radiation dose to the patient, the shielding should NOT be in place during scout image acquisition when using automatic exposure control or tube current modulation because the radiation dose to the patient may increase. Other techniques, including automated tube current modulation or kilovoltage selection, can provide the same level of anterior dose reduction at equivalent or superior image quality.

b. The examination may be conducted with or without IV contrast as clinically indicated. A contrast dosage of 1.5 to 2 mL/kg (to a maximum not exceeding the usual adult dose) is used routinely. Volume of contrast, rate of injection, scan delay time, and hand/power injection should be determined according to the location, size, and type of the IV access, the child's body size, the underlying disease (such as congestive heart failure), and the clinical indication. The use of dual-energy CT and low-kilovoltage imaging may allow further reduction in the volume of contrast needed, particularly for angiographic applications [166,167].

c. High-resolution algorithms for reconstruction of CT data may be useful if the primary indication is for the evaluation of interstitial lung disease, as sharper algorithms are helpful in the evaluation of lung parenchyma in older children. The original dataset can be reconstructed with both routine and high-resolution algorithms if both soft-tissue and pulmonary parenchymal information is needed, without need to rescan the patient. It is important to remember that not all diagnostic chest CT studies in infants and children require imaging of the entire anatomy of the chest. In certain clinical situations, if only a sampling of the lung parenchyma is required to answer a specific clinical question (eg, to rule out bronchiectasis or diffuse/interstitial lung disease), a limited number (eg, 4-6 slices) of 1 to 1.25 mm noncontiguous axial slices can be obtained and reconstructed in a high-resolution algorithm. The gap between the noncontiguous axial images may be increased incrementally as patient size increases. Expiratory images at larger intervals can be useful for evaluation of diseases of the small bronchi.

d. Postprocessing 2-D reformations, maximum intensity projection (MIP) reconstructions, and 3-D volume rendering may be useful adjuncts in displaying the anatomy. The 2-D reformation and sliding thin-slab MIP techniques have been found to increase sensitivity in the detection of lung nodules and arteriovenous malformations, and 3-D volume rendered images may also add value to presurgical planning and patient/family education, tumor and/or lung volume measurements, as well as be used for 3-D printing of illustrative models.

IV. SPECIFICATIONS OF THE EXAMINATION

B. Examination Technique [2-6,143-163]

2. Abdomen [2-6,160-163]

a. Scanning parameters should be optimized to obtain diagnostic image quality while adhering to the ALARA principle. The scan area should be minimized according to the clinical indication. The scanning parameters,

including kVp, tube current, and exposure time (mAs), should be changed according to body size, area of interest, and clinical indication. This can be achieved by using weight or dimension-based tables or by using automatic exposure control (see imagegently.org). The testicles should not be included in the scanned area unless absolutely necessary for the clinical indication. If dual-energy CT is used, noncontrast scans can be reconstructed after the scan, avoiding the use on precontrast scans.

b. IV contrast injection is usually used in the CT evaluation of the pediatric abdomen because of the paucity of body fat in many pediatric patients. There are some exceptions, including renal stone evaluation. A routine dose of 1.5 to 2 mL/kg is generally used. Volume of contrast, rate of injection, scan delay time, and hand/power injection should be determined according to the location, size, and type of the IV access, the child's body size, the underlying disease, and the clinical indication.

c. Enteric contrast may be used in the CT evaluation of the pediatric abdomen. Choices of administration route (eg, oral, rectal, or enteric tube) and type of contrast (eg, positive or neutral attenuation) will depend on factors such as the clinical questions to be answered and patient age. Enteric contrast is not typically used in renal stone protocol, CT angiography, or acute trauma.

d. In the evaluation of the pediatric patient for suspected appendicitis, IV contrast is typically used, particularly to avoid potential repeat scans that are due to equivocal findings. Precontrast scans and delayed scans are usually not necessary. Some centers use oral contrast material. If oral contrast is given, sufficient time should be allowed to elapse for the contrast to reach the right lower quadrant prior to scanning. Rectal contrast is rarely used.

e. Postprocessing 2-D reformations, MIP reconstructions, and 3-D volume rendering may be useful adjuncts in displaying the anatomy, especially in evaluation of vascular anatomy. The 3-D volume rendered images may be used for presurgical planning and patient/family education, tumor volume tracking measurements, as well as 3-D printing of illustrative models.

IV. SPECIFICATIONS OF THE EXAMINATION

B. Examination Technique [2-6,143-163]

3. Extremities

a. IV contrast is usually not necessary if only evaluation of the bone structure is needed. IV contrast may be necessary for assessment of blood vessels and soft tissues when indicated.

b. Sharper reconstruction algorithms are needed for better spatial resolution and bone detail. Smoother algorithms are better for soft-tissue evaluation and 3-D postprocessing.

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [168].

VI. EQUIPMENT SPECIFICATIONS

In the interest of pediatric patient safety, it is necessary to have a general knowledge of the CT equipment, including the use of weight- or dimension-adjusted mA and kVp, beam collimation, slice thickness, pitch, rotation time, matrix, image filter, noise-reducing reconstruction technique (eg, iterative reconstruction), display field of view (DFOV), and tube current modulation techniques (longitudinal and angular). In some CT scanners, the tube current can be automatically adjusted by a predetermined selection of the quality (eg, noise level or reference mAs) of the study. Other dose-reduction techniques include automatic exposure control or organ-based angular modulation that reduces mA to anterior organs, such as the breasts. Optimal kVp can be achieved by manual

charts according to patient size and type of study (eg, routine or CT angiography) or with automated selection technology. The equipment should be in good working order, meet manufacturer and regulatory standards, and be operated safely. The equipment needs to be tested for spatial and low-contrast resolution and be well-calibrated at all times [178]. Technologists and radiologists should be aware of important artifacts and know how to avoid problems associated with them. [2-6,144-147,149-151,156,162]

A. Performance Standards

To achieve acceptable clinical CT scans of body, the CT scanner should meet or exceed the following specifications:

1. Gantry rotation time: =1 second
2. Detector width: =1 mm
3. Tube voltage: ranging from 70 to 120 kVp
4. Limiting spatial resolution: 8 lp/cm for =32 cm DFOV and =10 lp/cm for <24 cm DFOV

With the advent of dual-energy CT and spectral CT [169-172], which can be performed with doses comparable to single-energy CT [173], more centers are making use of this technology in the diagnosis of pediatric disease [174,175], as the process of material decomposition allows for:

A.

1. Virtual noncontrast scans that can avoid dual-phase imaging and can show calcifications in kidneys, tumors, pancreatitis, and mural plaques in the presence of contrast. Virtual noncontrast images permit automated bone subtraction, improving visualization of vessels.
2. Low monoenergetic images, which improve CT angiography by boosting iodine signal-to-noise ratio(SNR), can salvage mistimed or poor bolus studies, and allow use of less iodine contrast in CT examinations.
3. Low monoenergetic images improve contrast-to-noise ratio (CNR) in soft tissues and thus lesion detection.
4. Low monoenergetic images to improve head CT gray-white matter differentiation and help in detection of low-contrast lesions and cerebral ischemia/stroke.
5. The use of virtual monoenergetic images allows to suppress artifact in the posterior fossa [176] and in the presence of metallic implants and surgical hardware.
6. Perfusion imaging iodine maps improve detection of pulmonary embolism, flow following repair of congenital heart disease, arteriovenous malformations, myocardial ischemia, and solid organ perfusion defects, such as pyelonephritis, and likewise demonstrate regions of hyperenhancement.
7. Iodine overlays are helpful to characterize indeterminate lesions and assess tumor vascularity.
8. Renal mass/cyst characterization. This technology can evaluate lesions "too small to characterize," discriminate hyperdense or protein-laden cysts from solid lesions, identify renal calculi within contrast material, and gauge tumor vascularity/viability and treatment response.
9. Renal stone characterization

B. Appropriate emergency equipment and medications must be immediately available to treat adverse reactions associated with administered medications. See Table 6 of the ACR Manual on Contrast Media [142]. The equipment, medications, and other emergency support must be appropriate for the range of age and size in the patient populations.

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 against reference levels described in the ACR–AAPM–SPR Practice Parameter for Diagnostic Reference Levels and Achievable Doses in Medical X-Ray Imaging [177].

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).

Equipment monitoring and the continuous quality control program should be in accordance with the ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Computed Tomography (CT) Equipment [178].

ACKNOWLEDGEMENTS

This practice parameter was revised according to the process described under the heading *The Process for Developing ACR Practice Parameters and Technical Standards* on the ACR website (https://www.acr.org/Clinical-Resources/Practice-Parameters-and-Technical-Standards) by the Committee on Practice Parameters – Pediatric Radiology of the ACR Commissions on Pediatric Radiology in collaboration with the ASER, SCBT-MR, and SPR.

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*Practice parameters and technical standards are published annually with an effective date of October 1in 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.

Development Chronology for this Practice Parameter

2008 (Resolution 22)

Amended 2009 (Resolution 11)

Revised 2014 (Resolution 3)

Revised 2019 (Resolution 6)

Amended 2023 (Resolution 2c, 2d)