ACR–SABI–SAR–SPR PRACTICE PARAMETER FOR THE PERFORMANCE OF COMPUTED TOMOGRAPHY (CT) OF THE ABDOMEN AND COMPUTED TOMOGRAPHY (CT) OF THE PELVIS

Revised 2021 (Resolution 46)

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.

---

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

Computed tomography (CT) is a radiologic modality that utilizes ionizing radiation to obtain cross-sectional images of a patient. The images are acquired in the patient's axial plane and may also be reprocessed to produce images in many additional anatomic planes or may be processed to produce volumetric data sets of structures like organs, vessels, or bones. Optimal performance of CT requires knowledge of anatomy and pathophysiology, familiarity with the basic physics and techniques of CT, and knowledge of radiation safety. This practice parameter outlines the principles for performing high-quality diagnostic abdominal CT and/or pelvic CT examinations.

II. INDICATIONS AND CONTRAINDICATIONS

A. Indications for abdominal CT and/or pelvic CT examinations include, but are not limited to:

1. Evaluation of abdominal, flank, or pelvic pain, including evaluation of suspected or known urinary calculi [1-3] and appendicitis [4-6]
2. Evaluation of abdominal or pelvic trauma [7-11]
3. Evaluation of renal and adrenal masses and of urinary tract abnormalities with CT urography [12-16]
4. Evaluation of known or suspected abdominal or pelvic masses or fluid collections, including gynecological masses [17-20]
5. Evaluation of primary or metastatic malignancies, including lesion characterization (eg, focal liver lesion) [21-24], staging, and treatment monitoring
6. Surveillance following locoregional therapies in abdominal malignancies, including percutaneous ablation, intra-arterial therapies (transarterial chemoembolization, selective interstitial radiation therapy), and targeted image-guided radiation therapy [25-28]
7. Assessment for recurrence of tumors following surgical resection [29-31]
8. Detection of complications following abdominal and pelvic surgery (eg, abscess, lymphocele, radiation change, and fistula/sinus tract formation [32-36]
9. Evaluation of diffuse liver disease (eg, cirrhosis, steatosis, iron deposition disease [37-40]) and disease of the biliary system [41-43]
10. Evaluation of abdominal or pelvic inflammatory and/or infectious processes, including inflammatory bowel disease, infectious bowel disease and its complications, without or with CT enterography [44-50], and of known or suspected renal or retroperitoneal infection
11. Assessment of abnormalities of abdominal or pelvic vascular structures [51-54]; noninvasive angiography of the aorta and its branches and noninvasive venography [55-58]
12. Clarification of findings from other imaging studies or laboratory abnormalities
13. Evaluation of known or suspected congenital abnormalities of abdominal or pelvic organs [59-61]
14. Evaluation for bowel obstruction or gastrointestinal bleeding [62-67]
15. Screening and diagnostic evaluation for colonic polyps and cancers with CT colonography [68-72]
16. Guidance for interventional or therapeutic procedures within the abdomen or pelvis [73-78]
17. Follow-up evaluation after interventional or therapeutic procedures within the abdomen or pelvis, including abscess drainage [79-82]
18. Treatment planning for radiation and chemotherapy and evaluation of tumor response to treatment [83-89]
19. Pre- and posttransplant assessment [90-95]

B. There are no absolute contraindications to abdominal CT or pelvic CT examinations. As with all procedures, the relative benefits and risks of the procedure should be evaluated before performing abdominal or pelvic CT, with and/or without the administration of intravenous (IV) iodinated contrast. Appropriate precautions should be taken to minimize patient risks, including radiation exposure and iodinated contrast delivery (see the ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media [96] and the ACR Manual on Contrast Media [97]).

For the pregnant or potentially pregnant patient, see the ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation [98].

III. QUALIFICATIONS AND RESPONSIBLITIES OF PERSONNEL

See the ACR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) [99].

IV. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for a CT of the abdomen and/or CT of the pelvis 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’s scope of practice requirements. (ACR Resolution 35 adopted in 2006 – revised in 2016, Resolution 12-b)

A. In general, a CT examination of the abdomen includes axial images from just above the dome of the diaphragm to the upper margin of the sacroiliac joints with a 5-mm or less slice thickness. A CT of the pelvis extends from the iliac crest through just below the ischial tuberosities with a 5-mm or less slice thickness (see Section VI). Occasionally, more inferior extension of imaging may be required to fully image pelvic structures of concern. Often, depending on the clinical indication for the study, both the abdomen and pelvis may be examined concurrently. Scans should be obtained through the entire area of interest. The scan field of view (FOV) and range should be optimized for each patient. Scans should generally be obtained during suspended respiration but may be obtained during free breathing for certain indications, such as radiation therapy planning.
B. The primary goal of CT scanning is to obtain diagnostic information from images of sufficient quality for the task. Protocols should be optimized to give the lowest radiation dose required to achieve appropriate image quality for a given task. This is especially important for radiosensitive groups, such as pediatric patients. Dose-reduction techniques should be considered when optimizing protocols. These techniques include, but are not limited to, automatic exposure control [100], automatic tube kV selection [101], iterative reconstruction [102], beam filtration [103], deep learning–based image reconstruction [104,105], and tube current modulation [106,107]. In certain cases, it may be appropriate to limit the area exposed and focus only on the area or organs of concern in order to limit the radiation dose. Choosing different mA (ie, image noise) and beam energy (ie, image contrast) as a function of indication allows for dose reduction in cases with high inherent contrast or low image quality tasks like skeletal structure evaluation [108-111].
C. In addition to axial images, at least one multiplanar reformation, such as coronal or sagittal images, should be reconstructed [112-116]. More complex oblique planes may be constructed from the source image data to answer specific clinical questions, to aid in disease visualization, or to assist in planning for interventional or surgical procedures. Additionally, 3-D reformations, such as maximum intensity projection (MIP), bone subtraction, and volume-rendered images may be reconstructed from the source image data or thin slices to clarify specific structures for studies such as CT angiography, CT urography, CT cystography, CT colonography, CT enterography, CT cholangiography, and/or other applications deemed necessary.
D. Abdominal and/or pelvic CT examinations may be performed during and/or after administering IV contrast medium using appropriate injection techniques [117,118]. The majority of clinical questions for abdominal and/or pelvic CT can be appropriately answered with a single-phase study. Multiple-phase studies, such as unenhanced, arterial, portal venous, or delayed-phase scanning, might be required in certain indications for improved detection and characterization of abnormalities, such as characterization of liver or renal lesions,

detection of active bleeding, etc. For specific indications, it may be necessary to perform an unenhanced study first. Abnormal findings on an unenhanced examination may require further evaluation with IV contrast administration or an alternative imaging study if contrast medium is contraindicated. Administration of IV contrast is generally not required for certain indications such as dedicated evaluation of bony structures and assessment of urolithiasis.

E. An enteric contrast agent can be used in abdominal and pelvis CT scans. The choice to use an enteric agent and type should be determined on a case-by-case basis. Some indications may not require use of oral contrast [119,120]. In some clinical situations, such as trauma or altered mental status, oral contrast is contraindicated due to risk of aspiration. An intraluminal gastrointestinal contrast agent may be administered orally, rectally, or by nasogastric or other tube to provide adequate distention and visualization of the gastrointestinal tract. This agent may be a positive contrast agent, such as dilute barium or a water-soluble iodinated solution; a neutral contrast agent, such as water or a nonabsorbable agent with similar x-ray attenuation as water; or a negative agent, such as air or carbon dioxide.

   Positive oral contrast material provides improved delineation of abscesses, suspected leaks, peritoneal implants, and intra-abdominal tumors. Positive contrast may obscure the visualization of bowel wall enhancement or hypoenhancement. Positive contrast may also interfere with 3-D reformations of blood vessels. Barium agents, if used for CT, should be no more than 3% wt/wt.

   Neutral enteric contrast agents provide bowel distention without obscuring bowel wall and therefore enable good visualization of bowel wall enhancement abnormalities and masses [121]. A variety of agents are available [121-123]. Water can be used if distention of only the proximal gastrointestinal tract is necessary. When distention of bowel beyond the proximal gastrointestinal tract is needed, contrast materials that contain materials less rapidly absorbed by the bowel can be used [124]. Neutral enteric contrast may reduce diagnostic accuracy for detection of abdominal fluid collections.

   Negative enteric contrast agents are used predominantly for CT colonography but can also be used in other scenarios, such as gastric or esophageal imaging [125].

F. Window width and level settings should be adjusted appropriately to view the visceral organs, the intra-abdominal fat and muscles, the pulmonary parenchyma at the lung bases, and the osseous structures. Window width and level settings should be further adjusted for low kVp single-energy or low kiloelectron volt (keV) monochromatic dual-energy CT images.

G. Although many of the settings of a CT scanner are automated, a number of technical parameters remain operator dependent [126]. The supervising physician should be familiar with how individual CT settings affect radiation dose and image quality. These settings include the following:
   1. Automated exposure control [127]
   2. Iterative reconstruction and similar noise reduction techniques
   3. Tube potential (kVp)
   4. Gantry rotation time
   5. Detector configuration and z axis detector width for multidetector systems
   6. Reconstructed slice thickness and spacing
   7. Pitch or table increment
   8. FOV
   9. Reconstruction algorithm or kernel

      Dual, multienergy, and spectral CT techniques can be used to improve the diagnostic evaluation of multiple abdominopelvic tasks, including incidentaloma characterization, increasing contrast material conspicuity and decreasing artifacts from some metallic objects [128-136]. These techniques may be used to create virtual monoenenergetic and material selective reconstructions (including iodine maps and virtual noncontrast reconstructions); these may be utilized to eliminate an unenhanced acquisition and decrease radiation dose in certain situations [129,132,133,137,138].

Low-kVp single-energy low keV monochromatic dual-energy images may also be used to reduce the volume of IV iodinated contrast medium. By nearing the iodine k edge (33.2 keV), these techniques can be used to increase the iodine conspicuity, thus compensating for the decreased volume of contrast medium administered, specifically for vascular applications [128,134].

H. Optimizing CT examination technique requires the supervising physician to select an appropriate CT protocol based on careful review of the patient history (to include risk factors that might increase the likelihood of adverse reactions to contrast media) and clinical indications, as well as all relevant imaging studies, when available. This optimization process may include determining whether CT examination of the abdomen, pelvis, or both is necessary. Adapting CT technique to accommodate patients with large body habitus is suggested with possible adjustments in acquisition technique and contrast injection parameters [139].

I. Protocols may be prepared by clinical indication and anatomy to be imaged [140]. Techniques should provide image quality consistent with the diagnostic needs of the examination at appropriate radiation dose levels [141-143]. For each area of interest or indication, the protocol should indicate the following:

1. The volume and type of intraluminal contrast media to be administered, the route of administration (oral, rectal, or via nasogastric, Foley catheter, or other tube), and the time intervals during which it should be delivered
2. If IV contrast material is used, the type, volume, rate of administration, and time delay(s) between administration and scan initiation. Bolus tracking or timing bolus should be used whenever indicated to optimize results [143-145].
3. Detector configuration
4. Pitch or table increment
5. Slice thickness
6. kVp and mAs per slice or range (minimum and maximum mAs for multidetector CT), as appropriate for adult or pediatric patients
7. Gantry rotation time
8. Automated exposure control
9. Reconstruction technique
10. Superior and inferior extent of the region of interest to be imaged
11. Reconstruction interval
12. Reconstruction kernel or algorithm
13. Reconstruction FOV
14. Instructions for which scans/images are sent to PACS
15. Use of 3-D and multiplanar reconstructions (MPR), where needed
16. For every CT examination, the information in the radiation dose report (CT dose index and dose length product) should be retained in the radiological record for future reference.

These protocols should be reviewed and updated periodically, and dated copies should be available to appropriate physicians and technical and administrative personnel at the facility. Each facility should review the scanner protocols periodically to confirm that they are in agreement with specified protocols.

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [146].

VI. EQUIPMENT SPECIFICATIONS

A. Performance Guidelines
CT equipment specifications for imaging of pediatric patients may be found in the ACR-ASER-SCBT-MR-SPR Practice Parameter for the Performance of Pediatric Computed Tomography (CT) [147] and the ACR

Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) [99].

B. Appropriate emergency equipment and medications must be immediately available to treat adverse reactions associated with administered medications. The equipment and medications should be monitored for inventory and drug expiration dates on a regular basis. The equipment, medications, and other emergency support must also be appropriate for the range of ages and sizes in the patient population. For additional information, refer to the ACR Manual on Contrast Media [97].

C. A soft-copy workstation (PACS station) review capability should be available to the radiologist. Remote viewing of images should also be available to authorized health care providers. A method should be available to transfer images outside the institution to authorized recipients.

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 [148].
For specific issues regarding CT quality control, see the ACR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) [99].

VII. RADIATION SAFETY IN IMAGING

When possible, CT imaging of the abdomen and pelvis should consider the following to minimize radiation dose and maintain image quality:

1. Center the patient in the gantry [149-153].
2. Keep the patient’s arms above the abdomen [154,155].
3. Remove unnecessary, densely radiopaque objects from the patient.
4. Patient shielding that is partially exposed to the beam may increase radiation exposure because of the automated exposure control. Therefore, patient shielding is not recommended for abdominal CT [156].

Use of low-dose CT technique should be strongly considered for certain imaging scenarios, such as the evaluation of nephrolithiasis, where fine detail is not needed, and follow-up studies with known abnormalities, especially in patients younger than 40 years old.

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

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 & 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).

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 Body Imaging (Abdominal) of the ACR Commission on Body Imaging, and the Committee on Practice Parameters – Pediatric Radiology of the ACR Commission on Pediatric Radiology, in collaboration with the SABI, SAR and SPR.

Writing Committee – members represent their societies in the initial and final revision of this practice parameter

ACR

Olga R. Brook, MD, Chair

Jessica Kurian MD

Alec Megibow, MD, MPH, FACR

Achille Mileto, MD

Timothy P. Szczykutowicz, PhD

SPR

Michael Furman, MD

Nathan Hull, MD

Ann Schechter-Stark, MD

SAR

Avinash Kambadakone, MD

SABI

Lakshmi Ananthakrishnan, MD

Committee on Practice Parameters - Body Imaging (Abdominal)

(ACR Committee responsible for sponsoring the draft through the process)

Benjamin M. Yeh, MD, Chair

Mahmoud M. Al-Hawary, MD

Mark E. Baker, MD, FACR

Olga R. Brook, MD

Lindsay Busby MD, MPH

Jay P. Heiken MD, FACR

David Kim, MD, FACR

Diego Martin, MD, PhD

Alec Megibow, MD, MPH, FACR

Achille Mileto, MD

Erick Remer, MD, FACR

Kumar Sandrasegaran, MD

Adam S. Young, MD, MBA

Committee on Practice Parameters – Pediatric Radiology

(ACR Committee responsible for sponsoring the draft through the process)

Terry L. Levin, MD, FACR, Chair

John B. Amodio, MD, FACR

Jesse Berman, MD

Tara M. Catanzano, MB, BCh

Harris L. Cohen, MD, FACR

Kassa Darge, MD, PhD

Dorothy L. Gilbertson-Dahdal, MD

Lauren P. Golding, MD

Jane Sun Kim, MD

Jennifer A Knight, MD

Jessica Kurian, MD

Matthew P. Lungren, MD, MPH

Helen R. Nadel, MD

Erica Poletto, MD

Richard B. Towbin, MD, FACR

Andrew T. Trout, MD

Committee on Practice Parameters – Pediatric Radiology

Safwan S. Halabi, MD

Esben S. Vogelius, MD

Jason Higgins, DO

Andrew B. Rosenkrantz, MD, Chair, Commission on Body Imaging

Richard A. Barth, MD, FACR, Chair, Commission on Pediatric Radiology

David B. Larson, MD, MBA, Chair, Commission on Quality and Safety

Mary S. Newell, MD, FACR, Chair, Committee on Practice Parameters and Technical Standards

Comment Reconciliation Committee

Timothy Crummy, MD, FACR Chair

Eve Clark, MD, Co-Chair

Lakshmi Ananthakrishnan, MD

Richard A. Barth, MD, FACR

Olga R. Brook, MD

Lindsay P Busby, MD, MPH

Richard Duszak Jr., MD, FACR

Michael Furman, MD

Dustin A. Gress, MS

Nathan Hull, MD

Avinash Kambadakone, MD

Amy Kotsenas, MD, FACR

Neil U. Lall, MD

David B. Larson, MD, MBA

Paul A. Larson, MD, FACR

Terry L. Levin, MD, FACR

Alec Megibow, MD, MPH, FACR

Achille Mileto, MD

Mary S. Newell, MD, FACR

Erick Remer, MD, FACR

Ann Schechter-Stark, MD

Timothy P. Szczykutowicz, PhD

Paula Yeghiayan, MD

Benjamin M. Yeh, MD

Comment Reconciliation Committee

Jessica Kurian MD

REFERENCES

1. Niemann T, Kollmann T, Bongartz G. Diagnostic performance of low-dose CT for the detection of urolithiasis: a meta-analysis. AJR Am J Roentgenol 2008;191:396-401.
2. Ciaschini MW, Remer EM, Baker ME, Lieber M, Herts BR. Urinary calculi: radiation dose reduction of 50% and 75% at CT--effect on sensitivity. Radiology 2009;251:105-11.
3. Glazer DI, Maturen KE, Cohan RH, et al. Assessment of 1 mSv urinary tract stone CT with model-based iterative reconstruction. AJR Am J Roentgenol 2014;203:1230-5.
4. Krajewski S, Brown J, Phang PT, Raval M, Brown CJ. Impact of computed tomography of the abdomen on clinical outcomes in patients with acute right lower quadrant pain: a meta-analysis. Canadian journal of surgery. Journal canadien de chirurgie 2011;54:43-53.
5. Bendeck SE, Nino-Murcia M, Berry GJ, Jeffrey RB, Jr. Imaging for suspected appendicitis: negative appendectomy and perforation rates. Radiology 2002;225:131-6.
6. Keyzer C, Cullus P, Tack D, De Maertelaer V, Bohy P, Gevenois PA. MDCT for suspected acute appendicitis in adults: impact of oral and IV contrast media at standard-dose and simulated low-dose techniques. AJR Am J Roentgenol 2009;193:1272-81.
7. Atri M, Hanson JM, Grinblat L, Brofman N, Chughtai T, Tomlinson G. Surgically important bowel and/or mesenteric injury in blunt trauma: accuracy of multidetector CT for evaluation. Radiology 2008;249:524-33.
8. Hamilton JD, Kumaravel M, Censullo ML, Cohen AM, Kievlan DS, West OC. Multidetector CT evaluation of active extravasation in blunt abdominal and pelvic trauma patients. Radiographics 2008;28:1603-16.
9. Murakami AM, Anderson SW, Soto JA, Kertesz JL, Ozonoff A, Rhea JT. Active extravasation of the abdomen and pelvis in trauma using 64MDCT. Emerg Radiol 2009;16:375-82.
10. Tillou A, Gupta M, Baraff LJ, et al. Is the use of pan-computed tomography for blunt trauma justified? A prospective evaluation. J Trauma 2009;67:779-87.
11. Goodman CS, Hur JY, Adajar MA, Coulam CH. How well does CT predict the need for laparotomy in hemodynamically stable patients with penetrating abdominal injury? A review and meta-analysis. AJR Am J Roentgenol 2009;193:432-7.
12. Caoili EM, Cohan RH, Korobkin M, et al. Urinary tract abnormalities: initial experience with multi-detector row CT urography. Radiology 2002;222:353-60.
13. Dyer R, DiSantis DJ, McClennan BL. Simplified imaging approach for evaluation of the solid renal mass in adults. Radiology 2008;247:331-43.
14. Silverman SG, Leyendecker JR, Amis ES, Jr. What is the current role of CT urography and MR urography in the evaluation of the urinary tract? Radiology 2009;250:309-23.
15. Sangwaiya MJ, Boland GW, Cronin CG, Blake MA, Halpern EF, Hahn PF. Incidental adrenal lesions: accuracy of characterization with contrast-enhanced washout multidetector CT--10-minute delayed imaging protocol revisited in a large patient cohort. Radiology 2010;256:504-10.
16. Mileto A, Nelson RC, Paulson EK, Marin D. Dual-Energy MDCT for Imaging the Renal Mass. AJR Am J Roentgenol 2015:W1-W8.
17. Hong X, Choi H, Loyer EM, Benjamin RS, Trent JC, Charnsangavej C. Gastrointestinal stromal tumor: role of CT in diagnosis and in response evaluation and surveillance after treatment with imatinib. Radiographics 2006;26:481-95.
18. Grabowska-Derlatka L, Derlatka P, Palczewski P, Danska-Bidzinska A, Pacho R. Differentiation of ovarian cancers from borderline ovarian tumors on the basis of evaluation of tumor vascularity in multi-row detector computed tomography--comparison with histopathology. International journal of gynecological cancer : official journal of the International Gynecological Cancer Society 2013;23:1597-602.
19. Mazzei MA, Khader L, Cirigliano A, et al. Accuracy of MDCT in the preoperative definition of Peritoneal Cancer Index (PCI) in patients with advanced ovarian cancer who underwent peritonectomy and hyperthermic intraperitoneal chemotherapy (HIPEC). Abdominal imaging 2013;38:1422-30.
20. Tsili AC, Tsangou V, Koliopoulos G, Stefos T, Argyropoulou MI. Early-stage cervical carcinoma: the role of

multidetector CT in correlation with histopathological findings. Journal of obstetrics and gynaecology : the journal of the Institute of Obstetrics and Gynaecology 2013;33:882-7.
21. Kamel IR, Choti MA, Horton KM, et al. Surgically staged focal liver lesions: accuracy and reproducibility of dual-phase helical CT for detection and characterization. Radiology 2003;227:752-7.
22. Jang HJ, Kim TK, Khalili K, et al. Characterization of 1-to 2-cm liver nodules detected on hcc surveillance ultrasound according to the criteria of the American Association for the Study of Liver Disease: is quadriphasic CT necessary? AJR Am J Roentgenol 2013;201:314-21.
23. Raman SP, Fishman EK. Advances in CT Imaging of GI Malignancies. Gastrointestinal cancer research : GCR 2012;5:S4-9.
24. Lee MH, Choi D, Park MJ, Lee MW. Gastric cancer: imaging and staging with MDCT based on the 7th AJCC guidelines. Abdominal imaging 2012;37:531-40.
25. Min JH, Lee MW, Rhim H, et al. Local tumour progression after loco-regional therapy of hepatocellular carcinomas: value of fusion imaging-guided radiofrequency ablation. Clinical radiology 2014;69:286-93.
26. Wah TM, Irving HC, Gregory W, Cartledge J, Joyce AD, Selby PJ. Radiofrequency ablation (RFA) of renal cell carcinoma (RCC): experience in 200 tumours. BJU international 2014;113:416-28.
27. Dollinger M, Jung EM, Beyer L, et al. Irreversible electroporation ablation of malignant hepatic tumors: subacute and follow-up CT appearance of ablation zones. Journal of vascular and interventional radiology : JVIR 2014;25:1589-94.
28. Mazioti A, Gatselis NK, Rountas C, et al. Safety and efficacy of transcatheter arterial chemoemboliazation in the real-life management of unresectable hepatocellular carcinoma. Hepatitis monthly 2013;13:e7070.
29. Kim JY, Kim SH, Lee HJ, Kim MJ, Kim YH, Cho SH. MDCT urography for detecting recurrence after transurethral resection of bladder cancer: comparison of nephrographic phase with pyelographic phase. AJR Am J Roentgenol 2014;203:1021-7.
30. Kim KW, Choi BI, Han JK, et al. Postoperative anatomic and pathologic findings at CT following gastrectomy. Radiographics 2002;22:323-36.
31. Pannu HK, Bristow RE, Montz FJ, Fishman EK. Multidetector CT of peritoneal carcinomatosis from ovarian cancer. Radiographics 2003;23:687-701.
32. Aguirre DA, Santosa AC, Casola G, Sirlin CB. Abdominal wall hernias: imaging features, complications, and diagnostic pitfalls at multi-detector row CT. Radiographics 2005;25:1501-20.
33. Blachar A, Federle MP, Pealer KM, Ikramuddin S, Schauer PR. Gastrointestinal complications of laparoscopic Roux-en-Y gastric bypass surgery: clinical and imaging findings. Radiology 2002;223:625-32.
34. Pickhardt PJ, Bhalla S, Balfe DM. Acquired gastrointestinal fistulas: classification, etiologies, and imaging evaluation. Radiology 2002;224:9-23.
35. Yu J, Turner MA, Cho SR, et al. Normal anatomy and complications after gastric bypass surgery: helical CT findings. Radiology 2004;231:753-60.
36. Catala V, Sola M, Samaniego J, et al. CT findings in urinary diversion after radical cystectomy: postsurgical anatomy and complications. Radiographics 2009;29:461-76.
37. Bandula S, Punwani S, Rosenberg WM, et al. Equilibrium contrast-enhanced CT imaging to evaluate hepatic fibrosis: initial validation by comparison with histopathologic sampling. Radiology 2015;275:136-43.
38. Zissen MH, Wang ZJ, Yee J, Aslam R, Monto A, Yeh BM. Contrast-enhanced CT quantification of the hepatic fractional extracellular space: correlation with diffuse liver disease severity. AJR Am J Roentgenol 2013;201:1204-10.
39. Kim DY, Park SH, Lee SS, et al. Contrast-enhanced computed tomography for the diagnosis of fatty liver: prospective study with same-day biopsy used as the reference standard. Eur Radiol 2010;20:359-66.
40. Miller WJ, Baron RL, Dodd GD, 3rd, Federle MP. Malignancies in patients with cirrhosis: CT sensitivity and specificity in 200 consecutive transplant patients. Radiology 1994;193:645-50.
41. Wang ZJ, Yeh BM, Roberts JP, Breiman RS, Qayyum A, Coakley FV. Living donor candidates for right hepatic lobe transplantation: evaluation at CT cholangiography--initial experience. Radiology 2005;235:899-904.
42. Ajiki T, Fukumoto T, Ueno K, Okazaki T, Matsumoto I, Ku Y. Three-dimensional computed tomographic cholangiography as a novel diagnostic tool for evaluation of bile duct invasion of perihilar cholangiocarcinoma. Hepato-gastroenterology 2013;60:1833-8.
43. Fidler JL, Knudsen JM, Collins DA, et al. Prospective assessment of dynamic CT and MR cholangiography in functional biliary pain. AJR Am J Roentgenol 2013;201:W271-82.
44. Guimaraes LS, Fidler JL, Fletcher JG, et al. Assessment of appropriateness of indications for CT enterography

in younger patients. Inflamm Bowel Dis 2010;16:226-32.
45. Hara AK, Alam S, Heigh RI, Gurudu SR, Hentz JG, Leighton JA. Using CT enterography to monitor Crohn's disease activity: a preliminary study. AJR Am J Roentgenol 2008;190:1512-6.
46. Kambadakone AR, Chaudhary NA, Desai GS, Nguyen DD, Kulkarni NM, Sahani DV. Low-dose MDCT and CT enterography of patients with Crohn disease: feasibility of adaptive statistical iterative reconstruction. AJR Am J Roentgenol 2011;196:W743-52.
47. Huprich JE, Fletcher JG, Fidler JL, et al. Prospective blinded comparison of wireless capsule endoscopy and multiphase CT enterography in obscure gastrointestinal bleeding. Radiology 2011;260:744-51.
48. Wallihan DB, Podberesky DJ, Sullivan J, et al. Diagnostic Performance and Dose Comparison of Filtered Back Projection and Adaptive Iterative Dose Reduction Three-dimensional CT Enterography in Children and Young Adults. Radiology 2015:140468.
49. Baker ME, Hara AK, Platt JF, Maglinte DD, Fletcher JG. CT enterography for Crohn's disease: optimal technique and imaging issues. Abdominal imaging 2015;40:938-52.
50. Hara AK, Swartz PG. CT enterography of Crohn's disease. Abdominal imaging 2009;34:289-95.
51. De Cecco CN, Ferrari R, Rengo M, Paolantonio P, Vecchietti F, Laghi A. Anatomic variations of the hepatic arteries in 250 patients studied with 64-row CT angiography. Eur Radiol 2009;19:2765-70.
52. Turkvatan A, Ozdemir M, Cumhur T, Olcer T. Multidetector CT angiography of renal vasculature: normal anatomy and variants. Eur Radiol 2009;19:236-44.
53. Vu M, Anderson SW, Shah N, Soto JA, Rhea JT. CT of blunt abdominal and pelvic vascular injury. Emerg Radiol 2010;17:21-9.
54. Fuentes-Orrego JM, Pinho D, Kulkarni NM, Agrawal M, Ghoshhajra BB, Sahani DV. New and evolving concepts in CT for abdominal vascular imaging. Radiographics 2014;34:1363-84.
55. Heijenbrok-Kal MH, Kock MC, Hunink MG. Lower extremity arterial disease: multidetector CT angiography meta-analysis. Radiology 2007;245:433-9.
56. Rubin GD, Armerding MD, Dake MD, Napel S. Cost identification of abdominal aortic aneurysm imaging by using time and motion analyses. Radiology 2000;215:63-70.
57. Ippolito D, Talei Franzesi C, Fior D, Bonaffini PA, Minutolo O, Sironi S. Low kV settings CT angiography (CTA) with low dose contrast medium volume protocol in the assessment of thoracic and abdominal aorta disease: a feasibility study. The British journal of radiology 2015;88:20140140.
58. Liu PS, Platt JF. CT angiography in the abdomen: a pictorial review and update. Abdominal imaging 2014;39:196-214.
59. Suzuki K, Nishimi D, Morioka H, Takanami M. Hematospermia associated with congenital arteriovenous malformation of internal iliac vessels. Int J Urol 2007;14:370-2.
60. Zeitoun D, Brancatelli G, Colombat M, et al. Congenital hepatic fibrosis: CT findings in 18 adults. Radiology 2004;231:109-16.
61. Lawler LP, Jarret TW, Corl FM, Fishman EK. Adult ureteropelvic junction obstruction: insights with three-dimensional multi-detector row CT. Radiographics 2005;25:121-34.
62. Delabrousse E, Lubrano J, Jehl J, et al. Small-bowel obstruction from adhesive bands and matted adhesions: CT differentiation. AJR Am J Roentgenol 2009;192:693-7.
63. Sundaram B, Miller CN, Cohan RH, Schipper MJ, Francis IR. Can CT features be used to diagnose surgical adult bowel intussusceptions? AJR Am J Roentgenol 2009;193:471-8.
64. Artigas JM, Marti M, Soto JA, Esteban H, Pinilla I, Guillen E. Multidetector CT angiography for acute gastrointestinal bleeding: technique and findings. Radiographics 2013;33:1453-70.
65. Wang Z, Chen JQ, Liu JL, Qin XG, Huang Y. CT enterography in obscure gastrointestinal bleeding: a systematic review and meta-analysis. Journal of medical imaging and radiation oncology 2013;57:263-73.
66. Boudiaf M, Soyer P, Terem C, Pelage JP, Maissiat E, Rymer R. Ct evaluation of small bowel obstruction. Radiographics 2001;21:613-24.
67. Fidler JL, Gunn ML, Soto JA, et al. Society of abdominal radiology gastrointestinal bleeding disease-focused panel consensus recommendations for CTA technical parameters in the evaluation of acute overt gastrointestinal bleeding. Abdom Radiol (NY) 2019;44:2957-62.
68. Johnson CD. CT colonography: coming of age. AJR Am J Roentgenol 2009;193:1239-42.
69. Plumb AA, Halligan S, Pendse DA, Taylor SA, Mallett S. Sensitivity and specificity of CT colonography for the detection of colonic neoplasia after positive faecal occult blood testing: systematic review and meta-analysis. Eur Radiol 2014;24:1049-58.

70. Kriza C, Emmert M, Wahlster P, Niederlander C, Kolominsky-Rabas P. An international review of the main cost-effectiveness drivers of virtual colonography versus conventional colonoscopy for colorectal cancer screening: is the tide changing due to adherence? Eur J Radiol 2013;82:e629-36.
71. Pickhardt PJ, Hassan C, Halligan S, Marmo R. Colorectal cancer: CT colonography and colonoscopy for detection--systematic review and meta-analysis. Radiology 2011;259:393-405.
72. American College of Radiology. ACR–SAR–SCBT-MR practice parameter for the performance of computed tomography (CT) colonography in adults. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CT-Colonog.pdf. Accessed January 13, 2020.
73. Gervais DA, Brown SD, Connolly SA, Brec SL, Harisinghani MG, Mueller PR. Percutaneous imaging-guided abdominal and pelvic abscess drainage in children. Radiographics 2004;24:737-54.
74. Singh B, May K, Coltart I, Moore NR, Cunningham C. The long-term results of percutaneous drainage of diverticular abscess. Ann R Coll Surg Engl 2008;90:297-301.
75. Stattaus J, Kalkmann J, Kuehl H, et al. Diagnostic yield of computed tomography-guided coaxial core biopsy of undetermined masses in the free retroperitoneal space: single-center experience. Cardiovasc Intervent Radiol 2008;31:919-25.
76. Cronin CG, Gervais DA, Hahn PF, Arellano R, Guimaraes AR, Mueller PR. Treatment of deep intramuscular and musculoskeletal abscess: experience with 99 CT-guided percutaneous catheter drainage procedures. AJR Am J Roentgenol 2011;196:1182-8.
77. Yamakado K, Takaki H, Nakatsuka A, et al. Percutaneous transhepatic drainage of inaccessible abdominal abscesses following abdominal surgery under real-time CT-fluoroscopic guidance. Cardiovasc Intervent Radiol 2010;33:161-3.
78. Heilbrun ME, Zagoria RJ, Garvin AJ, et al. CT-guided biopsy for the diagnosis of renal tumors before treatment with percutaneous ablation. AJR Am J Roentgenol 2007;188:1500-5.
79. Liao WI, Tsai SH, Yu CY, et al. Pyogenic liver abscess treated by percutaneous catheter drainage: MDCT measurement for treatment outcome. Eur J Radiol 2012;81:609-15.
80. Shin S, Lee JM, Kim KW, et al. Postablation assessment using follow-up registration of CT images before and after radiofrequency ablation (RFA): prospective evaluation of midterm therapeutic results of RFA for hepatocellular carcinoma. AJR Am J Roentgenol 2014;203:70-7.
81. Schima W, Ba-Ssalamah A, Kurtaran A, Schindl M, Gruenberger T. Post-treatment imaging of liver tumours. Cancer imaging : the official publication of the International Cancer Imaging Society 2007;7 Spec No A:S28-36.
82. Park MH, Rhim H, Kim YS, Choi D, Lim HK, Lee WJ. Spectrum of CT findings after radiofrequency ablation of hepatic tumors. Radiographics 2008;28:379-90; discussion 90-2.
83. Kawamoto S, Permpongkosol S, Bluemke DA, Fishman EK, Solomon SB. Sequential changes after radiofrequency ablation and cryoablation of renal neoplasms: role of CT and MR imaging. Radiographics 2007;27:343-55.
84. Meijerink MR, van Cruijsen H, Hoekman K, et al. The use of perfusion CT for the evaluation of therapy combining AZD2171 with gefitinib in cancer patients. Eur Radiol 2007;17:1700-13.
85. Schlemmer M, Sourbron SP, Schinwald N, et al. Perfusion patterns of metastatic gastrointestinal stromal tumor lesions under specific molecular therapy. Eur J Radiol 2011;77:312-8.
86. Schramm N, Englhart E, Schlemmer M, et al. Tumor response and clinical outcome in metastatic gastrointestinal stromal tumors under sunitinib therapy: comparison of RECIST, Choi and volumetric criteria. Eur J Radiol 2013;82:951-8.
87. Kim SH, Kamaya A, Willmann JK. CT perfusion of the liver: principles and applications in oncology. Radiology 2014;272:322-44.
88. Viswanathan C, Truong MT, Sagebiel TL, et al. Abdominal and pelvic complications of nonoperative oncologic therapy. Radiographics 2014;34:941-61.
89. Aird EG, Conway J. CT simulation for radiotherapy treatment planning. The British journal of radiology 2002;75:937-49.
90. Hermoye L, Laamari-Azjal I, Cao Z, et al. Liver segmentation in living liver transplant donors: comparison of semiautomatic and manual methods. Radiology 2005;234:171-8.
91. Peterson MS, Baron RL, Marsh JW, Jr., Oliver JH, 3rd, Confer SR, Hunt LE. Pretransplantation surveillance for possible hepatocellular carcinoma in patients with cirrhosis: epidemiology and CT-based tumor detection rate in 430 cases with surgical pathologic correlation. Radiology 2000;217:743-9.

92. Sahani DV, Rastogi N, Greenfield AC, et al. Multi-detector row CT in evaluation of 94 living renal donors by readers with varied experience. Radiology 2005;235:905-10.
93. Zamboni GA, Romero JY, Raptopoulos VD. Combined vascular-excretory phase MDCT angiography in the preoperative evaluation of renal donors. AJR Am J Roentgenol 2010;194:145-50.
94. Kawamoto S, Montgomery RA, Lawler LP, Horton KM, Fishman EK. Multi-detector row CT evaluation of living renal donors prior to laparoscopic nephrectomy. Radiographics 2004;24:453-66.
95. Singh AK, Nachiappan AC, Verma HA, et al. Postoperative imaging in liver transplantation: what radiologists should know. Radiographics 2010;30:339-51.
96. American College of Radiology. ACR–SPR practice parameter for the use of intravascular contrast media. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/IVCM.pdf. Accessed January 13, 2020.
97. American College of Radiology. ACR manual on contrast media, version 10.3. Available at: https://www.acr.org/Clinical-Resources/Contrast-Manual. Accessed January 13, 2020.
98. American College of Radiology. ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CT-Equip.pdf. Accessed January 13, 2020.
99. American College of Radiology. ACR practice parameter for performing and interpreting diagnostic computed tomography (CT). Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CT-Perf-Interpret.pdf. Accessed January 13, 2020.
100. Kalra MK, Maher MM, Toth TL, et al. Techniques and applications of automatic tube current modulation for CT. Radiology 2004;233:649-57.
101. Yu L, Li H, Fletcher JG, McCollough CH. Automatic selection of tube potential for radiation dose reduction in CT: a general strategy. Medical physics 2010;37:234-43.
102. Geyer LL, Schoepf UJ, Meinel FG, et al. State of the Art: Iterative CT Reconstruction Techniques. Radiology 2015;276:339-57.
103. Primak AN, Giraldo JC, Eusemann CD, et al. Dual-source dual-energy CT with additional tin filtration: Dose and image quality evaluation in phantoms and in vivo. AJR Am J Roentgenol 2010;195:1164-74.
104. Greffier J, Hamard A, Pereira F, et al. Image quality and dose reduction opportunity of deep learning image reconstruction algorithm for CT: a phantom study. Eur Radiol 2020;30:3951-59.
105. Singh R, Digumarthy SR, Muse VV, et al. Image Quality and Lesion Detection on Deep Learning Reconstruction and Iterative Reconstruction of Submillisievert Chest and Abdominal CT. AJR Am J Roentgenol 2020;214:566-73.
106. Ketelsen D, Buchgeister M, Fenchel M, et al. Automated computed tomography dose-saving algorithm to protect radiosensitive tissues: estimation of radiation exposure and image quality considerations. Investigative radiology 2012;47:148-52.
107. Gandhi D, Crotty DJ, Stevens GM, Schmidt TG. Technical Note: Phantom study to evaluate the dose and image quality effects of a computed tomography organ-based tube current modulation technique. Medical physics 2015;42:6572-8.
108. Marin D, Nelson RC, Samei E, et al. Hypervascular liver tumors: low tube voltage, high tube current multidetector CT during late hepatic arterial phase for detection--initial clinical experience. Radiology 2009;251:771-9.
109. Marin D, Nelson RC, Schindera ST, et al. Low-tube-voltage, high-tube-current multidetector abdominal CT: improved image quality and decreased radiation dose with adaptive statistical iterative reconstruction algorithm--initial clinical experience. Radiology 2010;254:145-53.
110. Wintersperger B, Jakobs T, Herzog P, et al. Aorto-iliac multidetector-row CT angiography with low kV settings: improved vessel enhancement and simultaneous reduction of radiation dose. Eur Radiol 2005;15:334-41.
111. Gleeson TG, Moriarty J, Shortt CP, et al. Accuracy of whole-body low-dose multidetector CT (WBLDCT) versus skeletal survey in the detection of myelomatous lesions, and correlation of disease distribution with whole-body MRI (WBMRI). Skeletal Radiol 2009;38:225-36.
112. Tsili AC, Argyropoulou MI, Gousia A, et al. Renal cell carcinoma: value of multiphase MDCT with multiplanar reformations in the detection of pseudocapsule. AJR Am J Roentgenol 2012;199:379-86.
113. Yun BL, Kim SH, Kim SJ, et al. Added value of multiplanar reformations to axial multi-detector row computed tomographic images for the differentiation of macrocystic pancreas neoplasms: receiver

operating characteristic analysis. Journal of computer assisted tomography 2010;34:899-906.
114. Neville AM, Paulson EK. MDCT of acute appendicitis: value of coronal reformations. Abdominal imaging 2009;34:42-8.
115. Sandrasegaran K, Rydberg J, Tann M, Hawes DR, Kopecky KK, Maglinte DD. Benefits of routine use of coronal and sagittal reformations in multi-slice CT examination of the abdomen and pelvis. Clinical radiology 2007;62:340-7.
116. Jaffe TA, Martin LC, Thomas J, Adamson AR, DeLong DM, Paulson EK. Small-bowel obstruction: coronal reformations from isotropic voxels at 16-section multi-detector row CT. Radiology 2006;238:135-42.
117. Tschugunow A, Puesken M, Juergens KU, et al. Optimization of scan delay for routine abdominal 64-slice CT with body weight-adapted application of contrast material. Rofo 2009;181:683-90.
118. Yamashita Y, Komohara Y, Takahashi M, et al. Abdominal helical CT: evaluation of optimal doses of intravenous contrast material--a prospective randomized study. Radiology 2000;216:718-23.
119. Kielar AZ, Patlas MN, Katz DS. Oral contrast for CT in patients with acute non-traumatic abdominal and pelvic pain: what should be its current role? Emerg Radiol 2016;23:477-81.
120. Kammerer S, Höink AJ, Wessling J, et al. Abdominal and pelvic CT: is positive enteric contrast still necessary? Results of a retrospective observational study. Eur Radiol 2015;25:669-78.
121. Dillman JR, Towbin AJ, Imbus R, Young J, Gates E, Trout AT. Comparison of Two Neutral Oral Contrast Agents in Pediatric Patients: A Prospective Randomized Study. Radiology 2018;288:245-51.
122. Wong J, Moore H, Roger M, McKee C. CT enterography: Mannitol versus VoLumen. Journal of medical imaging and radiation oncology 2016;60:593-98.
123. Zheng MQ, Zeng QS, Yu YQ, et al. Evaluation of the performance of two neutral oral contrast agents in computed tomography enterography: A randomized controlled trial. J Dig Dis 2020;21:112-19.
124. Baker ME, Hara AK, Platt JF, Maglinte DD, Fletcher JG. CT enterography for Crohn's disease: optimal technique and imaging issues. Abdominal imaging 2015.
125. Cansu A, Ahmetoglu A, Kul S, et al. Diagnostic performance of using effervescent powder for detection and grading of esophageal varices by multi-detector computed tomography. Eur J Radiol 2014;83:497-502.
126. Flohr TG, Schaller S, Stierstorfer K, Bruder H, Ohnesorge BM, Schoepf UJ. Multi-detector row CT systems and image-reconstruction techniques. Radiology 2005;235:756-73.
127. Ehman EC, Yu L, Manduca A, et al. Methods for clinical evaluation of noise reduction techniques in abdominopelvic CT. Radiographics 2014;34:849-62.
128. Clark ZE, Bolus DN, Little MD, Morgan DE. Abdominal rapid-kVp-switching dual-energy MDCT with reduced IV contrast compared to conventional MDCT with standard weight-based IV contrast: an intra-patient comparison. Abdominal imaging 2015;40:852-8.
129. Han SC, Chung YE, Lee YH, Park KK, Kim MJ, Kim KW. Metal artifact reduction software used with abdominopelvic dual-energy CT of patients with metal hip prostheses: assessment of image quality and clinical feasibility. AJR Am J Roentgenol 2014;203:788-95.
130. McCollough CH, Leng S, Yu L, Fletcher JG. Dual- and Multi-Energy CT: Principles, Technical Approaches, and Clinical Applications. Radiology 2015;276:637-53.
131. Marin D, Boll DT, Mileto A, Nelson RC. State of the art: dual-energy CT of the abdomen. Radiology 2014;271:327-42.
132. Itani M, Bresnahan BW, Rice K, et al. Clinical and Payer-Based Analysis of Value of Dual-Energy Computed Tomography for Workup of Incidental Abdominal Findings. Journal of computer assisted tomography 2019;43:605-11.
133. Patel BN, Boltyenkov AT, Martinez MG, et al. Cost-effectiveness of dual-energy CT versus multiphasic single-energy CT and MRI for characterization of incidental indeterminate renal lesions. Abdom Radiol (NY) 2020;45:1896-906.
134. Shuman WP, Mileto A, Busey JM, Desai N, Koprowicz KM. Dual-Energy CT Urography With 50% Reduced Iodine Dose Versus Single-Energy CT Urography With Standard Iodine Dose. AJR Am J Roentgenol 2019;212:117-23.
135. Kaza RK, Ananthakrishnan L, Kambadakone A, Platt JF. Update of Dual-Energy CT Applications in the Genitourinary Tract. AJR Am J Roentgenol 2017;208:1185-92.
136. McCollough CH, Boedeker K, Cody D, et al. Principles and applications of multienergy CT: Report of AAPM Task Group 291. Medical physics 2020;47:e881-e912.
137. Shuman WP, O'Malley RB, Busey JM, Ramos MM, Koprowicz KM. Prospective comparison of dual-energy CT

aortography using 70% reduced iodine dose versus single-energy CT aortography using standard iodine dose in the same patient. Abdom Radiol (NY) 2017;42:759-65.

138. Parakh A, Negreros-Osuna AA, Patino M, McNulty F, Kambadakone A, Sahani DV. Low-keV and Low-kVp CT for Positive Oral Contrast Media in Patients with Cancer: A Randomized Clinical Trial. Radiology 2019;291:620-29.
139. Fursevich DM, LiMarzi GM, O'Dell MC, Hernandez MA, Sensakovic WF. Bariatric CT Imaging: Challenges and Solutions. RadioGraphics 2016;36:1076-86.
140. Szczykutowicz TP, Rubert N, Belden D, et al. A Wiki-Based Solution to Managing Your Institution's Imaging Protocols. J Am Coll Radiol 2016;13:822-4.
141. Tamm EP, Rong XJ, Cody DD, Ernst RD, Fitzgerald NE, Kundra V. Quality initiatives: CT radiation dose reduction: how to implement change without sacrificing diagnostic quality. Radiographics 2011;31:1823-32.
142. Yu L, Bruesewitz MR, Thomas KB, Fletcher JG, Kofler JM, McCollough CH. Optimal tube potential for radiation dose reduction in pediatric CT: principles, clinical implementations, and pitfalls. Radiographics 2011;31:835-48.
143. Lee CH, Goo JM, Ye HJ, et al. Radiation dose modulation techniques in the multidetector CT era: from basics to practice. Radiographics 2008;28:1451-9.
144. Goshima S, Kanematsu M, Kondo H, et al. MDCT of the liver and hypervascular hepatocellular carcinomas: optimizing scan delays for bolus-tracking techniques of hepatic arterial and portal venous phases. AJR Am J Roentgenol 2006;187:W25-32.
145. Kondo H, Kanematsu M, Goshima S, et al. MDCT of the pancreas: optimizing scanning delay with a bolus-tracking technique for pancreatic, peripancreatic vascular, and hepatic contrast enhancement. AJR Am J Roentgenol 2007;188:751-6.
146. American College of Radiology. ACR practice parameter for communication of diagnostic imaging findings. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CT-Equip.pdf. Accessed January 13, 2020.
147. American College of Radiology. ACR-ASER-SCBT-MR-SPR practice parameter for the performance of pediatric computed tomography (CT). Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CT-Colonog.pdf. Accessed January 13, 2020.
148. American College of Radiology. ACR–AAPM technical standard for diagnostic medical physics performance monitoring of computed tomography (CT) equipment. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CT-Equip.pdf. Accessed January 13, 2020.
149. Harri PA, Moreno CC, Nelson RC, et al. Variability of MDCT dose due to technologist performance: impact of posteroanterior versus anteroposterior localizer image and table height with use of automated tube current modulation. AJR Am J Roentgenol 2014;203:377-86.
150. Habibzadeh MA, Ay MR, Asl AR, Ghadiri H, Zaidi H. Impact of miscentering on patient dose and image noise in x-ray CT imaging: phantom and clinical studies. Phys Med 2012;28:191-9.
151. Schindera ST, Nauer C, Treier R, et al. [Strategies for reducing the CT radiation dose]. Der Radiologe 2010;50:1120, 22-7.
152. Gudjonsdottir J, Svensson JR, Campling S, Brennan PC, Jonsdottir B. Efficient use of automatic exposure control systems in computed tomography requires correct patient positioning. Acta Radiol 2009;50:1035-41.
153. Li J, Udayasankar UK, Toth TL, Seamans J, Small WC, Kalra MK. Automatic patient centering for MDCT: effect on radiation dose. AJR Am J Roentgenol 2007;188:547-52.
154. Liu H, Gao Y, Ding A, Caracappa PF, Xu XG. The profound effects of patient arm positioning on organ doses from CT procedures calculated using Monte Carlo simulations and deformable phantoms. Radiation protection dosimetry 2015;164:368-75.
155. Brink M, de Lange F, Oostveen LJ, et al. Arm raising at exposure-controlled multidetector trauma CT of thoracoabdominal region: higher image quality, lower radiation dose. Radiology 2008;249:661-70.
156. American College of Radiology. ACR Endorses AAPM Position on Gonadal and Fetal Shielding Available at: https://www.acr.org/Advocacy-and-Economics/Advocacy-News/Advocacy-News-Issues/In-the-June-8-2019-Issue/ACR-Endorses-AAPM-Position-on-Patient-Gonadal-and-Fetal-Shielding. Accessed September 16, 2020.

*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

Development Chronology for This Practice Parameter

1995 (Resolution 2)

Amended 1996 (Resolution 24, 53)

Revised 1997 (Resolution 31)

Revised 2001 (Resolution 8)

Revised 2006 (Resolution 13, 17, 35)

Amended 2009 (Resolution 11)

Revised 2011 (Resolution 32)

Amended 2014 (Resolution 39)

Revised 2016 (Resolution 22)

Revised 2021 (Resolution 46)

Amended 2023 (Resolution 2c, 2d)