Protocol Design

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Computed tomography (CT) scanners have become markedly more complex over the past three decades, with a myriad of new options for performing CT examinations. Technical developments in the past have focused on helical technology, increased speed of gantry rotation, increasing number of detector rows, and increasing tube outputs to maintain adequate signal-to-noise ratios. These advances have resulted in our ability to image faster, capture rapidly moving structures such as the heart, and improve both temporal and spatial resolution. However, achieving these goals may also result in increased radiation exposure for our patients.

Currently many new strategies and technologies are being developed to address concerns over CT radiation exposure. Network radiology exam databases and software to load outside examinations into regional PACs have been developed to prevent unnecessary duplication of CT exams. Decision support to determine appropriateness of the exam before ordering are assuring appropriate CT exams are being performed. Home-grown and commercial software solutions have been developed to track radiation exposure by machine, CT protocol, geographic location, and patient, which is important to document processes and have data to promote quality improvement. The ACR Dose Index Registry has been developed to determine national Diagnostic Reference Levels.

CT vendors have developed multiple technical options to reduce the dose from CT exams. These include but are not limited to: X-ray beam filtration, X-ray beam collimation, tube current modulation, peak kilovoltage optimization, improved detector efficiency, and noise-reduction reconstruction algorithms. Other strategies to reduce dose occur at the ordering stage when referring doctors and patients are made aware of duplicate exams and referring doctors are educated about alternative exams with lower dose or no radiation. A third area with potential to reduce radiation dose involves specific CT protocol development to maximize diagnostic yield while tailoring dose to the appropriate indication and patient size. All of these attempts to reduce dose adhere to the "As Low As Reasonably Achievable" (ALARA) principle.

The first steps are to be sure the examination is JUSTIFIED:

1. Make sure the exam is truly clinically indicated.
2. Make sure the exam has not been performed recently at another location — ask the patient.
3. Make sure an alternative imaging exam such as ultrasound or magnetic resonance imaging (MRI) is not available which could provide the same information without radiation exposure, particularly in pediatric and pregnant patients.

If the exam is clinically indicated, be sure it is OPTIMIZED to tailor the CT dose:

1. Have a technologist meet with the patient before the exam to confirm that symptoms match the indications for the CT exam.
2. Choose a specific exam protocol which addresses the clinical question while minimizing dose (see below).
3. Center the patient carefully in the CT gantry. Asymmetric positioning can result in decreased image quality and an increase in patient dose.

4. Minimize "image creep" so only the area requested is imaged. For example, if a chest CT is ordered, a full abdomen should not be performed. Likewise, if a renal mass is the clinical question, a pelvis should not be routinely performed.

At the dictation level, consider the following:

1. If recommending follow-up imaging, attempt to use recommended guidelines for both primary and incidental findings.
2. In younger patients, consider follow-up with modalities that use lower or no radiation dose (ultrasound or MRI).

At the protocol development and quality improvement levels, consider the following:

1. A radiologist, medical physicist, and lead technologist should regularly review departmental CT protocols to make sure they are optimized. For example, a renal calculus protocol should use a lower dose than a screening abdomen/pelvis protocol because the inherent high contrast of a renal calculus enables the use of lower dose techniques to make the diagnosis.
2. Have a medical physicist run regular periodic quality improvement (QI) sessions on CT exams to make sure dose is within prescribed ranges. Compare CT exposures to currently developing Diagnostic Reference Levels (DRLs) to compare your protocols to regional and national values.
3. Confirm that CT techniques for adult head, abdomen-pelvis, chest, and pediatric head and pediatric abdomen exams are at or below the reference levels suggested by the ACR (currently 75, 25, 21, 40, and 20 mGy respectively).
4. Pre-load specific CT protocols on individual CT scanners to avoid potential technologist error in entering parameters. Because you cannot see radiation, higher doses can be administered inadvertently by manually entering parameters for each exam.

5. Use automatic exposure control techniques of tube current modulation (available from all manufacturers) to reduce dose.

6. Attempt to minimize phase creep. Multiphase exams expose a body part more than once during the CT exam and thus increase dose per exam. An example is a three-phase liver where a non-contrast, arterial phase then portal venous phase series is performed through the same body part during one exam. Multiphase exams are very useful for specific indications, but should not be routinely used to answer general questions.

7. Consider the use of "split bolus" techniques with a power injector to gain different physiologic information (as in multiphase exams) with one radiation exposure. An example is a renal split bolus where injection of contrast is performed first, then after, a set delay, a second bolus of contrast is administered and imaging is performed once. The first bolus results in opacification of the ureters; the second results in nephrographic enhancement. Use of the split bolus in this example results in physiologic information about both the ureters and the renal parenchyma with only one radiation exposure.

8. Consider reporting the dose of the exam in the dictation, then downloading it to an electronic medical record for monitoring in a local, regional, or national database.

9. Imaging institutions and patients should consider keeping a record of the number of imaging exams involving radiation, including the year performed.

See the Medical Physicists section of the Image Wisely website for further information. In addition, there are a number of websites which list specific protocols for various types of CT scanners and manufacturers. Some examples include:

- https://www.radiology.wisc.edu/sections/msk/protocols.php

- http://www.ctisus.com/protocols
- http://www.aapm.org/pubs/CTProtocols/

SUGGESTED READING

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