Pediatric Imaging: Radiation Exposure and How We Image

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During the past decade, technological advances have improved the accessibility, accuracy, and speed of medical imaging. This is particularly true of the newest computed tomography (CT) scanners equipped with multirow detectors that provide exceptional diagnostic accuracy and capture multiple images in seconds, obviating the need for patient sedation. These advances, although resulting in significantly improved diagnostic benefits, have led to a rapid increase in CT scanning, particularly in children. In the United States, CT contributes to half of all medical radiation exposures; pediatric CT scans compose 10% of all CT scans.

Although the benefits of CT are significant, debate is ongoing about potential risks posed by the low-level radiation exposure associated with CT, especially in children. Children may be particularly susceptible to developing cancer because of the increased radiosensitivity of their growing organs and their long expected life spans. However, the risk from exposure to low-level radiation is uncertain, and the dose actually delivered by CT is estimated. Furthermore, the estimates of risk for cancers related to radiation are based on extrapolation from studies of atomic bomb survivors who received substantially higher doses of radiation than those used in medical imaging. Nevertheless, techniques to significantly reduce the dose of radiation from CT have been implemented.

A variety of imaging modalities are available to the radiologist: radiography, fluoroscopy, nuclear scintigraphy, CT, and positron emission tomography (PET) use ionizing radiation; and magnetic resonance (MR) imaging and ultrasonography do not. The choice of modality can be confusing. Some examinations optimize anatomic detail or are complementary when used in conjunction with another modality. Others provide functional data or offer unique information not provided by other imaging modalities. The ideal modality differs with each patient and reflects the diagnostic question being asked and the patient's clinical condition, specifically, the child's tolerance for a specific modality. When feasible, use of MR or ultrasonography is preferable in children. However, CT and other modalities that use ionizing radiation should not be avoided when indicated. In some patients, CT scanning is simply the best choice given the information sought by the clinician. Discussion with the pediatric radiologist optimizes and individualizes the choice of imaging.

Whenever possible, ultrasonography should be used in the imaging of children. Ultrasonography is readily available, portable, requires no sedation, and imposes no ionizing radiation. The small body habitus of children is ideal for ultrasonography, and the development of high-frequency pediatric probes allows for scanning at various depths. Ultrasonography is the optimal initial examination to evaluate the hepatobiliary and genitourinary systems. If additional imaging is required, MR cholangiography, MR urography, or pelvic MR may be obtained. The diagnosis of intussusception is best made using ultrasonography. Similarly, ultrasonography is the initial examination in cooperative children with suspected

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appendicitis. Ultrasonography of the head, routinely performed in the NICU, readily demonstrates intracranial hemorrhage, ischemia, or structural abnormalities. In infants younger than 6 months, acetabular anatomy and hip position with and without stress can be dynamically assessed with ultrasonography. Similarly, in suspected pyloric stenosis, ultrasonography can distinguish the transient findings of pylorospasm from true pyloric muscle thickening. Doppler imaging allows assessment of the degree, direction, and velocity of vascular flow, as well as systolic and diastolic flow patterns. Advances in Doppler technology now provide exquisite vascular anatomic detail. New ultrasonography techniques promise added benefits and include 3-dimensional imaging, elastography (useful for solid tumors, liver fibrosis, etc), and microbubble ultrasonography contrast agents. Limitations include the presence of air (limited use in assessing the lungs) and bone.

Magnetic resonance imaging also imparts no ionizing radiation. It is the study of choice in evaluating congenital heart disease after echocardiography, the central nervous system, and the musculoskeletal system. Cardiac MR provides anatomic and functional information. In the brain it provides superior assessment of the parenchyma than does CT and is the optimal examination in a child with seizures or developmental delay. In children with ventriculoperitoneal shunts, both the degree of hydrocephalus and shunt location are well assessed with MR. Low-dose CT scan protocols for ventriculoperitoneal shunt assessment are the alternative for children unable to undergo MR. In the musculoskeletal system, MR provides unique information about marrow disease. With intravenous contrast, MR is indicated for suspected osteomyelitis and in the evaluation of bone tumors. In addition, it is the modality of choice in assessing joints and soft tissues in inflammatory conditions or after trauma. MR has replaced the fluoroscopic small bowel follow-through in the evaluation of inflammatory bowel disease and is increasingly used in the diagnosis of appendicitis: fast MR protocols are available to rapidly define abdominal and pelvic fluid collections in children with ruptured appendicitis. Magnetic resonance urography and cholangiography provide anatomic and functional assessment of the urinary and hepatobiliary systems. However, MR examinations are costly, limited in availability, and lengthy, requiring the patient to remain still for a prolonged period of time. In young children, sedation is often necessary. When sedation is contraindicated, CT serves as the best alternative to MR.

The rapidity of CT imaging makes it the preferred modality for children who cannot hold their breath or remain still without sedation. Given recent publications on the adverse effect of anesthesia on brain development in young children and infants, CT provides an alternative, fast, and efficient method of imaging without sedation. In addition, CT is effective in unstable patients for whom sedation is not possible or those with a contraindication to MR.

Contrast-enhanced CT scanning is the study of choice in trauma. It rapidly provides detailed information about central nervous system, solid organ, and vascular injury as well as the presence of a pneumothorax or pneumoperitoneum. Abdominal ultrasonography is insufficient in assessing abdominal or pelvic injury; a normal ultrasonography finding does not exclude solid organ or bowel injury. Evaluation of lung parenchyma for entities such as interstitial disease, congenital lung lesions, pulmonary infections, nodules, or masses requires chest CT—no other imaging modality allows detailed evaluation of the lung parenchyma.

Radiation exposure from fluoroscopy depends on the dose parameters, duration of the study, patient size, and use of appropriate shielding and coning of the fluoroscopic beam. Initiatives to reduce the dose of fluoroscopic radiation have been effective. Fluoroscopy remains the modality of choice to evaluate the gastrointestinal tract in infants and young children. Although ultrasonography has been proposed to replace fluoroscopy when malrotation or volvulus is suspected, most pediatric radiologists continue to perform fluoroscopic upper gastrointestinal tract series. Similarly, fluoroscopic guidance generally remains the modality of choice for air reduction of an intussusception. Contrast enemas for functional and structural distal bowel obstruction in infants remain the diagnostic imaging modality of choice. With the development of microbubble ultrasonography contrast, fluoroscopic voiding cystograms, which evaluate bladder and urethral anatomy and assesses for vesicoureteral reflux, may be replaced by ultrasonography in the future.

The correct imaging modality is the one that provides the most accurate answer to the clinical question at hand in the quickest, safest, and easiest manner for the individual patient. In all instances, whenever possible, discussion with dedicated pediatric radiologists who subscribe to the As Low As Reasonably Achievable (ALARA) principle and to the American College of Radiology Appropriateness Criteria is encouraged. Discussions between pediatricians and their pediatric radiology colleagues serve to guide the pediatrician in selecting the best imaging modality for each patient, eliminate potentially unnecessary studies, and reduce

radiation exposure. The potential risks of medical radiation must be weighed against the diagnostic benefits of imaging.

COMMENT: For those of us who grew up in the era of radiography and fluoroscopy, the variety of imaging choices now available is astonishing and, for many of us, confusing. I could not have been more relieved to see CT scanning replace the horror of pneumoencephalography, even if my first experience with CT came as a medical student on an elective in neurology, when the resident I was accompanying explained to a woman in her 60s that she would be going for a new diagnostic test that would "take cuts of your brain!" I could see in her panicked eyes the picture of a deli slicing machine. Then came ultrasound, all kinds of scintigraphy, MR imaging, and PET scans, and each modality over time has become more sophisticated, with its own expanding set of bells and whistles. Add to the complexity of the choice among so many modalities the issues of exposure to radiation (especially for children) and the possible need for sedation (again, especially for children), and clearly the knowledgeable pediatric radiologist has a major role to play in guiding our choices.

Another consideration entirely is how many of the imaging studies we order are really necessary. Aside from the worry about potential litigation if enough tests are not ordered, economic pressures come into play. Scanners are expensive, and once purchased, whether by hospitals or imaging practices, can only be paid for when they are used, and so they are used and used and used. Sometimes, probably often, overused.

– Henry M. Adam, MD
Associate Editor, *In Brief*

Parent Resources from the AAP at HealthyChildren.org

- https://www.healthychildren.org/English/health-issues/conditions/treatments/Pages/Imaging-Tests.aspx

For a comprehensive library of AAP parent handouts, please go to the *Pediatric Patient Education* site at http://patiented.aap.org.

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