

Computed Tomography: Spinning a Revolution in Pediatric Imaging

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Over the past 50 years, computed tomography (CT) has had a profound effect on our understanding of pediatric diseases. Although considered a mature technology, CT has undergone a remarkable evolution that has made the modality a mainstay of pediatric radiology.

The Birth and Infancy of CT

The earliest CT scanners of the 1980s made the modality impractical for imaging children. Long scan times, in particular, caused respiratory misregistration and severe motion artifacts. That began to change in the 1990s, however, with the introduction of the four-row multidetector spiral CT, ushering in the era of pediatric CT.¹ Spiral scanning permitted faster gantry rotation times and better temporal resolution, substantially reducing—but not eliminating—motion artifacts.

In those days, alleviating patient motion in pediatric CT meant intravenous sedation and occasional general anesthesia in patients younger than five years. Sedation

remained widely utilized through the 1990s and early 2000s, but even with that limitation, CT imaging became routine in the evaluation of pediatric trauma, tumors, complicated infections, and some lung and vascular diseases.

Four-detector ultimately gave way to 16-, and then 64-detector technology, but gantry rotation speeds still fell short of eliminating motion artifacts in most children.

Adolescence: Dual-Source CT

A game changer arrived with the 2006 debut of the dual-source CT scanner, which featured two tubes and two corresponding detectors. On the single-source system, pitch was limited to less than 1.5; scans acquired at higher pitch values resulted in sampling gaps and led to image reconstruction artifacts. Dual-source CT, conversely, allowed for pitch values as high as 3.4,

permitting faster table speeds and shorter scan times as the second detector filled in the sampling gaps. The clinical benefit was a high-quality, motion-free CT scan that covered large anatomic areas and eliminated the need for sedation in infants and children (Figures 1,2).²

Multidetector CT boasted another significant advantage: expanding image interpretation from transverse reconstructions to volumetric visualization and analysis. This led to a greater role for CT in evaluating congenital heart, vascular, and coronary artery diseases. The recent addition of cinematic rendering has led to more photorealistic 3D images than was possible with other 3D reconstruction methods (Figure 3).

Early Adulthood: Making CT Safer for Kids

After the race for detector power slowed down, the race for dose

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Disclosure: Dr. Siegel is a speaker for Siemens Healthineers who receives honoraria and reimbursement for travel.

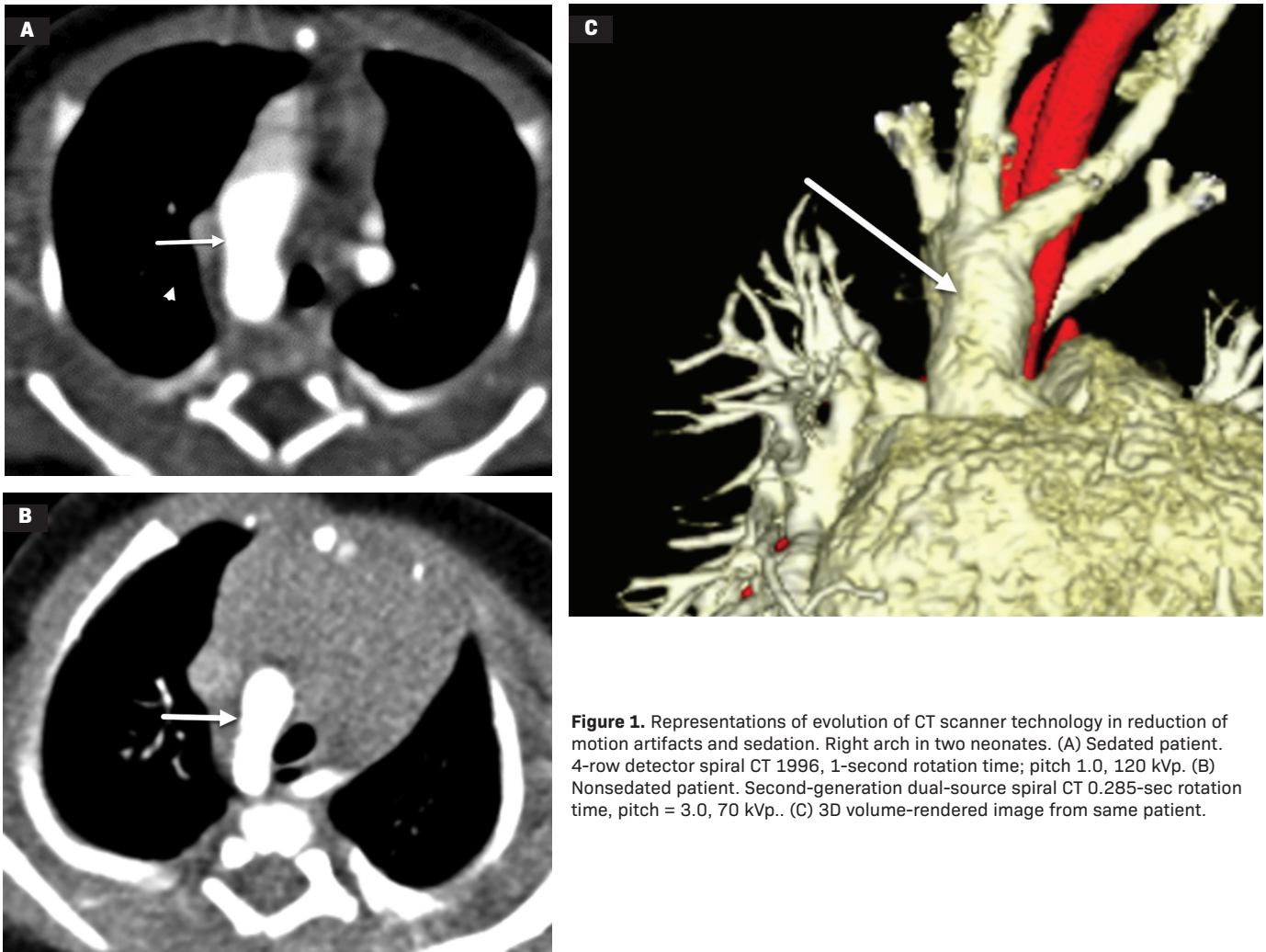


Figure 1. Representations of evolution of CT scanner technology in reduction of motion artifacts and sedation. Right arch in two neonates. (A) Sedated patient. 4-row detector spiral CT 1996, 1-second rotation time; pitch 1.0, 120 kVp. (B) Nonsedated patient. Second-generation dual-source spiral CT 0.285-sec rotation time, pitch = 3.0, 70 kVp. (C) 3D volume-rendered image from same patient.

reduction sped up. This ushered in technologies to automate the selection of key acquisition parameters that had a strong impact on dose, most notably tube current (milliamperage, mAs) and peak tube voltage (kilovoltage, kVp).^{3,4} The ability to individualize mAs and kVp to patient size profoundly impacted dose reduction.

Automated tube current modulation emerged in the late 1990s, replacing longstanding fixed tube current. Automated kilovoltage imaging followed in the early 2000s, lowering the voltage from 120 to 70 and 80 kVp in younger children. Iterative reconstruction then appeared on the scene, cleaning up image noise associated with lower tube

current and kilovoltage. The Image Gently® campaign launched in the 2000s brought national attention to the importance of dose reduction in pediatric CT imaging.

Not all dose reduction methods, however, were successful. Bismuth breast shields were widely recommended in the early 2000s, but it later became known that incorrect use of the shields actually raised the radiation dose and shielding was abandoned in 2012.⁵

The story of dose reduction is not over. Recently, a tin (Sn) filter was added to dual-source systems for noncontrast chest CT examinations performed at 100 kVp. This filter attenuates low-energy photons that contribute to dose but generally

contribute little to image quality and leads to significantly greater dose reduction compared to conventional CT protocols at 70, 80, and 100 kVp.

CT at Maturity: Improving Contrast, Optimizing Images

There was one more challenge in children that is not routinely present in adults; ie, inherently low levels of image contrast owing to smaller body size and less perivisceral fat. Early on, faster gantry rotations, dual-source geometries, and low kilovoltage imaging, in particular at 70 and 80 kVp, created images with high levels of iodine conspicuity, improving vascular imaging and lesion detection and characterization.

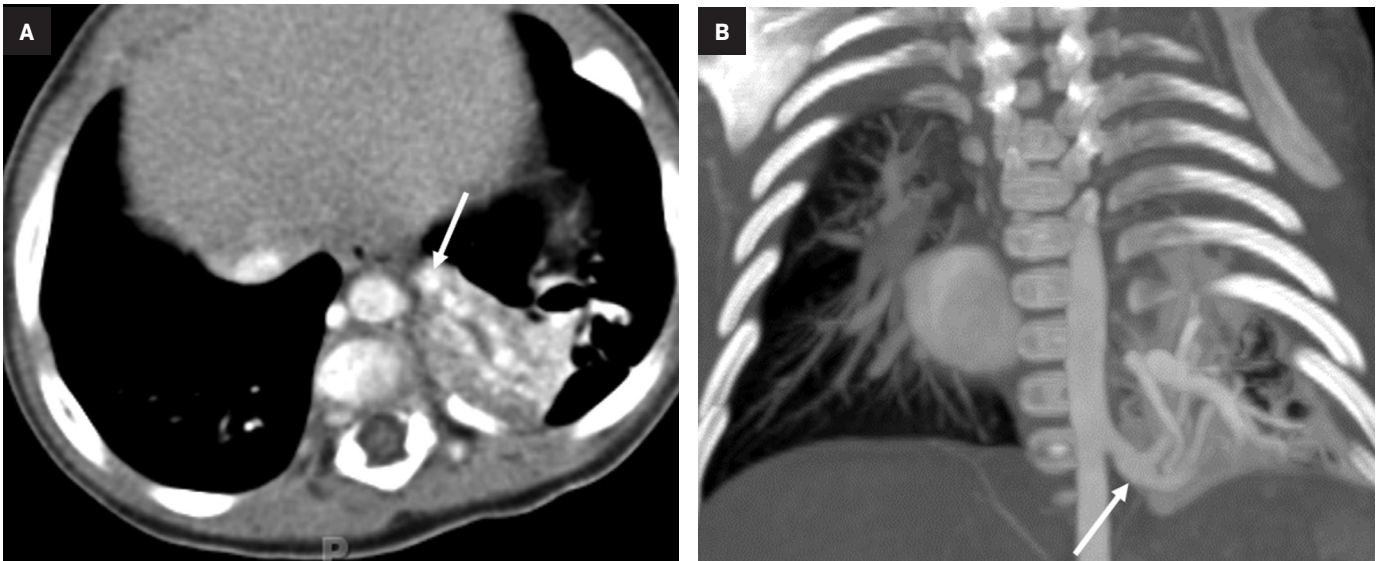


Figure 2. Pulmonary sequestration, representations of evolution of CT scanner technology. Pulmonary sequestration two neonates. (A) Sedated patient. 4-row detector spiral CT 1994, 1-second rotation time; pitch 1.0, 120 kVp. (B) Nonsedated patient. Dual-source spiral scanner 0.285-sec rotation time, pitch = 3.0, 70 kVp. Arrow = anomalous artery arising from the aorta.

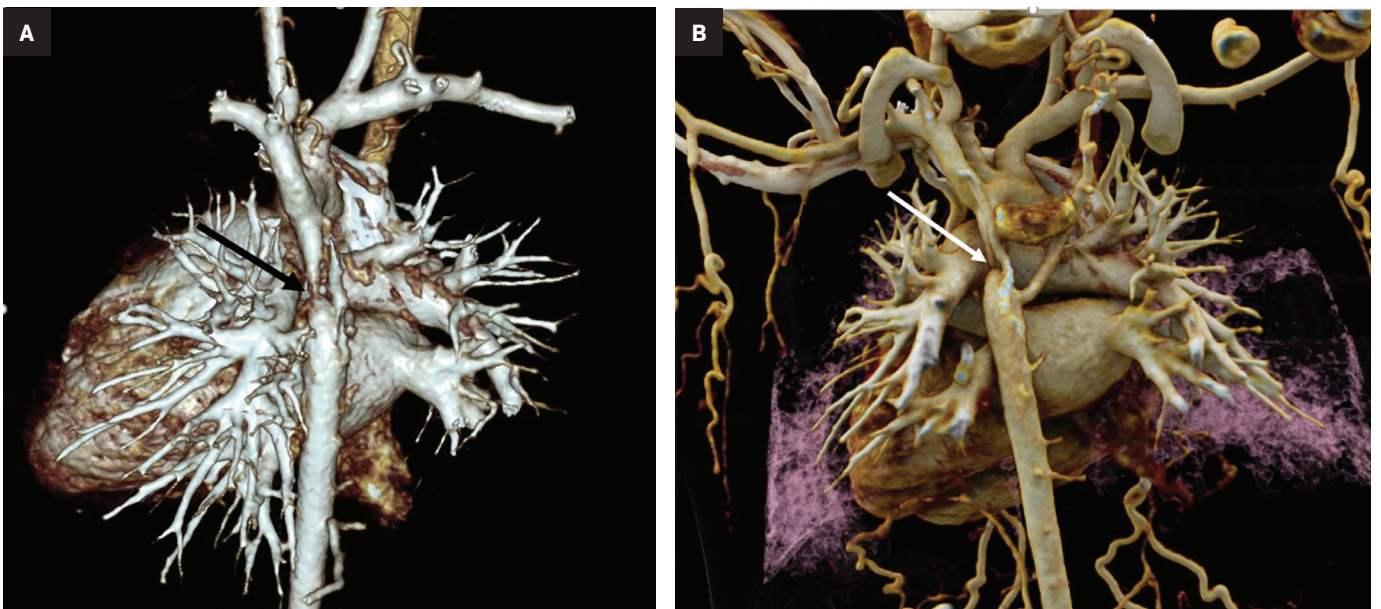


Figure 3. Advanced 3D reconstructions. Three-year-old with coarctation. (A) 3D volume-rendered image. (B) 3D cinematic-rendered image. The cinematic-rendered image depicts the high-grade coarctation, relative positions of the aorta and pulmonary artery, and collateral vessels with a higher level of detail than the volume-rendered image. Arrow indicates coarctation.

Image optimization improved even more when dual-energy CT arrived on the scene, allowing generation of monoenergetic and material decomposition images.⁶ The former play a role in improving image quality by reducing metal-implant artifacts and increasing contrast conspicuity in children with poor vascular enhancement related to slow injection rates and small intravenous

catheters (Figure 4). The latter images expand CT into new clinical applications, such as assessing lung perfusion (Figure 5) and predicting tumor response to treatment.

Looking Ahead

What new developments can we expect in pediatric CT going forward? Near-term innovations

include photon-counting CT to further improve image quality and reduce radiation output. Photon scanning will also offer more options for multi-energy imaging. In this era of precision or personalized medicine, look for greater use of radionomics, linking imaging phenotypes to genotypes.

The past few decades have undeniably been a golden age for

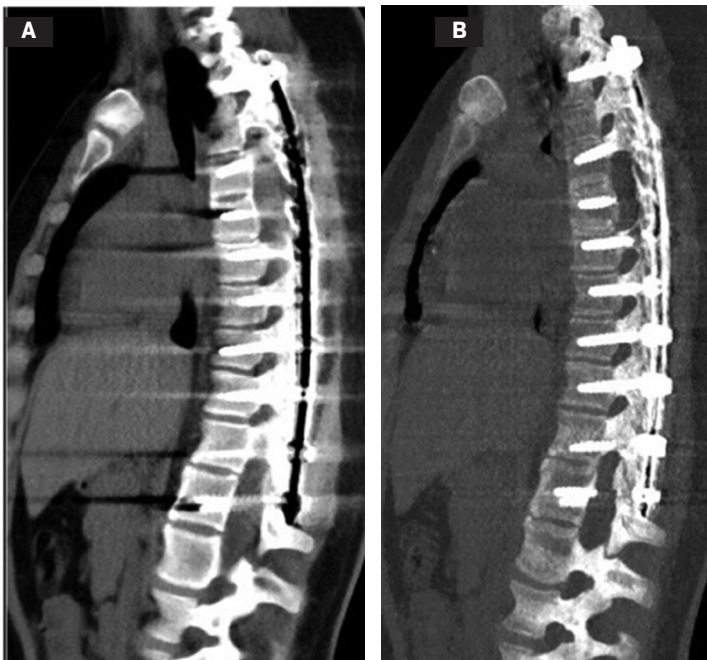


Figure 4. Artifact reduction using monoenergetic reconstructions. A 13-year-old with posterior spinal fusion. (A) Sagittal 140 kVp image shows streak artifacts obscuring the metal rod and surrounding tissues. (B) Sagittal monoenergetic image at 150-keV reduces streak artifacts, improving evaluation of the metal rod and surrounding anatomic structures.

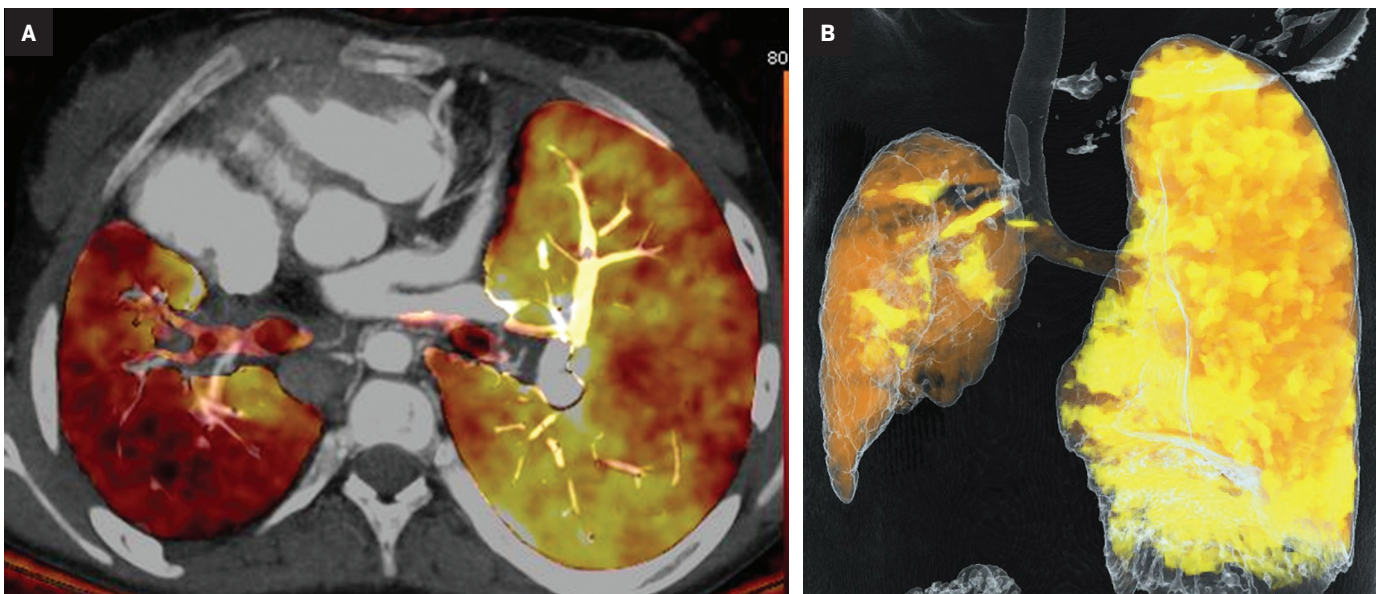


Figure 5. Lung perfusion application using DECT material decomposition reconstructions. A 13-year-old with hypoplastic right lung. (A,B) Axial and volumetric blood volume images, respectively, show decreased iodine content in a small right lung, indicating decreased perfusion and a well-perfused left lung.

pediatric imaging. If the past is any indication, this specialty can expect an even brighter future.

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