# Perspective

# Minimizing Radiation Dose for Pediatric Body Applications of Single-Detector Helical CT: Strategies at a Large Children's Hospital

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There has been much recent debate concerning the rising number of indications for which helical CT is used and the radiation dose with which helical CT is associated [1–4]. Increasing numbers of publications suggest more widespread use of CT as the primary imaging technique in multiple clinical scenarios: the child with abdominal pain, suspected appendicitis, or suspected renal calculi. A major disadvantage with this increased use of helical CT is the associated radiation exposure. Radiation dose is particularly important in children because of the relatively increased lifetime cancer risk of children compared with that of adults [5–7]. Recent publications have focused on the fact that the radiation dose associated with helical CT is much greater than the dose associated with most other imaging procedures [1, 3, 4]. CT, which accounts for approximately 4% of the medical radiographic examinations, reportedly contributes 40% of the total collective dose to the population [1, 4]. Although the true cancer risk of low-dose radiation is debated [8], it is well accepted that the radiation dose for a particular imaging study should be minimized [5–7]. Because of these reasons, in cases in which it is decided that the potential benefits from the information obtained on helical CT are greater than the risk of the radiation dose, technical factors should be adjusted to minimize the radiation dose. This adjustment is the responsibility of the radiologist supervising the examination. Little attention has been given to the technical parameters that can be adjusted to reduce the radiation dose associated with CT. In this perspective, we review the adaptations made to our helical CT protocols with the intention of reducing the radiation dose to pediatric patients. We hope that by calling attention to the issue of reducing radiation exposure in the pediatric population, these adaptations will be implemented for helical CT in pediatric and general imaging departments. Two parameters that can be adjusted easily and that have a profound effect on radiation dose are tube current and pitch.

## Tube Current (mA)

In conventional radiography, the need to tailor tube current and peak kilovoltage for each examination is visually obvious on the radiograph produced. The penalty for ignoring these details on CT is not apparent on the images produced. This has allowed the routine use of mA settings that are unnecessarily high. In pediatric patients, the mA setting can be adjusted, or reduced, according to the child's size. It is unacceptable to use a tube current setting that is appropriate for an adult on a child. In review articles concerning helical CT of pediatric patients, the recommended tube current setting has been progressively decreasing over the past several years [9, 10, 11]. A recent review article on the subject suggested 80–140 mA for helical CT of the chest and 100–160 mA for evaluation of the abdomen [10]. Although few articles have compared image quality using different tube current settings for the abdomen in pediatric patients, several investigations have suggested that the tube current setting can be significantly reduced from adult doses within the chest without loss of important diagnostic information [12–15]. A recent article that compared helical CT of the chest with tube currents as low as 12.5 mA with that of a more standard technique (175 mA) showed that although there was a statistically significant increase in the amount of noise on the low-dose images, in none of the low-dose examinations was diagnostic information lost [12]. These researchers suggested that radiation exposure could be reduced to 5–20% of the current standard. With all other technical factors (e.g., kVp, time) held constant, patient radiation dose is directly proportional to tube current. A

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50% reduction in tube current results in a decrease in radiation dose by 50%. Therefore, a CT scan obtained using the standard of 175 mA will deliver a dose that is 14 times greater than that of a CT scan obtained at 12.5 mA [11].

Despite these publications, other data suggest that adjustment of the tube current setting from standard adult doses for pediatric patients is largely overlooked [15, 16]. For example, in a recent study [17] that evaluated the effective dose to pediatric patients undergoing abdominal CT, the tube current setting used to calculate the dose for the pediatric patients was 220 mA.This value is much higher than the tube current setting suggested in the pediatric radiology literature [12–15]. In addition, in a review of techniques for helical CT examinations of pediatric patients performed elsewhere and submitted for a second interpretation, the average tube current setting used exceeded that typically suggested for an adult and had no relationship to patient age or size [17]. Another factor that may contribute to this lack of mA adjustment is that many of the available helical CT units are equipped with software that automatically chooses the tube current setting based on optimal image quality calculated for adults. Efforts must be made to override these automatic parameter settings when imaging children.

At our institution, a large children's hospital with a busy body CT section, we have adjusted CT protocols so that the tube current setting is chosen based on patient weight (Table 1). This table was created for use on a single-slice helical CT scanner (CT/i; General Electric Medical Systems, Milwaukee, WI). The chosen tube current setting is significantly lower than those we have used in the past. In some instances in which very small lesions may be present, such as in the evaluation of an immunocompromised child for fungal liver disease, we consider increasing the values in Table 1 by 50 mA to decrease noise. However, this increase is rarely necessary.

The major disadvantage of decreasing the mA is an increase in noise and the associated potential for degradation of image quality [1]. We have taken several steps to ensure that the potential increase in noise does not compromise the diagnostic information provided using a lower mA that is chosen based on patient weight. First, it is the consensus of our group, which consists of six pediatric body imagers, that the images are of high quality with no loss of diagnostic information (Fig. 1). We are not aware of any cases in which a diagnosis that was not detected on our reduced-dose CT examination has become evident at a later time. In addition, we have not repeated studies at an increased mA because of poor technical quality. Second, we have used phantoms to evaluate differences in noise using the techniques that we use in children of various sizes. Noise is related to the number of photons detected and is inversely proportional to the square root of the mAs. However, smaller patients attenuate the X-ray beam less, resulting in more photons reaching the detector and, therefore, less noise. Thus, the potential for increased noise caused by decreasing the tube current in younger patients is counterbalanced by the smaller size of the younger patients.

We used a 32-cm phantom made of Lucite (Ineos Acrylics, Southampton, UK) to simulate the abdomen of a larger child. The standard deviation for Hounsfield units, a measure of image noise [10], was 10.66 H using the appropriate technique for a child of this size (100 mA). In contrast, when we evaluated a 16-cm phantom to simulate the abdomen of an infant with the appropriate technique (50 mA), the standard deviation was 10.78 H. Therefore, the amount of noise was similar in the images of the larger child and the infant phantoms despite using half the tube current for the infant phantom. We used our infant-sized phantom (16 cm) to document the relationship between tube current and radiation dose. Keeping other technical parameters constant (120 kVp, 24-cm field of view, 1-sec exposure, 10-mm collimation), we compared the exposure produced with a tube current of 100 mA with that produced with a tube current of 50 mA. The skin exposure was 1.59 R (0.410 mC/kg) using a tube current of 100 mA and 0.79 R (0.204 mC/kg) using a tube current of 50 mA. Therefore, reducing the mA by half resulted in a decreased radiation dose by half (0.499 ratio). Finally, measurements of standard deviation of Hounsfield units performed in our clinical studies have not shown increased noise in images of small children compared with those of larger children when using weight-based reduced mA and appropriate child size-adjusted collimation. For example, the standard deviation within a 26-mm$^2$ area within the abdominal aorta, at the level of the superior pole of the right kidney, on unenhanced CT images measured 11.59 H for a 17-year-old boy (140 mA, 10-mm collimation, 120 kVp) and 9.06 H for a 2-year-old boy (140 mA, 5-mm collimation, 120 kVp). Despite the smaller collimation and lower mA, the noise (standard deviation) was actually less in the small child.

**TABLE 1** Suggested Tube Current (mA) by Weight of Pediatric Patients for Single-Detector Helical CT

| Weight | | mA | |
|---|---|---|---|
| lb | Kg | Chest | Abdomen or Pelvis |
| 10–19 | 4.5–8.9 | 40 | 60 |
| 20–39 | 9.0–17.9 | 50 | 70 |
| 40–59 | 18.0–26.9 | 60 | 80 |
| 60–79 | 27.0–35.9 | 70 | 100 |
| 80–99 | 36.0–45.0 | 80 | 120 |
| 100–150 | 45.1–70.0 | 100–120 | 140–150 |
| >150 | >70 | ≥140 | ≥170 |

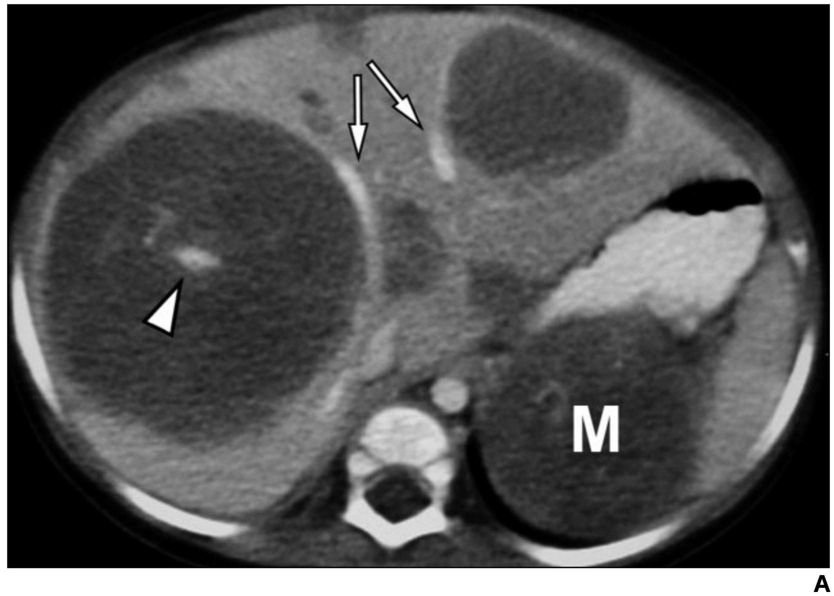
### Pitch

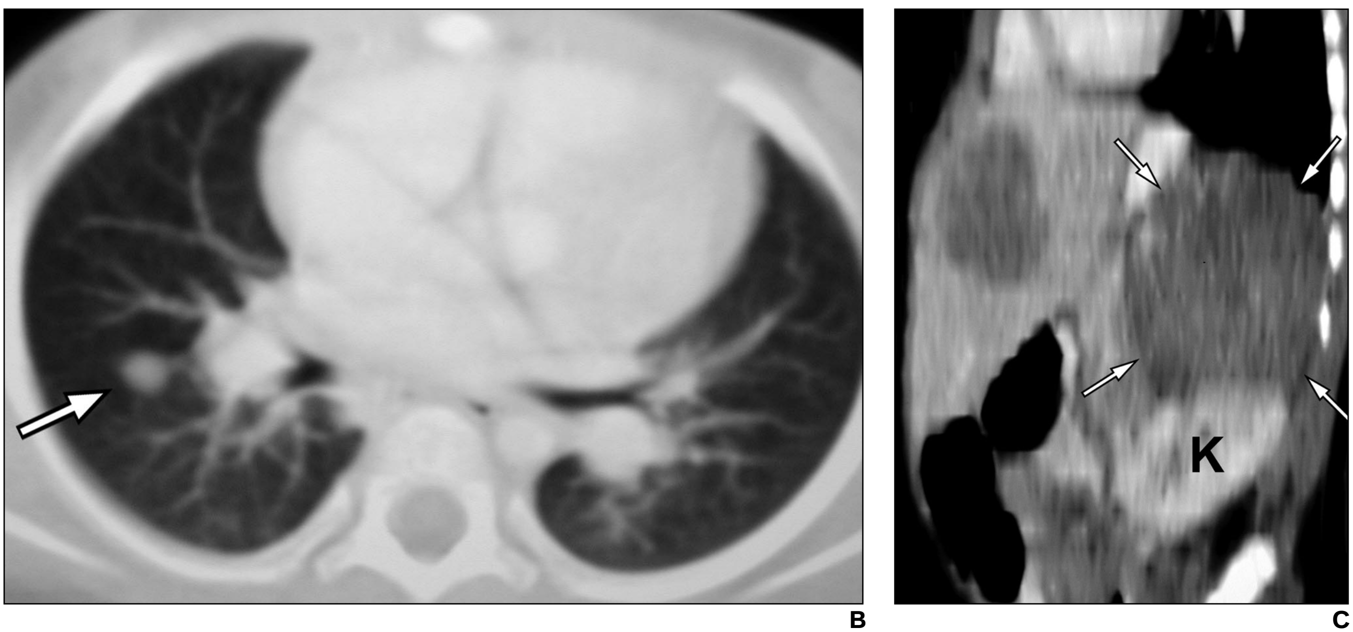
In addition to tube current, the other parameter that can be adjusted to significantly decrease radiation dose in helical scanning is pitch. When the pitch is doubled, the radiation dose is reduced by half [9, 18]. This reduction is related to the time that the X-ray beam is required to scan the area. If the pitch is increased, the amount of time needed to cover the anatomic area of interest and the resultant dose to the patient are decreased. One study showed that by increasing the pitch from 1:1 to 1.5:1, the radiation dose was decreased by 33% without a loss of diagnostic information [18]. We have had a similar experience with maintaining imaging quality (Fig. 1). Our standard pitch for helical CT in pediatric patients is 1.5:1, and we sometimes increase it to 1.7:1 or 2:1 for follow-up examinations or general abdominal surveys. We used our infant-sized phantom (16 cm) to document the relationship between pitch and radiation dose. Keeping other technical parameters constant (120 kVp, 100 mA, 24-cm field of view, 1-sec exposure, 10-mm collimation), we compared the exposure produced with a pitch of 1.0 with that produced with a pitch of 1.5. The skin exposure was 6.94 R (1.79 mC/kg) using a pitch of 1.0 and 5.02 R (1.30 mC/kg) using a pitch of 1.5. Therefore, the dose using a pitch of 1.5 resulted in a radiation dose that was approximately two thirds (ratio of 0.72 versus an expected ratio of 0.67) that when using a pitch of 1.0.

### Other Adjustments to Reduce Radiation Dose of Helical CT

Helical CT radiation dose can be further reduced in pediatric patients by appropriately addressing several additional issues. First, inappropriate referrals for CT can be eliminated. Examinations that can be equally served by alternative examinations with less or no radiation exposure, such as sonography or MR im-

**Fig. 1.—**8-month-old female infant with palpable abdominal mass, which later proved to be neuroblastoma. Diagnostic images were obtained with 60 mA and 1.5:1 pitch.
**A**, CT scan shows left adrenal mass (M) and multiple low-attenuation hepatic masses displacing middle and left hepatic veins (*arrows*). Note one mass that engulfs right hepatic vein (*arrowhead*).
**B**, CT scan of chest shows right lung nodule (*arrow*) that later was found to be metastatic neuroblastoma.
**C**, Sagittal reconstruction shows suprarenal, rather than intrarenal, position of adrenal mass (*arrows*). Note well-demarcated border between mass and left kidney (K). Hepatic masses are visible, as in **A** and **B**.




aging, can be appropriately triaged. Second, in most pediatric patients, unenhanced images are unnecessary when IV contrast material is to be administered. In the previously mentioned review of CT studies referred from outside institutions, not only was the tube current setting not adjusted for pediatric patients, but in many examinations the entire region of interest was imaged twice—before and after IV contrast material administration [17]. This practice doubled the radiation dose unnecessarily. If unenhanced imaging is indicated, every effort should be made to limit the area of scanning.

One CT parameter that has a much less profound effect on dose than tube current setting or pitch is collimation. Small changes in collimation do not largely affect radiation dose, assuming that tube current is not increased with a smaller collimation to compensate for increased noise. We typically decrease the collimation in young children because of their smaller size.

## Summary

Adjustments of the standard helical CT protocols for adults can result in reduced radiation dose when imaging children. It is the radiologist's responsibility to critically evaluate the CT techniques used at their institution. Adjustments to CT protocols should be made to choose the appropriate mA and pitch when imaging children.

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