

# Minimizing Ionizing Radiation Imaging in Pediatric Patients

## Abstract

Ionizing and nonionizing modalities in radiation play a central role in diagnosis and evaluation of pediatric injuries. Ionizing radiation risks are often minimized. Children are more radiosensitive due to their bone marrow and cells rapidly dividing; causing their DNA to be vulnerable. Research shows that computed tomography has been used inappropriately among pediatric patients, thus exposing patients to unnecessary radiation. Radiation safety such pediatric protocols, campaigns, and applying ALARA are essential in minimizing exposure while maintaining diagnostic quality. Prioritizing nonionizing modalities when clinically appropriate outweighs the long-term radiation risks for pediatric patients.

## Objectives

- To identify pediatric patients are more radiosensitive.
- To identify the potential risk and stages of malignancy associated with radiation exposure in pediatric patients.
- Establish radiologists and technologists play an essential role in protecting pediatric patients from excessive ionizing radiation.
- To evaluate the clinical problem and select the most proper diagnostic examination, ensuring that computed tomography is not used unnecessarily when other modalities can provide sufficient diagnostic information for pediatric patients.
- To understand the concept of ALARA and review guidelines for the proper use of computed tomography and other modalities.
- To review the Image Gently Alliance campaign and promote education on appropriate radiation safety protocols for pediatric patients.

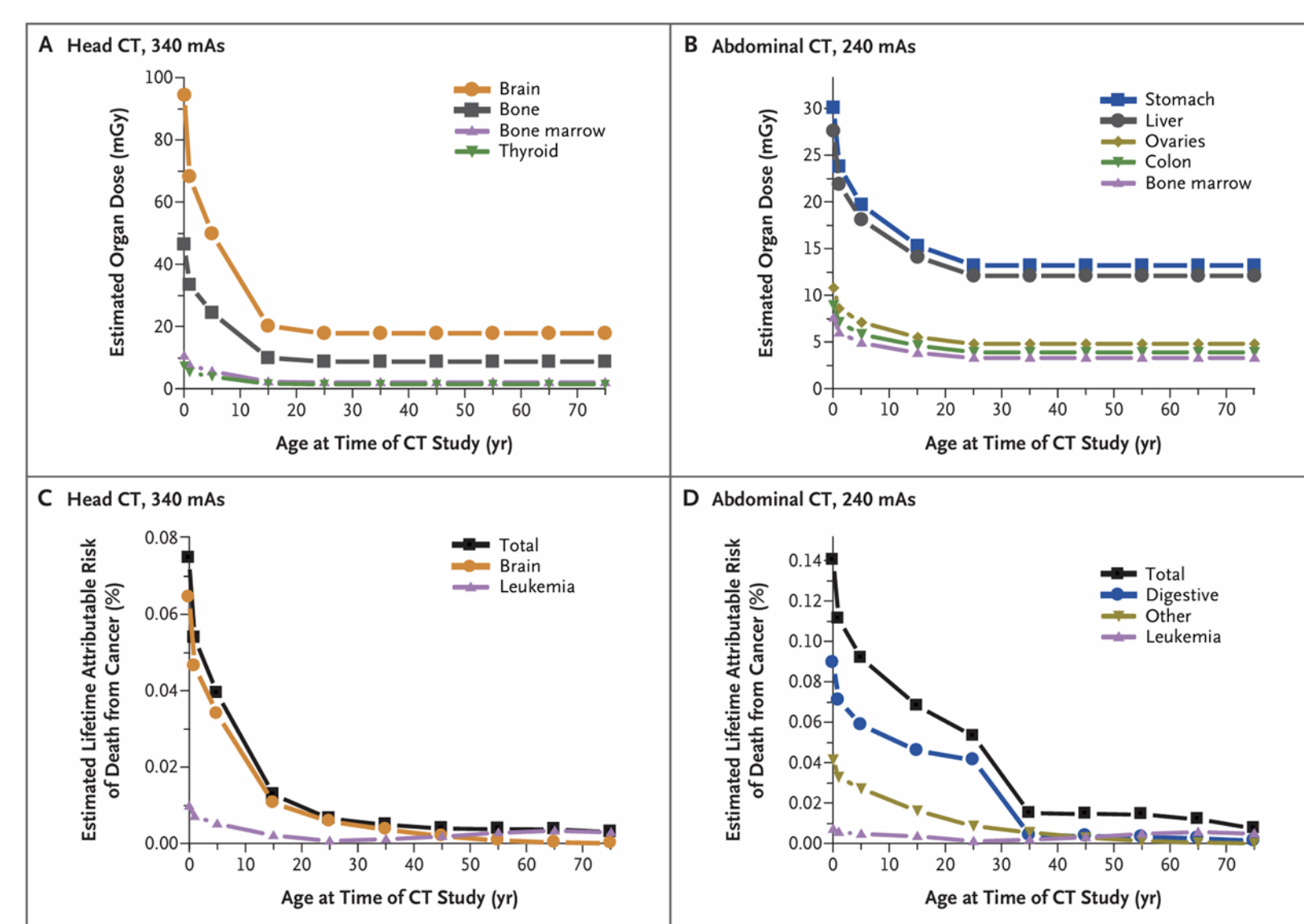
## Materials and Methods

The following research project is based on a literature review methodology, to analyze pediatric imaging with ionizing modalities, including the overutilization of computed tomography, and expanded on radiation safety guidelines.

## Results

Ionizing radiation is a high energy released by atoms that travel as electromagnetic radiation, capable of removing electrons, making the atoms charged. The chemically reactive atoms may disrupt molecular bonds, damage DNA, and interfere with cellular function (Padovan and Baldassarre, 2025). Children are more radiosensitive than adults because their cells are immature, rapidly dividing, and spend more time in vulnerable phases of the cell cycle. Highly proliferative stem cell populations such as those in bone marrow are susceptible to radiation-induced damage and could stop replicating or regenerate slower (Bolus, 2017). The distribution of hematopoietic bone marrow significantly differs in infants than adults, increasing pediatric vulnerability. Adults concentrate approximately 70% of active bone marrow in the trunk, 9% in extremities, and 8% in the head. In contrast, infants have a more diffuse distribution, with 29% in the trunk, 35% in the extremities, and 27% in the head (Alzen & Benz-Bohm, 2011). Radiation induced malignancy has more time to manifest as malignancy in children due to their longer life expectancy, implicating the earlier they are exposed to ionizing radiation, the higher their risk of developing cancer.

**Figure 1.** “Estimated Organ Doses and Lifetime Cancer Risks from Typical Single CT scans of the Head and the Abdomen.”

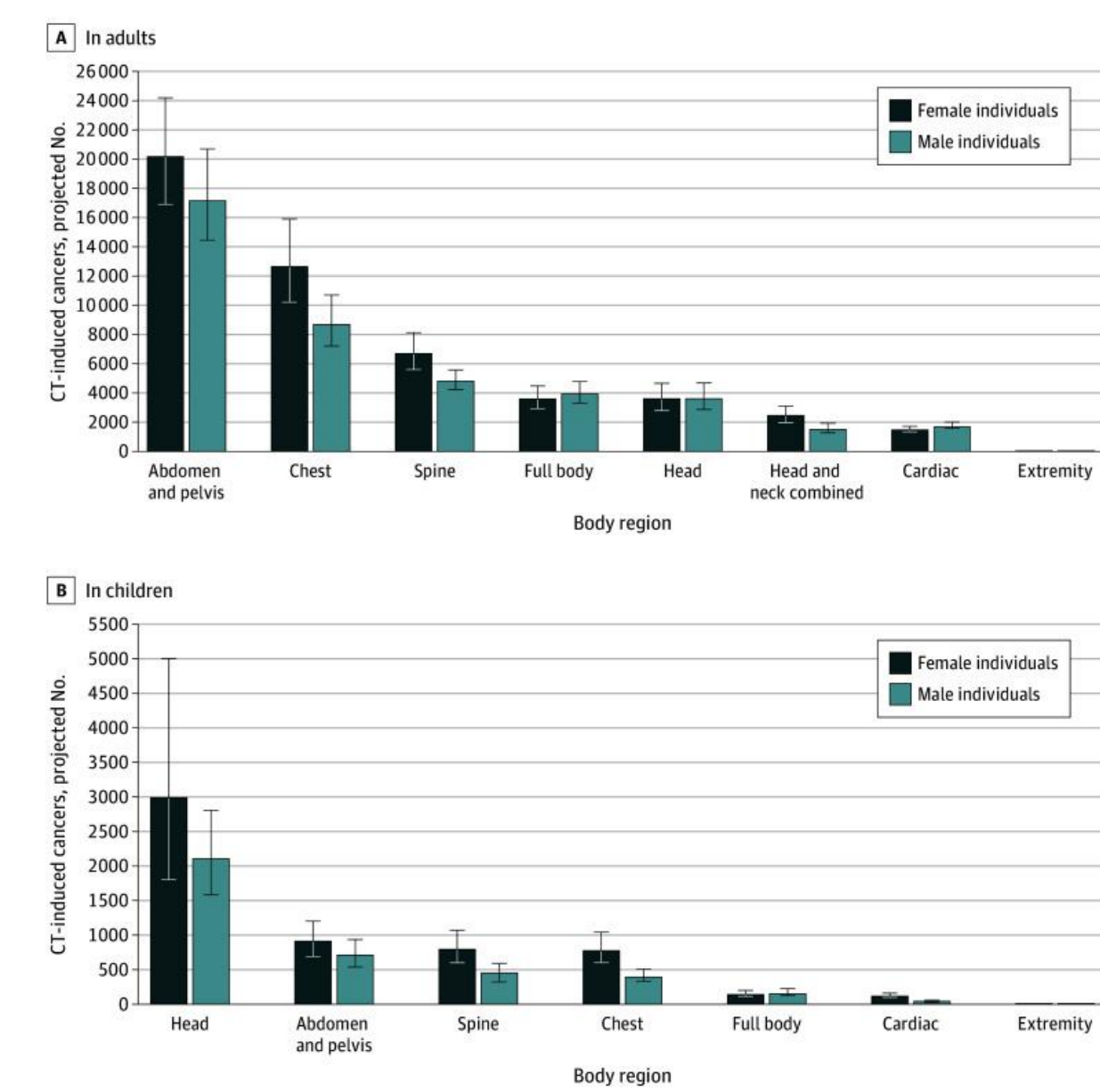


*Note.* From “Computed Tomography — An Increasing Source of Radiation Exposure” by Hall, E. J., & Brenner, D. J. (2008). Cancer risks from diagnostic radiology. *The British journal of radiology*, 81(965), 362–378. <https://doi.org/10.1259/bjr/01948454>

In Figure 1, Panels A and B demonstrate that the brain and stomach receive the highest doses in CT. The average mAs used are 340 for head scans and 240 for abdominal scans.

According to the Smith-Bindman study on medical imaging and pediatric exposure, the cumulative radiation dose to bone marrow was associated with an increased risk to all hematologic cancers. The study followed a retrospective cohort of 3,724,623 children born between 1996 and 2016; it was found that for every 100 mGy of bone marrow dose, the risk of hematologic malignancy increases by 2.54 times above the baseline. Indicating cancer has a non-linear threshold, and ionizing radiation should be kept as low as reasonably achievable (Smith-Bindman et al., 2025).

**Figure 2:** “Projected Number of Computed Tomography (CT)–Induced Cancers by Body Region Imaged in Adults and Children, by Sex.”



*Note.* From “Projected Lifetime Cancer Risks From Current Computed Tomography Imaging” by Smith-Bindman, R., Chu, P. W., Azman Firdaus, H., Stewart, C., Malekheadayat, M., Alber, S., Bolch, W. E., Mahendra, M., Berrington de González, A., & Miglioretti, D. L. (2025). Projected Lifetime Cancer Risks From Current Computed Tomography Imaging. *JAMA internal medicine*, 185(6), 710–719. <https://doi.org/10.1001/jamainternmed.2025.0505>

Figure 2 is a study conducted in 2023 on the projected cancers by computed tomography category. Head CT contributed the largest number of cancers in children, showing a 90% uncertainty limit. The relevancy that prevailed was if the practice of unguided CT examinations continue, “CT-associated cancer could eventually account for 5% of all new cancer diagnoses annually (Marin et al., 2024).”

**Table 1** “Recommendations for Emergency Department Advanced Imaging Strategies for Common Pediatric Conditions”

Clinical Problem	Risk-Stratification Tools	Recommendations	First-Line Imaging (if Available) <sup>c</sup>	Alternative/Additional Imaging
Headache (atraumatic)		Emergent neuroimaging is not necessary in patients with uncomplicated headache or those with stable headaches that meet criteria for migraine. <sup>b</sup>	MRI	CT
Abdominal Trauma		Imaging is warranted if signs of abdominal injury or unexplained elevated transaminases (>80 u/L) <sup>d6</sup>	CT (with IV contrast)	
Appendicitis	Pediatric Appendicitis Score <sup>54</sup> Alvarado score <sup>55</sup> Pediatric Appendicitis Risk Calculator <sup>31</sup>		US <sup>b</sup>	MRI without contrast, CT with IV contrast, repeat US, <sup>d</sup> observation

IV, intravenous; US, ultrasonography; XR, radiography. All imaging is without contrast unless otherwise specified.  
a. Excludes patients with concern for child abuse.  
b. Indicates Choosing Wisely recommendation.  
c. When MRI is recommended, it should be performed only in a stable patient given the duration of obtaining and completing the examination.  
d. Patients with equivocal initial ultrasonography (eg, nonvisualized appendix) may undergo follow-up ultrasonography after a period of observation (eg, 6–12 hours).

*Note.* Adapted from “Optimizing Advanced Imaging of the Pediatric Patient in the Emergency Department: Policy Statement” by Marin, Jennifer R., et al. “Optimizing Advanced Imaging of the Pediatric Patient in the Emergency Department: Policy Statement.” *Annals of Emergency Medicine*, vol. 84, no. 2, Aug. 2024, pp. e13–e23, <https://doi.org/10.1542/peds.2024-066854>

Table 1 is based on hospital guidelines, Choosing Wisely recommendations, the American College of Radiology Appropriateness Criteria. Evidence-based guidelines are used as tools to reduce variability in practice and create a standardized approach for evaluation. There are three categories imaging usually falls under: “imaging that determines the need for emergent intervention provided by the originating ED, imaging that may determine whether transfer is needed, and imaging in a patient who will be transferred regardless of imaging findings (Marin et al., 2024).” An example may be a child comes in for abdominal pain and may be at moderate risk of appendicitis, but ultrasonography nor MRI are available at the ED. The options for imaging are ordering a CT at the referring ED or transferring the child to another place for ultrasonography or MRI (Marin et al., 2024). According to a study on ultrasound, CT, or MRI for acute appendicitis diagnosis in children and adolescents, a clinical assessment should be completed first and if necessary, the first-line imaging would be ultrasound. Ultrasound is deemed safe, widely available, and highly accurate, based on the study ultrasound sensitivity rate was at ~0.93-0.95 and specificity was ~0.89-0.93. If the ultrasound is deemed nondiagnostic (appendix not visualized or no secondary signs to confirm or exclude appendicitis), which occurs in 40% of cases, the second-line imaging would be magnetic resonance imaging (MRI). MRI is used as second-line imaging because it has a very high accuracy, sensitivity 0.96, specificity of 0.98, and equivocal rate of 8.6%. If the MRI is considered equivocal, either it can be repeated or the third-line imaging would be used, which is CT. It is essential if a CT is done, low-dose protocols are used (Castro-Luna et al., 2025).

According to (Smith-Bindman et al., 2023) it is essential for all Emergency Departments to

- Evaluate pediatric readiness.
- Have mechanism to securely transmit or share images.
- Have processes in place to ensure timely and efficient transfer of pediatric patients who require specialized care.
- Have policies in place for imaging consultation with a pediatric radiologist with expertise in pediatric image.
- Strive to provide high-quality ultrasonography services as first-line imaging for pediatric patients when indicated for common pediatric complaints
- Partner with imaging services to ensure that CT protocols and parameters are pediatric-specific and adhere to ALARA principle.

Implementing structured guidelines and protocols demonstrates reduction in radiation exposure and improves adherence to “As Low as Reasonably Achievable” principles. In a recent study, on pre versus post implementation of imaging guidelines on injured children, pre-implementation conveyed 51% of computed tomography exams were not indicated as needed per guidelines, versus post implementation of guidelines 25% of examinations were unnecessary (Mahdi et al., 2023).

It is essential to assess the awareness of radiation exposure from CT among physicians, especially when a CT scan is ordered. The survey was conducted among pediatricians in Saudi Arabia and received responses from 162 respondents. It was found that 15% were aware of the ALARA concept and 54% thought multi-slice CT did not give a high radiation dose. Overall, 83% were not aware of CT radiation exposure and 70% misunderstood that MRI uses radiation (Al-Rammah, 2016). In another recent study, although knowledge of radiation and radiation risks increased among the 293 respondents, the study found that awareness of pediatric radiation, radiation exposure in pregnant women, and radiation dose remained low (Rawashdeh et al., 2020).

The Image Gently Campaign aims to raise awareness of possible harmful effects of cumulative radiation over a period. The alliance uses the motto “Be wise. Adjust for size.” In recent years there has been increased utilization of CT which leads to a higher patient radiation dose. Radiation protection experts have warned physicians that children are more sensitive to radiation and the cumulative effects. There are three things Goske wanted to emphasize in the first phase. They aim to significantly reduce the amount of radiation used in pediatric CT scans, scan only, when necessary, do it once, and in the correct region, finally they want to optimize and monitor pediatric CT scanning. The goal of the campaign is to create and establish kid-size radiation doses as the standard of care for the U.S. Eventually, the phases will include other ionizing radiation imaging modalities and address the utilization of alternative nonionizing imaging modalities like MRI and ultrasound. (Diagnostic Imaging, 2008).

Computed tomography has become one of the most utilized imaging modalities, making dose optimization crucial for CT technologist. Technologist should continuously apply ALARA in CT practice (ALARA in 2025: Modern Radiation Safety for CT, Fluoroscopy, and General Radiography):

- Cardinal Principles: Time, Distance, and Shielding
  - Time reduces dose.
  - Doubling distance from the source reduces the exposure by ¼.
  - Shield, when necessary, allows for the necessary anatomy and lower exposure.
- Use lower kVp Compatible with Diagnostic Quality
  - Reduces dose in pediatric patients.
- Automatic Exposure Control
  - Controls mA based on patient size and anatomy.
- Protocol Standardization
  - Reduce variability and unnecessary multiphase exams.

## Conclusion

Ionizing radiation is utilized in computed tomography and has become essential in pediatric healthcare. Ionizing radiation has a non-threshold linear relationship with cancer thus, if unguided examinations continue, the risk of exposure-induced cancer continues to thrive. It is shown through research enabling guidelines, protocols, and reinstating ALARA when assessing pediatric injuries and conditions, minimizes the usage of ionizing radiation in pediatric patients. Providers, emergency departments, and technologists have the duty to keep ionizing radiation at a low dose. It is due to the vulnerability of children; it is essential to prioritize the clinically necessary imaging examinations.

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