Pediatric CT and Image Gently®

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The utility of CT in patients of all ages is undeniable [1-4], and was paralleled by its increasing use over the last decade of the 20th and the first decade of the 21st centuries [5, 6]. Approximately 11% of the estimated 69 million CT scans performed in the US as of data reported in 2000 and 2007 were performed on children [5-7]. This use, which obviated other procedures which were more invasive and carried increased acute risks, such as diagnostic rather than therapeutic laparotomies [8] , nevertheless also accrued increased radiation exposure. According to the NCRP Report No. 160 [9] in the quarter century between 1980 and 2006, radiation exposure from medical procedures had increased sevenfold, largely secondary to the use of CT and nuclear medicine[7].

Since that time, the Image Gently Alliance, which focuses on children, and the Image Wisely campaign, which focuses on adult patients, have made significant inroads into the education of radiologists, technologists, referring physicians and the public, with a goal of decreasing unnecessary radiation exposure by improving *justification* and *optimization*. That is, when studies are indicated, they should be performed with the lowest radiation exposure that will allow diagnosis. In simple terms: right patient, right exam, at the right time, done the right way.

The child could be considered the paradigm underscoring the importance of this process. Why is this so? What makes children different? Children differ from adults in a number of important ways relevant to radiation exposure and potential stochastic risks. Compared to adults, (1) children are smaller, (2) they are growing, and (3) they have longer remaining lifespans.

1- Children are smaller than adults. For any given set of CT scanning parameters, the effective dose is higher for smaller cross-sectional areas. This is because dose is defined as absorbed energy per unit mass, and therefore the same energy in a smaller mass will result in a higher dose per unit mass. In addition, in the case of CT, where the beam is applied circumferentially, dose in the center of a small patient will be higher than in the center of a large patient, due to the lesser attenuation of the surrounding tissue in a small patient. These effects will be most pronounced in the youngest patients with smaller body mass and radius. Calculated dose parameters that are displayed in current CT scanners are based on data obtained from the 32 cm phantom. In an average adult, whose size is equivalent to 29 cm, the 32 cm acrylic phantom will underestimate the dose to that average adult by approximately 30% [10]. This, of course, would be compounded in pediatric patients. In an analysis of effective dose by body mass, effective dose in pediatric patients was increased by 50% compared to adult patients despite a reduction of approximately 25% in scanning parameters in that series. The increase was most marked in the infants, in whom effective dose increased 100% [10]. It is therefore very important to realize that, for a given set of CT scanning parameters, we must CHILD-SIZE the scanning parameters just to maintain the same image noise that is acceptable in the CT images of our adult patients.

2- Children are growing. Because of this, their tissues are more radiosensitive than adult tissue. According to the International Commission on Radiation Protection (ICRP), estimates of attributable lifetime risk for a single dose of radiation vary considerably with age, are increased in patients younger than 30 years, but particularly in patients younger than 10 years [11]. With the exception of leukemia, girls are also believed to be more radiosensitive than boys for most cancers, particularly breast and thyroid. This increased radiosensitivity is believed to be related to other promoting factors which are hormone-dependent and which differ between males and females, rather than to other potential inherent differences in radiation sensitivity [12].

3- Children have longer remaining life spans. Potentially induced cancers do not become manifest until after a latency period, which varies with the type of cancer and age of the patient. The longer life expectancy of the pediatric patient allows sufficient time for a latency period to occur. Further, with a longer life, the chances of repeated and increased cumulative doses are increased.

Strategies to reduce radiation dose follow the ALARA principle (As Low As Reasonably Achievable); i.e., obtaining diagnostic examinations at the lowest possible dose. At all ages, CT examinations should only be performed when indicated, and consideration should be given to alternative modalities, such as Ultrasound and MRI, as appropriate. Multiphase examinations double or triple the radiation dose, are rarely indicated in pediatrics, and should only be used when absolutely necessary, with adjustment of parameters as possible. For example, if pre-contrast images are necessary to assess for calcifications within a tumor, the pre-contrast scan should be restricted to the site of the tumor, and can be done with much lower scanning parameters, as image noise would not interfere with detection of calcifications. By the same token, follow-up examinations to assess changes in size of a large tumor, or renal calculus burden, can be done with limited scanning field and much lower scanning parameters and exposure [13]. Institutions should be accredited by an organization that evaluates image quality and radiation dose indices and documents that CT doses are "child-sized."

Significant inroads have been made in reducing radiation exposure to the pediatric patient since the launch of the Image Gently and Image Wisely campaigns. There have been over 50,000 pledges to the Image Gently website, and a similar number to Image Wisely by the end of 2016 (with 20,000 new pledges in the first month of 2017 alone). Beginning in 2007-2008, a decreasing trend in the number of CT scan examinations for pediatric patients has been observed [14]. Further, improvement in CT hardware and software, particularly the introduction of Iterative and Module Based or Modeled Iterative Reconstruction algorithms, show promise in lowering radiation exposure, in some cases by 90 percent in the submillisievert range, approaching plain film exposures even for cardiac gated studies[15-20].

In summary, the principles of justification and optimization underlie both the request and the performance of diagnostic imaging examinations. CT is a valuable tool, which helps us save lives and avoid more invasive procedures. As other imaging modalities, it needs to be used judiciously, with understanding of potential risk factors, and the relationship of these risk factors to the age and size of our patients.

Cross links:

www.cancer.gov/cancertopics/causes/radiation/radiation-risks-pediatric-CT

http://www.imagegently.org/

http://www.radiologyinfo.org/

www.pedrad.org

http://www.eurosafeimaging.org/

http://www.wfpiweb.org/

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