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Imaging challenges: a U.S. perspective on controlling exposure to ionizing radiation in children with cancer

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Abstract

Issues pertaining to control of radiation dose exposures in pediatric imaging are on the forefront of patient care worldwide. Certain factors contribute to appropriate – or inappropriate – use of ionizing radiation in pediatric medical imaging. Such issues include naiveté regarding cancer risk and the role of medical imaging in its development, misinformation about exposure to ionizing radiation, resource availability, staffing, scheduling “snags,” costs, limited evidence-based imaging practice information and shrinking funding. These issues will be introduced in this paper.

Keywords

Radiation exposure; Dose; ALARA; Biologic effects; Children

Introduction

Issues pertaining to control of radiation dose exposures in pediatric imaging are on the forefront of patient care worldwide. The presentations in this ALARA program have addressed these issues from multiple vantage points: clinical needs for information to staging and monitoring disease and disease response, imaging techniques and limitations, imaging requirements for research purposes, biologic effects of radiation exposures, particularly in children, and the potential contribution of medical imaging on the later development of cancer.

This presentation will offer some additional factors that contribute to appropriate – or inappropriate – use of ionizing radiation in pediatric medical imaging. Issues include naiveté and misinformation, resource availability, staffing, scheduling “snags,” costs, limited evidence-based imaging practice information and shrinking funding.

The rapid technologic evolution and escalating use of medical imaging [1] is occurring in parallel with a dramatic increase in complexity of oncologic therapy and concurrent improvement in cure and long-term outcomes of children and adolescents treated for cancer. The overall estimated 5-year survival of children with cancer, regardless of the primary diagnosis or stage, is 79.6% [2,3]. Thus, the population of childhood cancer survivors is growing rapidly.

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Current estimates suggest that the number of childhood cancer survivors may reach as high as 1 in every 250 young adults ages 15 to 45 years by 2010 [4]. Complicating the lives of these patients are long-term morbidities resulting from the disease itself and associated treatment toxicities, not the least of which are secondary malignant neoplasms. The cumulative incidence of secondary malignant neoplasms 20 years after the diagnosis of childhood cancer is estimated to be 3.2% [5]. Monitoring for the development of such tumors typically includes the use of medical imaging.

The development of secondary malignant neoplasms (SMN) is of multifactorial etiology, discussed at length in other papers in this supplement. These lesions manifest at varying times depending on the type and intensity of prior treatment, patient-specific genetic predisposition to cancer, and environmental exposures (including exposures to ionizing radiation). As a general rule, development of leukemia as an SMN plateaus 10–15 years after treatment exposures from primary therapy [5–7]. However, the risk associated with the development of secondary malignant solid tumors continues to rise throughout life [5–7].

In caring for children and adolescents with cancer, the goals for patient and disease assessments are the same whether approached from the perspective of medical imaging or from the perspective of clinical management. Unique to the pediatric cancer population is the prevalence of protocol-based treatment. As such, imaging is directed by scientific hypotheses as well as by clinical needs; images initiated from these two aspects need not coincide.

General disease-driven indications for imaging include:

- Initial diagnosis and staging
- Assessment of therapeutic response
- Assessment of treatment toxicity and complications
- End of therapy evaluation
- Post-therapy monitoring

Many evaluation time-points are expected based on the primary malignancy and treatment protocol. However, additional imaging might be needed to assess for infection, unexplained pain, neurologic event and reasons for which imaging is typically used in the general pediatric population (i.e. trauma, appendicitis, child abuse, etc.). Thus, children undergoing treatment for cancer usually require considerably more imaging than the general pediatric population but they might also be more susceptible to the harmful effects of imaging than the general population because of prior exposures and underlying genetic predisposition to cancer development.

This paper will explore potential challenges to implementing ALARA principles in pediatric oncology, most of which would also serve as challenges in implementing these principles in other patient groups.

Naiveté

- “Exposure to ionizing radiation for imaging is the least of their [kids with cancer] worries.”
- “Loss of life from cancer will supersede cancer death from imaging exposures.”

Because exposures received in childhood and adolescence are cumulative and last a lifetime, any exposure to ionizing radiation must be considered on the basis of risk and benefit of the examination in pediatric patients as a whole. Children with cancer are a small subset of the pediatric population, comprising about one to two children per 10,000 new cases of cancer per

year in the United States [3,8]. As mentioned above, these children typically undergo medical imaging multiple times from diagnosis of their disease and throughout treatment. However, these children also participate in *usual* kid activities such as play and sports and also develop the same acute illnesses as children in the general population such as appendicitis and pneumonia. In these instances, children with cancer are typically cared for in local community hospitals for non-cancer-related issues – as are most children in the general population.

Whether or not a child is receiving care for cancer, urgent medical treatment is typically provided in local community hospitals where the predominant patient population is adult. Thus, pediatric patients represent a minority of the practice. Pediatric CT protocols may well not be in place and these patients might be approached as “little adults,” without regard for their increased susceptibility to the effects of ionizing radiation. It is through initiatives such as the Image Gently Campaign [<http://www.imagegently.org>] that awareness is raised and education is propagated regarding the sensitivity and susceptibility of pediatric patients to the hazards of exposure to ionizing radiation from medical imaging.

Evidence-based imaging

“We’ve always done it this way.”

Rapid technologic advancements easily overpower and overtake evidence-based clinical implementation of new modalities and techniques. Decision-making based on scientific evidence of new methods and new technologies lags behind modality implementation, and pediatric evidence and use lags behind adult use. As such, adult dose parameters and techniques might be utilized by default for imaging pediatric patients.

Clinical experience with evidence-based guidelines has shown the potential for providing conformity and uniformity of care, improved utilization of resources and, one would hope, improved patient care as in the management of pediatric abdominal trauma [9–11], head injury [12], status epilepticus [13], possible appendicitis [14] and other scenarios. Within the realm of pediatric oncology, two examples showing where evidence-based guidelines have provided direction for disease evaluation and response are detection of pulmonary metastases and primary bone tumor imaging. The literature is replete with evidence supporting CT over chest radiograph for detection of pulmonary metastases [15–18]. The recently developed spiral imaging methods have been shown to be superior to conventional single-slice technology [18]. Whether the increased detectability will correlate with improved outcomes has not been determined for many tumors [19,20]. Determination of local tumor extent in cases of primary bone tumors has been shown to be comparable between CT and MRI; no statistically significant difference has been shown between the methods [21]. However, the Children’s Oncology Group Bone Tumor Committee requires MRI as opposed to CT for determining local tumor extent and follow-up to take advantage of MRI’s improved soft-tissue assessment and multiplanar capabilities, obviating patient exposure to ionizing radiation [22].

The choice of imaging modality in pediatric oncology might also be influenced by less obvious factors. Comparing results from a contemporary treatment regimen to those of a previous regimen can be hampered by a change in imaging technique and even more so by a change in imaging modality. Hence, modification of techniques and even the choice of the modality might lag behind evidence-based imaging in deference to consistency in imaging technique to better assess treatment response. Second, when multi-institutional treatment protocols are designed, constraints might be instituted on the type of imaging based on the availability of like methods at each participating healthcare facility. One additional factor that can influence the choice of imaging modality is the cost of the study. MRI – which can be more sensitive to some findings than CT and involves no ionizing radiation -- typically costs more than CT of the same site, even without the added costs of sedation or anesthesia, which is more often needed with

pediatric MRI than with CT. Further, utilization of an imaging modality or technique might not have been approved by third-party payers at the time of its use for disease evaluation; the technique itself might even be under study for its utility. In such cases, funding must be obtained through extramural sources, institutional research funds, endowments, private payments or other sources. In cases where funding is absent, a potentially valuable imaging method might be omitted from a study, a less desirable method (and potentially one using ionizing radiation) might be substituted, or, in the case of multi-institutional studies, used inconsistently and only in facilities financially able to support its use.

Education

Children imaged with adult techniques

In order to educate others regarding the appropriate use of and techniques for medical imaging, we pediatric radiologists must first develop a widely regarded reputation of being specialists with advanced knowledge, skill, collegiality, compassion, reliability and availability. The American College of Radiology recently completed a survey of 1,000 American adults [23] and elucidated several disturbing impressions:

“What we have learned, although surprising — is not totally unexpected:

Many people thought that radiologists were not doctors

Many considered radiologists to be “passionless”

Many did not think radiologists had to be college-educated” [23]

Thus, in developing the many roles of a radiologist -- medical professional, consultant, clinician, collaborator, educator, scientist, etc., -- we must also develop a rapport with patients, their families and our medical colleagues [24–26]. In so doing, we facilitate exchange of educational and practice-oriented ideas that benefit patients and improve their care. The feasibility of such multidisciplinary interchange is evident in the success of the ImageGently Campaign [<http://www.imagegently.org>], where the American Academy of Pediatrics is an Alliance Organization, as well as in the multidisciplinary participants of the ALARA Conferences [27,28].

We can also facilitate appropriate use of imaging and techniques by embracing the appropriateness criteria established by the American College of Radiology (ACR) [29] and sharing this information with ordering clinicians. By fostering collegial interaction, we can educate others to welcome enlightenment and perhaps eliminate such practices as:

“I want CT because I can’t read US” – oncologist

“I can’t read water’s views so I want all three views of the sinuses” – immunologist

“Well, while he/she is on the table, let’s also cover....”

Little if any control over outside studies performed with/for original diagnosis

Once imaging has been performed at an institution local to the patient’s residence and a potential malignancy identified, it is common for a pediatric patient to be referred to a tertiary care pediatric institution for further evaluation and treatment. In such a scenario, pre-existing studies may or may not be transferred with the patient. Depending on the urgency of the patient’s medical needs (i.e. airway compromise or acute intracranial hemorrhage from tumor), studies may or may not be repeated; repeated studies add to the burden of ionizing radiation exposure in each patient.

Efforts should be made by the referring institution to transfer existing disease-related imaging along with the patient and for the receiving institution to obtain and review outside studies. Recognizing that many initial imaging studies are not performed as staging studies and, thus, might need to be repeated at the treating institution, obtaining prior studies can frequently limit repeat examinations and decrease exposure to radiation. Alternatively, information obtained from prior studies can be used to limit or more closely tailor repeat studies, thereby minimizing radiation exposure, which accumulate exposure savings over time.

Most tertiary care institutions have means by which several methods of image transfer can be managed: CDs, hard copy, electronic web-based transfer, etc. One of the simplest means by which to have access to existing studies is by having the patient or parent hand-carry such studies from one institution to the next. For expeditious transfer, verbal request for this imaging can be initiated at the time of patient transfer by the receiving oncologist. In this way, such imaging can also be reviewed upon patient arrival, thus improving patient assessment. Secondly, verbal or written request for such imaging can be undertaken once the patient has been received and his or her medical status determined.

Scheduling, resource availability, complexity and optimization

- “CT is so much easier to schedule”
- Completing staging work-up prior to diagnosis of a malignancy
- I’ll order the staging work-up to get the appointment slots and can always cancel the orders – then the orders are not cancelled

Certainly, potentially impacting the implementation of ALARA principles of practice is the ability to schedule ALARA-friendly imaging. Imaging an uncooperative or frightened pediatric patient might well influence the choice of imaging modality. Although MRI might be ideal for disease staging in pediatric patients from the standpoint of no exposure to ionizing radiation, it often requires sedation or general anesthesia to be completed; delay in the daily patient schedule can result if sedation is needed and has not been prospectively planned. In contrast, CT is fast, more readily accessible and, despite the exposure to ionizing radiation, can be considered “peds-friendly.”

The expediency with which imaging studies are scheduled for anxious patients and families varies by institutions, departments and physicians. In some cases, particularly when attempting to minimize inconvenience to patients and families and when sedation or general anesthesia is needed, clustering of imaging studies might be desirable. However, such practice predisposes children to unnecessary imaging, unnecessary potential for contrast toxicity, and potential complications from sedation or anesthesia should histologic examination of biopsy material prove the disease to be benign. Similarly, scheduling of studies with the intent of securing the appointment and subsequently cancelling unneeded studies runs the risk of the study being completed because of an oversight in not cancelling the imaging request.

With the complexities of scheduling pediatric patients in mind, every effort should be made to facilitate their completion, address needs specific to young patients and their families such as coordinating imaging studies with clinical visits, managing patient preparation for imaging studies, and providing safe and efficient sedation or general anesthesia, all of which can contribute to minimizing exposure to ionizing radiation.

Personnel supply and demand

Key to incorporating ALARA principles in caring for pediatric oncology patients is not only the accessibility of appropriate imaging modalities but adequate technologist staffing of these

technologies and the availability of radiologists skilled at interpreting pediatric oncology studies.

The 2008 survey performed by the American Society of Radiologic Technologists (ASRT) found vacancy rates of about 8% for ultrasonographers and 5% of MR technologists [30]. Underscoring the shortage of US technologists are the U.S. Department of Labor projections for an additional need of 8,700 US technologists by 2016 [31]. Without an adequate technologist support skilled at caring for pediatric patients, ALARA-supporting studies cannot be performed. Further, many facilities will not consider a sonographer for employment without 1–2 years' experience, further delaying entry into the pool of available US technologists.

In parallel with a modest shortage of US technologists and mild shortage of MR technologists is a considerable shortage of pediatric radiologists. As of the year 2000 census, approximately 29% of the population of the United States (80,473,265) was younger than 19 years [32]. In 2006, pediatric radiologists numbered 800–900, composing about 3% of radiologists [33,34]. Current estimates based on the placement service of the ACR indicate a continuing shortage of pediatric radiologists amounting to about 11% [35]. Most pediatric radiologists are concentrated in large cities and academic centers and are thus not readily accessible to many pediatric patients [34]. At about the time of the ALARA Oncology Conference, 84 positions for pediatric radiologists were listed on the website of the Society for Pediatric Radiology. It also appears that there has been only a nominal increase in the number of candidates granted the Certificate of Added Qualifications in pediatric radiology during the last several years -- 28 in 2005, 24 in 2006 and 31 in 2007 [personal communication, ABR, April 2008].

Along with educational initiatives addressing conservation of exposure of pediatric patients to ionizing radiation from medical imaging, a shift and expansion of the pool of technologists with expertise in US and MRI might support expansion of using these modalities for pediatric oncologic imaging. In parallel, a shift of radiologists specialized in the care of pediatric patients seems to be needed to facilitate imaging according to ALARA principles.

Conclusion

- Children with cancer represent an at-risk group of patients who can most benefit from imaging while also being at greatest risk for imaging toxicities.
- Imaging is complex and multimodality, as is the multidisciplinary approach to disease and treatment management.
- Exposures in childhood and adolescence last a lifetime.
- Knowledge and education are our responsibilities.
- Research is necessary to answer these questions and address these issues.
- Collaboration with other healthcare providers, technologists, vendors, patients and others is the key to successfully establishing ALARA principles for all medical imaging.

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