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EDITORIAL

An amazing accomplishment—CT manufacturers deserve our thanks

Thomas L. Slovis · Donald P. Frush · Marilyn J. Goske

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In the latter half of the 1990s, CT technical advancements proceeded at an extremely rapid pace. The emphasis was on producing exquisite CT image quality and the ability to try these new techniques for, it seemed, almost any indication. The highly sophisticated technology was complex and understood by few of its users. And, as well, proponents for significant CT radiation safety with lower doses for children were few.

Then, in 2001, *USA Today* [1] reported on three articles that had appeared in the February issue of *AJR* [2–4]. The gist of the newspaper article, as reported (incorrectly), was that CT scans *will* result in fatal cancer in children.

The public outcry was remarkable and caught pediatric radiologists off-guard. In an editorial, Slovis and Berdon [5] stated that "The technology is unequivocally running the physicians" and that it is clear radiologists do not know all the answers to dose reduction. The Society for Pediatric Radiology presented the first ALARA (as low as reasonably achievable radiation dose) conference in August 2001, published in April 2002 [6]. The course was made possible by the sponsorship of GE Medical Systems and William Radaj, GE's marketing director for CT. In addition, GE Medical Systems announced that proceeds from the meeting would be added to a special allocation of US $25,000 for the SPR Research and Education Foundation to award as grants for studies in radiation dose reduction in children [7].

What is obvious today was not so apparent then—that the radiation dose you end up with depends to a certain extent on how the equipment is designed and built [8]. As an example, the concept of auto exposure control was discussed [8]. However, the prevailing value was on the *full measure of image quality* and this was the primary consideration when purchasing a CT scanner.

By the SPR meeting of 2002, other manufacturers had joined GE—Philips Medical Systems, Siemens Medical Solutions and Toshiba America Medical Systems—in a daylong seminar on radiation dose reduction. In an editorial accompanying the publication of the seminar, Berdon and Slovis [9] said "The manufacturers have made 'low dose' a priority. The next generation of CT (hopefully with 'free' upgrades to current CT) will make it harder to give adult doses to children."

From these quite modest beginnings, the melding of expertise of medical physicists (American Association of Physicists in Medicine), radiologic technologists (American Association of Radiologic Technologists), radiologists, regulatory and federal agencies and other organizations (such as the National Cancer Institute, the U.S. Food and Drug Administration and the NCRP) *and* the manufacturers have since produced substantive results. Five ALARA conferences on various aspects of dose reduction followed from 2003 to 2011 [10–14]. The formation of the Alliance for Radiation Safety in Pediatric Radiology (2008), with its 73+ member organizations and representation of more than 800,000 medical professionals worldwide, dramatically increased the visibility of this project. This group formed the Image Gently campaign and vendor summits in 2008 [15] and 2010 [16], and participated in the 2009 FDA conference, "Initiative to Reduce Unnecessary Radiation Exposure

T. L. Slovis (✉)
Department of Diagnostic Imaging, Children's Hospital of Michigan, Wayne State University School of Medicine,
3901 Beaubien Blvd.,
Detroit, MI 48201, USA
e-mail: tslovis@med.wayne.edu

D. P. Frush
Division of Pediatric Radiology, Duke University Medical Center,
Durham, NC, USA

M. J. Goske
Department of Radiology,
Cincinnati Children's Hospital Medical Center,
Cincinnati, OH, USA

from Medical Imaging" [17], and the July 2012 FDA public workshop for draft guidance, "Pediatric Information for X-ray Imaging Device Premarket Notifications" [18]. The emphasis on dose awareness and optimization, and the development of educational materials and advocacy for this cause, have spread from CT to all imaging modalities that use radiation. A major effort effort led by Drs. Steven Don and Susan John to work with manufacturers of digital radiography equipment through the Medical Imaging Technology Alliance (MITA) to develop target ranges for exposure of common radiography examinations has already yielded results [19].

In the last decade, technical advancement focusing on dose reduction has been substantial. The generic developments that afford radiation dose reduction include improved detector efficiency and tube current modulation and larger detector arrays (decreasing over-beaming, which is wasted radiation). There was also single rotation volume CT over relatively large areas (which can comprise an entire region such as the chest in an infant, improving examination quality), adaptive collimation (minimizing over-ranging—unused radiation at the beginning and end of a spiral scan acquisition) and faster gantry rotation times (potentially improving quality through increased contrast enhancement as well as reducing motion artifact). In addition, other advancements included spectral (e.g., dual-energy) CT, prospective gating for cardiac CT, contrast bolus tracking to optimize contrast enhancement (potentially allowing for parameter modifications that reduce radiation dose but with sufficiently diagnostic contrast and noise profiles) and, most important, image reconstruction methods including iterative reconstruction.

The recent availability of dose alerts and notifications prior to scanning, promoted by the National Electrical Manufacturers Association [20], can also prevent excessive doses during CT examination. New access control standards provide even more safeguards by requiring software features that ensure only authorized users can change protocols and that all changes are documented. Detailed display of estimation methods, e.g., $CTDI_{vol}$ for the smaller (16 cm) or larger (32 cm) phantoms, allows a more transparent depiction of radiation dose indices and potential adjustment of CT examinations prior to scanning. Other advancements that are more vendor-specific include organ-based tube modulation (reducing tube current over an arc of scan acquisition), dual-source technology and kVp modulation. There are rapid development and spread of technology to capture and archive dose elements ($CTDI_{vol}$ and DLP), as well as programs to monitor CT radiation dose indices at the local (i.e., hospital or practice) level as well as nationally, through the American College of Radiology's Dose Index Registry. The potential is on the horizon to incorporate the new, more accurate dose estimate, the size-specific dose estimate (SSDE) developed by the AAPM [21], and to include this in the CT dose report and determine whether the patient's estimated radiation dose falls within diagnostic reference levels prior to the scan.

It is clear that radiation dose management is a primary mission for those involved in the development and manufacture of CT equipment [22, 23]. For example, size- or age-based, region-specific and even indication-based protocols are more widely available than they were a decade ago. The manufacturers (Toshiba, Siemens, Philips and GE) have also contributed to development of modules that are on the Image Gently website [24]. Additional information on vendor-specific dose-reduction guidelines is found on the adult-focused Image Wisely website [25]. The manufacturers are expanding their work on protocols to include children. Representatives from the SPR CT Committee and Image Gently are part of the AAPM Working Group on Standardization of CT Nomenclature and Protocols, a major effort led by Dr. Cynthia McCollough to provide basic vendor-specific CT protocols for common scan indications.

All involved have learned that the CT examination (and its resultant dose) must be tailored to the patient's condition; for example, an image for an initial brain CT might have a different resolution and dose than one for a child with a ventricular shunt and repetitive CT examinations. The clinical presentation and requisite scan information are clearly important variables in protocol for the CT examination.

The industry commitment to patient care is now more clearly directed toward a *balance* between image quality and radiation dose. The pediatric imaging community, as well as the broader radiology community, acknowledge contributions possible only through dedicated work from vendor partners, and appreciate these improvements in radiation protection. It is always a somewhat sensitive issue when discussing industry responsibilities in research and development, manufacturing and clinical application. There is a delicate balance between the business of medicine and clinical applications dealing with a delivery of high-quality and safe health care. Recognizing this often complex relationship among manufacturing, medical research, and clinical application, it is nonetheless clear that our industry partners have provided significant technical, operational and educational resources that have helped us to provide better CT imaging care to both children and adults.

To our partners who manufacture radiation-producing equipment, for all that you have done and will continue to do, we thank you.

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