

GE Healthcare

Delivering the Right Dose

A guide to understanding
CT dose metrics in an evolving
regulatory environment.



The Changing Landscape of Managing Radiation Dose in CT Imaging

Deliver the Right Dose

The use of computed tomography (CT) scans has soared over the last three decades. In 1980, there were 3 million CT scans performed in the United States. By 2011 that figure had risen to over 85 million.^{1,2,3} CT ranks as one of the top five medical developments in the last 40 years.⁴

With the growth of CT both consumer and provider radiation dose awareness is elevated. Today, dose management is one of the top 10 technology issues confronting administrators at hospitals and radiology clinics.⁵ As states like Connecticut and Minnesota consider adopting legislation similar to the California and Texas mandates on radiation dose, you should be prepared to measure, track, and review your own radiation dose levels. With increased regulatory and compliance requirements, you need to deliver the best possible outcome to your patients while managing your overall dose trends – balancing radiation dose with image quality.

Lack of standardization of imaging protocols across an enterprise can lead to widely varying patient dose. Healthcare systems without a dose informatics system may not have an accurate overall view of the radiation delivered to patients.

Know Where You Stand

The Joint Commission Sentinel Event Alert of August 24, 2011 urges the medical community to take steps to “reduce risks due to avoidable diagnostic radiation” by increasing awareness among staff and patients and providing “the right test and the right dose through effective processes, safe technology and a culture of safety.” Among the Joint Commission’s proposal are three key recommendations:

- Invest in dose reduction and optimization technologies
- Investigate dose patterns outside of appropriate ranges and tracking dose from repeated exams
- Capture dose information in the electronic medical record and in the national dose registry

Capturing an accurate estimate of radiation dose is challenging. As CT technology continues to advance so do the radiation dose metrics that quantify scanner output from multiple acquisitions. GE Healthcare’s DoseWatch software provides a standards-based approach to estimating radiation dose and utilizes the latest analytics like size-specific dose estimate (SSDE) to align with the medical physics community.*

Estimating Radiation Dose in CT

Radiation output for CT is commonly reported in terms of a volume CT dose index (CTDI_{vol}) in units of milligray (mGy) to one of two possible phantoms based on the scan field of view. These are a 16-cm-diameter cylindrical acrylic phantom (head or pediatric body exams) and a 32-cm-diameter cylindrical acrylic phantom (body exams). CTDI_{vol} is not patient absorbed dose, skin dose, or organ dose. It is a useful metric in comparing protocols across devices and evaluating the effects of parameter settings. Actual patient dose may be overestimated or underestimated relative to CTDI_{vol}, in some cases by a factor of 2 to 3 when compared against CTDI_{vol}^{32cm}.^{6,7}

There are multiple metrics available for characterizing radiation output from CT devices. However, transforming this information into an estimate of actual patient dose for every procedure is difficult due to confounding factors such as variability in body habitus, positioning and imaging technique.

A standards-based approach to this problem is the calculation of SSDE. Developed by the American Association of Physicists in Medicine (AAPM) in their Task Group 204 report, SSDE is calculated using a measure of device radiation output – the CTDI_{vol} – and patient diameter or effective diameter.

Collecting the data and performing the calculation by hand can be time consuming – making the information easily accessible across an enterprise is even more daunting.

Current Measurements of Radiation Dose in CT

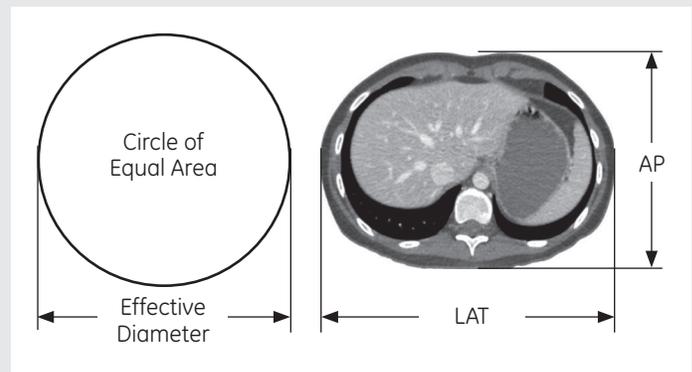
	Unit	Calculation	Description
CTDI _{vol} (Volume Computed Tomography Dose Index)	mGy milligray	Radiation absorbed by 16/32 cm phantom	Describes scanner radiation output independent of patient size.
DLP (Dose Length Product)	mGy x cm	CTDI _{vol} x irradiated scan length	Describes the total amount of energy delivered to the patient.
Effective Dose	mSv millisievert	DLP x coefficient for body region OR weighted sum of organ equivalent doses using ICRP 60 or ICRP 103 weighting factors.	A calculated quantity that serves as a common scale in radiation protection by attributing equal values to different exposure situations that are presumed to carry roughly the same risk with regard to stochastic effects.*
SSDE (Size-Specific Dose Estimate)	mGy	CTDI _{vol} x conversion factor for diameter of the scanned region/patient	Estimate of absorbed dose, accounting for patient size.

* Effective Dose is a quantity intended for use in radiological protection and was not developed for use in epidemiological studies or other specific investigations of human exposure.

The Standards-based Method for Estimating Dose in CT is SSDE.

In 2011, the American Association of Physicists in Medicine (AAPM), in collaboration with the International Commission on Radiation Units and Measurements (ICRU) and the Image Gently campaign of the Alliance for Radiation Safety in Pediatric Imaging, released the Task Group 204 report describing the conversion of CTDI_{vol} values for the torso (chest-abdomen and/or pelvis) into something more representative of actual patient dose.⁷

Using physical measurements from anthropomorphic phantoms, cylindrical phantoms and Monte Carlo measurements, the task group developed conversion factors between CTDI_{vol} and SSDE, expressed in units of mGy. The conversion factors are based on one of five metrics: the patient AP dimension, the lateral dimension, the sum of the AP and lateral dimensions, the calculated effective diameter, or an age-based effective diameter taken from ICRU Report 74. Evaluation of SSDE shows that the combination of AP and lateral measurements, either as a sum or calculated effective diameter, is more useful than either alone.⁹ The age-based metric is effective for preadolescent patients (up to 13 years), but it becomes less accurate for teenage and young adult patients due to their widely varying body dimensions. Generally, the most effective method for determining SSDE is direct measurement of patient dimensions from the CT radiograph. Although uncertainties associated with SSDE can be as high as 20%, this is a significant improvement compared to CTDI_{vol} values which can underestimate pediatric CT dose by as much as 300%.⁷



In DoseWatch automated segmentation of localizer images provides patient dimensions without manual effort. By following TG204 methodology DoseWatch performs an automated calculation of SSDE using AP and/or lateral localizers. The resulting SSDE value is captured in the patient dose history.

SSDE as a Surrogate for Organ Dose

SSDE provides an estimate of average dose within the scan volume for a specific patient size and has been recognized as a reasonable estimate of organ dose to large organs contained within that volume.^{10,11} Organ dose is defined as an average absorbed dose over a tissue or organ and is expressed in SI units of joules per kilogram ($J\ kg^{-1}$) or gray (Gy). As described in Publication 60 of the International Commission on Radiological Protection (ICRP, 1991), the quantity may be used to reflect the probability of subsequent stochastic effects such as radiation induced cancer. Unless the dose is fairly uniformly distributed over the organ of interest, the term is not directly relevant to deterministic effects as their occurrence is threshold-based and the dose-response is non-linear.

In the mid-1940s, it was recognized that both the type and energy of the absorbed radiation influenced the biological effect.¹² This concept eventually led to the ICRP 60 definition of organ equivalent dose (HT), which accounts for differences in cell damage potential and stochastic effects induced by different types and energies of radiation. The quantity has units of joules per kilogram ($J\ kg^{-1}$) but is given the special name sievert (Sv). It is calculated by summing the product of organ absorbed dose for each type of radiation, and that radiation's weighting factor, W_R :

$$H_T = \sum D_{T,R} \cdot W_R$$

For photons in diagnostic imaging, the weighting factor is 1. Note that for the same value of equivalent dose in different organs and tissues, there may be different probabilities of harm as well as different severities of injury. A more detailed discussion of radiation weighting factors is found in ICRP publications 92 and 103.

In some cases organ dose may be estimated via direct radiation measurements at sampling points on or near the tissue. However it is more often based on measurements using test objects (phantoms) or calculations stemming from mathematical models which describe organ geometry, tissue composition, and the radiation field. The derived organ dose may be substantially different from the actual dose when there are significant differences in body habitus, organ dimension or organ location relative to the phantom or model used in the calculation.^{11,13,14,15} Caution should always be applied when attributing derived organ dose to a specific patient, even when calculated from an anthropomorphic model.

SSDE, $CTDI_{vol}$, DLP and effective dose are current measures of radiation in CT that will evolve with technology advances. As the medical community develops new methodologies for calculating dose and regulatory requirements emerge, having a flexible yet rigorous dose monitoring system is paramount. With GE Healthcare's DoseWatch solution you have a partner with experience and breadth in the healthcare industry to provide a dose monitoring solution that works with your changing landscape.



An Enterprise-Wide Approach to Dose Management

What if you could analyze radiation data across modalities and devices?

Join other forward-looking healthcare systems taking advantage of the troves of information they generate to discover ways to provide better care and gain a competitive edge in the marketplace. DoseWatch uses multi-modality and vendor-neutral capabilities to capture imaging radiation data across the enterprise.

What if you could identify and alleviate the causes of dose outliers?

DoseWatch can help you deliver the right dose by identifying radiation events above your threshold and providing tools that enable you to optimize dose while maintaining appropriate image quality. You'll receive alerts notifying you when an exam has exceeded the dose threshold, so you can take immediate steps.

Not only is DoseWatch a powerful tool, it's a cornerstone of GE Healthcare's overall dose-management strategy focusing on people, process and technology. When you partner with GE Healthcare, you take a holistic approach to managing and controlling radiation dose.

For more information, visit www.doseoptimization.gehealthcare.com.

Biographies

William J. O'Connell, Dr.PH



Dr. William J. O'Connell is a senior medical physicist in the DoseWatch program of GE Healthcare's Dose Management Services.

Dr. William J. O'Connell is a board certified medical physicist in Dose Management Services. Prior to this

Dr. O'Connell served as Director of Clinical Radiation Safety at Columbia University Medical Center in New York City and Assistant Professor of Radiology at New York Medical College in New York.

He is editor of the Diagnostic Radiological Physics Examination (RAPHEX) and a long-time member of the American Association of Physicists in Medicine (AAPM). He served as a member of the New York Thyroid Center in the Section of Endocrine Surgery at Columbia University Medical Center and presented research on the clearance of radiiodine at several Society of Nuclear Medicine meetings. He has lectured extensively on radiation protection and radiation physics at Columbia University, New York Medical College, Fordham University and Manhattan College and currently sits on the board of directors

on the American Registry of Magnetic Resonance Imaging Technologists (ARMRIT).

Dr. O'Connell received his undergraduate degree from Rochester Institute of Technology in Rochester, New York, his master's degree from New York Medical College and his doctoral degree in medical physics from Columbia University in New York City. He is a Diplomate of the American Board of Radiology (Nuclear Medicine Physics) and is certified by the Nuclear Medicine Technology Certification Board. He is also licensed to practice diagnostic radiological physics, nuclear medicine physics and health physics in the State of New York.

Dr. O'Connell's interest is patient radiation dose in conjunction with medical imaging procedures – seeking to lower patient radiation exposure while maintaining high levels of image quality. He will be assisting GE Healthcare clinical partners with the implementation of enhanced tools to aid in refining the delivery of clinical imaging procedures while maintaining the three fundamental principles of radiation protection – justification, optimization and adherence to applicable radiation dose limits.

David E. Miller, PhD, CHP



Dr. David E. Miller is a senior medical physicist in the DoseWatch program of GE Healthcare's Dose Management Services.

Dr. David E. Miller is a medical physicist and board certified health physicist with more than 15 years of experience in cross-disciplinary clinical research and engineering activities within industry,

academia and healthcare. His areas of expertise encompass clinical research, quantitative image analysis, radiation safety, informatics, program management and software development.

Dr. Miller served as an associate professor of radiology and director of the Quantitative Image Analysis core of the Colorado Translational Research Imaging Center (C-TRIC) at the University of Colorado Anschutz Medical Campus. At the University of Colorado Hospital he provided clinical physics support to nuclear medicine and collaborated extensively with the UC Thyroid Tumor Program and the UC Cancer Center. He also served as an alternate radiation safety officer at UC Denver, supporting the C-TRIC PETCT research facility and the Co-60 irradiator program. He has held multiple leadership roles within academia and industry, focusing on imaging biomarkers in the

context of drug discovery and development. He has lectured extensively at industry meetings, clinical symposia and in support of graduate student and resident education.

He received his PhD in nuclear science and engineering in 1996 from Rensselaer Polytechnic Institute in Troy, New York, where he focused on boron neutron capture therapy for bone cancer. In 2001 he received a masters of science degree in medical physics from the University of Colorado Health Sciences Center, addressing quantification of white matter disease in multiple sclerosis. He is a principal or contributing author on over 30 peer reviewed publications as well as many scientific abstracts. Dr. Miller has been a principal investigator on multiple industry research awards and has been a grant reviewer for the National Institutes of Health. He is also an associate editor for "Medical Physics", a journal of the American Association of Physicists in Medicine. His current research interests include imaging biomarkers, informatics, analytics and predictive tools.

Dr. Miller supports global research, product development and field implementations of DoseWatch. He will be overseeing research focusing on IT integration issues, regulatory reporting, pediatric dose reduction and advanced dose analytics development.

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About GE Healthcare

GE Healthcare provides transformational medical technologies and services that are shaping a new age of patient care. Our broad expertise in medical imaging and information technologies, medical diagnostics, patient monitoring systems, drug discovery, biopharmaceutical manufacturing technologies, performance improvement and performance solutions services help our customers to deliver better care to more people around the world at a lower cost. In addition, we partner with healthcare leaders, striving to leverage the global policy change necessary to implement a successful shift to sustainable healthcare systems.

Our "healthymagination" vision for the future invites the world to join us on our journey as we continuously develop innovations focused on reducing costs, increasing access and improving quality around the world. Headquartered in the United Kingdom, GE Healthcare is a unit of General Electric Company (NYSE: GE). Worldwide, GE Healthcare employees are committed to serving healthcare professionals and their patients in more than 100 countries. For more information about GE Healthcare, visit our website at www.gehealthcare.com.

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