Trends in Use of Medical Diagnostic Procedures and Efforts to Address Optimization and Justification

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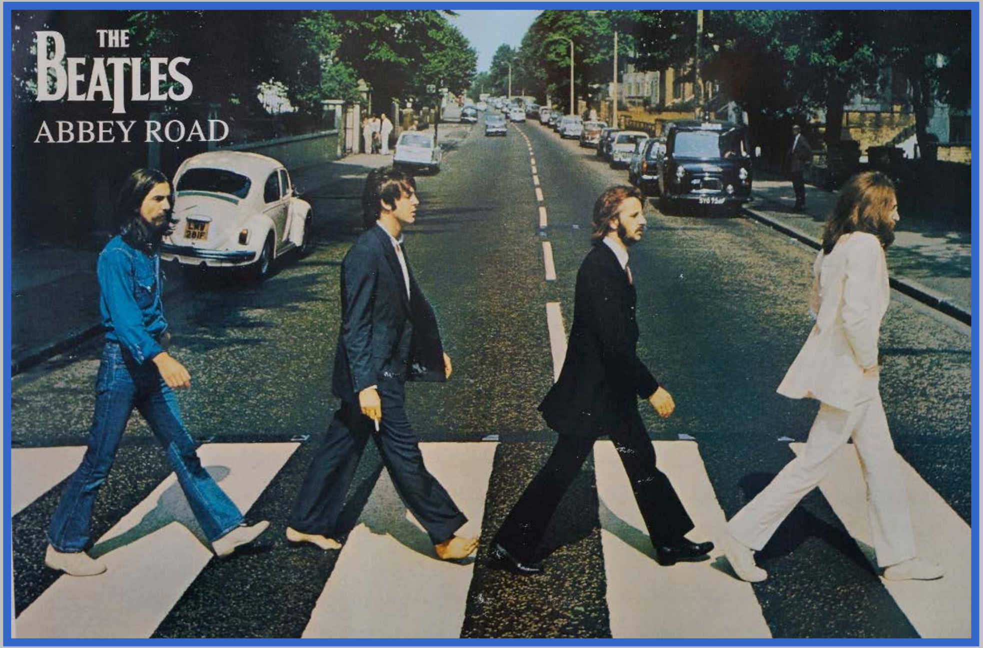
Gilbert W. Beebe
WEBINAR

12-14-21

No Disclosures



- **Yesterday**
- **I Want to Hold Your Hand**
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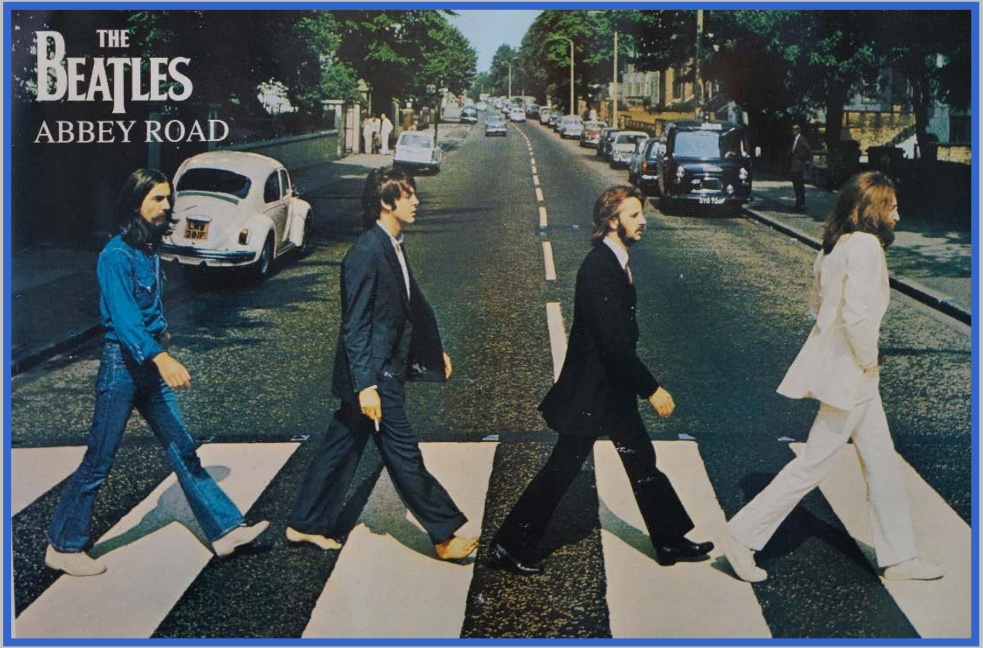

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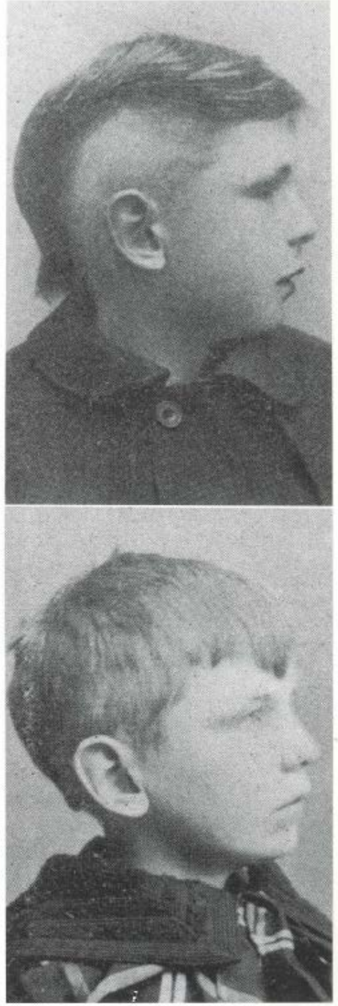


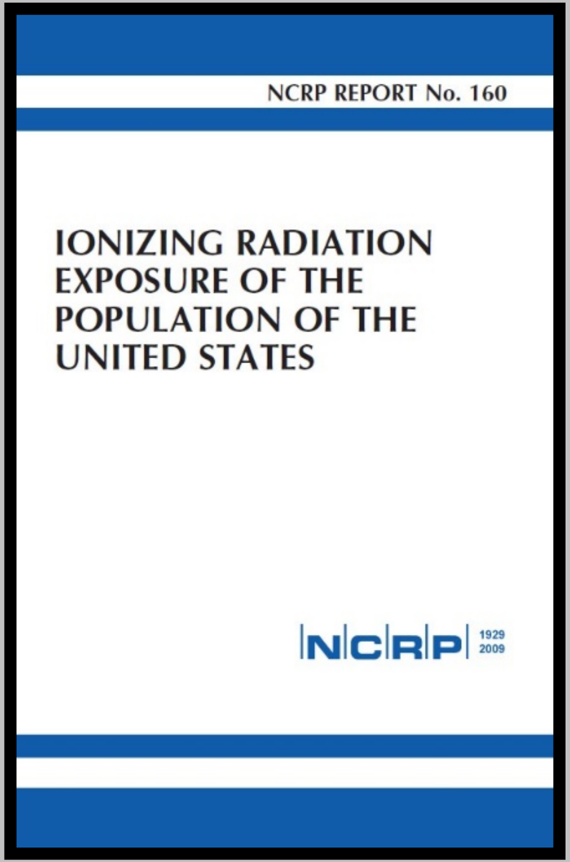
Effect of x-rays on the hair (Kolle, 1897). *Top*, Large area of hair missing from the side of a boy's head 3 weeks after an x-ray exposure of 40 minutes with the tube about 18 inches from the skull. The boy gave no history of pain, itching, or other signs of inflammation; all he knew was that on the previous night the hair had suddenly fallen out. *Bottom*, Appearance of the boy 4 months later. The new hair grew well and had been cut three times.[6]

The New York Times

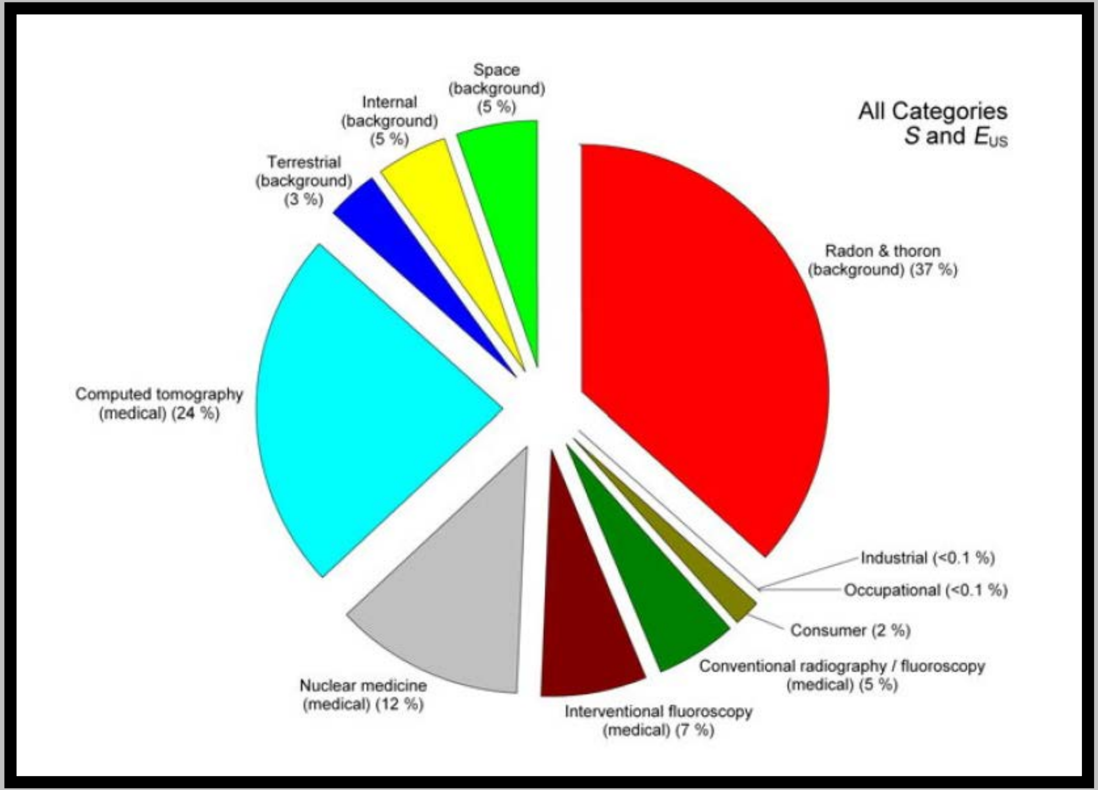
http://www.nytimes.com/2009/10/16/us/16radiation.html

http://www.nytimes.com/2010/08/01/health/01radiation.html?_r=4&ref=health&pagewanted=all

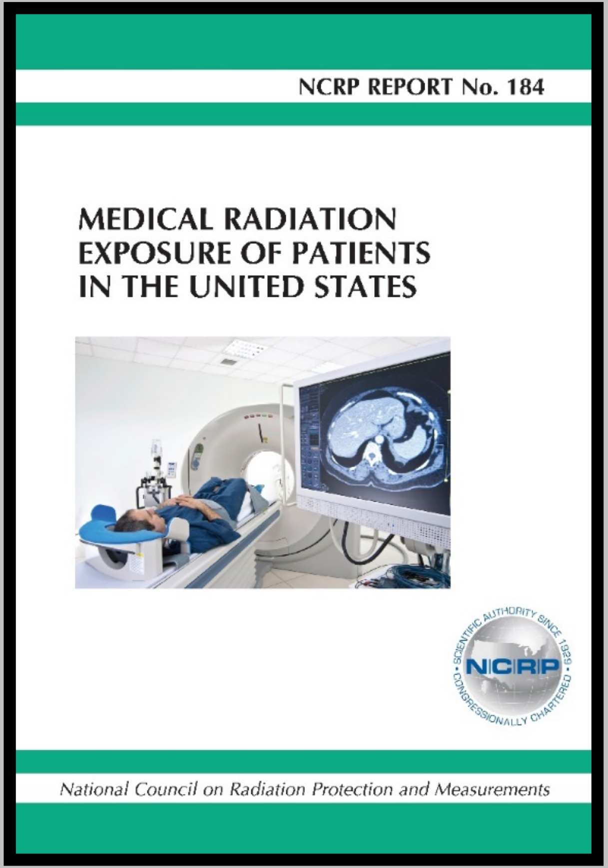
Eisenberg RL. Radiology: An Illustrated History 1992 Mosby—Year Book



2006: Nearly 50% of U.S. annual exposure was from medical sources

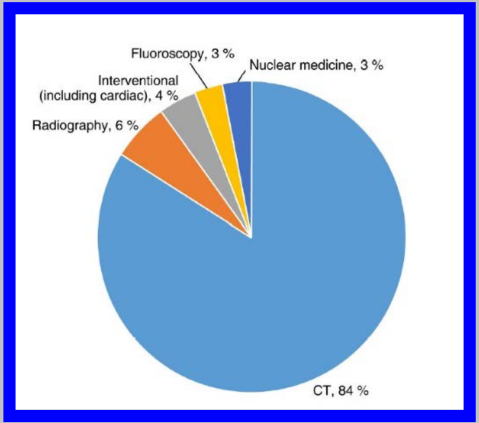


Ionizing radiation procedures account for the majority of pediatric imaging examinations

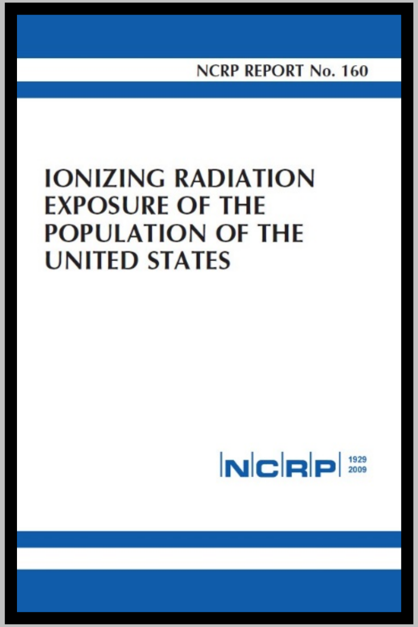


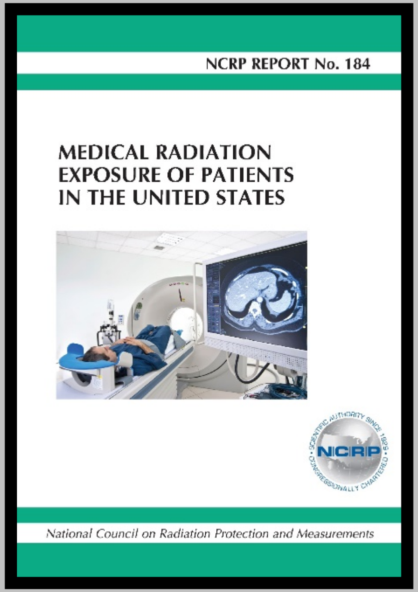
Relative percentages of ionizing radiation examinations performed across the age range up to 18 yrs:

- Radiography → 86%
- CT → 9.5%
- Fluoroscopy → 3%
- Nuclear imaging → 1%
- Interventional procedures → 0.5%

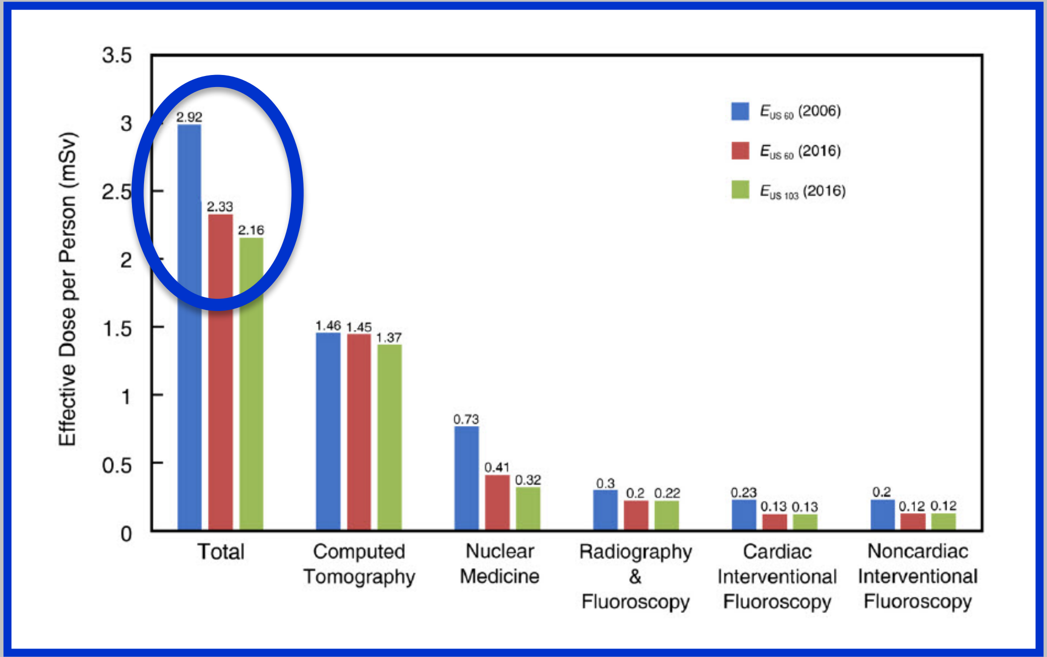


…but CT accounts for 84% of U.S. per capital medical radiation dose in children





Estimated average annual individual ED in U.S. from diagnostic and interventional patient radiation exposures (mSv) (from NCRP)



Annual individual (per capita) effective dose from diagnostic and interventional medical procedures was estimated to have been

- **2.9 mSv in 2006**
- **2.3 mSv in 2016: *20% decrease***

What is (May be) Monitored?
Radiation Dose Indices[1]

All:

- number/type of examinations
- effective dose

<u>Radiography</u> : K_{ar} P_{ka},EI, DI (AGD mammography)
<u>Fluoroscopy</u> : time, K_{ar} P_{ka}
<u>CT</u> : $CTDI_{vol}$, DLP, SSDE
<u>Nuclear Medicine</u> : administered activity

[1]*file:///C:/Users/frush943/Downloads/Gress-2017-Aapm-----------medical-physics-pra.pdf*

Received: 30 November 2016 | Revised: 30 November 2016 | Accepted: 20 January 2017
DOI: 10.1002/acm2.12089

AAPM REPORTS & DOCUMENTS

WILEY

AAPM medical physics practice guideline 6.a.: Performance characteristics of radiation dose index monitoring systems

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The American Association of Physicists in Medicine (AAPM) is a nonprofit professional society whose primary purposes are to advance the science, education and professional practice of medical physics. The AAPM has more than 8,000 members and is the principal organization of medical physicists in the United States.

The AAPM will periodically define new practice guidelines for medical physics practice to help advance the science of medical physics and to improve the quality of service to patients throughout the United States. Existing medical physics practice guidelines will be reviewed for the purpose of revision or renewal, as appropriate, on their fifth anniversary or sooner.

Each medical physics practice guideline represents a policy statement by the AAPM, has undergone a thorough consensus process in which it has been subjected to extensive review, and requires the approval of the Professional Council. The medical physics practice guidelines recognize that the safe and effective use of diagnostic and therapeutic radiology requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published practice guidelines and technical standards by those entities not providing these services is not authorized.

file:///C:/Users/frush943/Downloads/Gress-2017-Aapm------------medical-physics-pra.pdf

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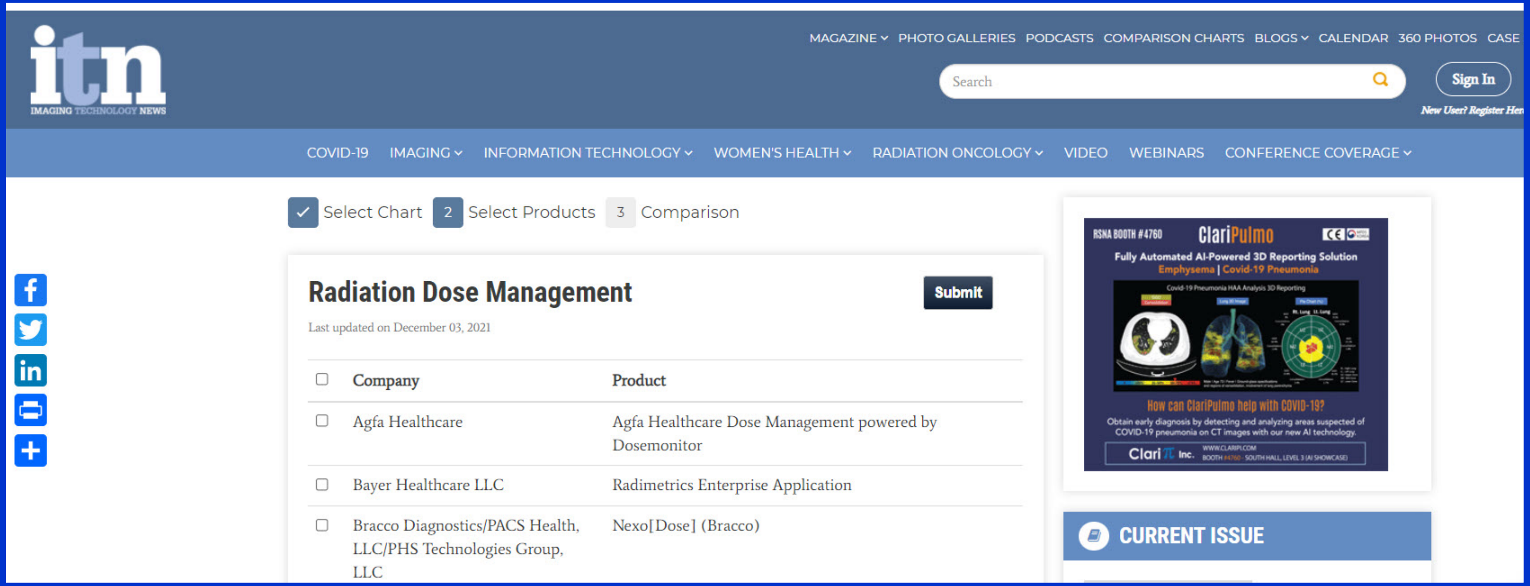
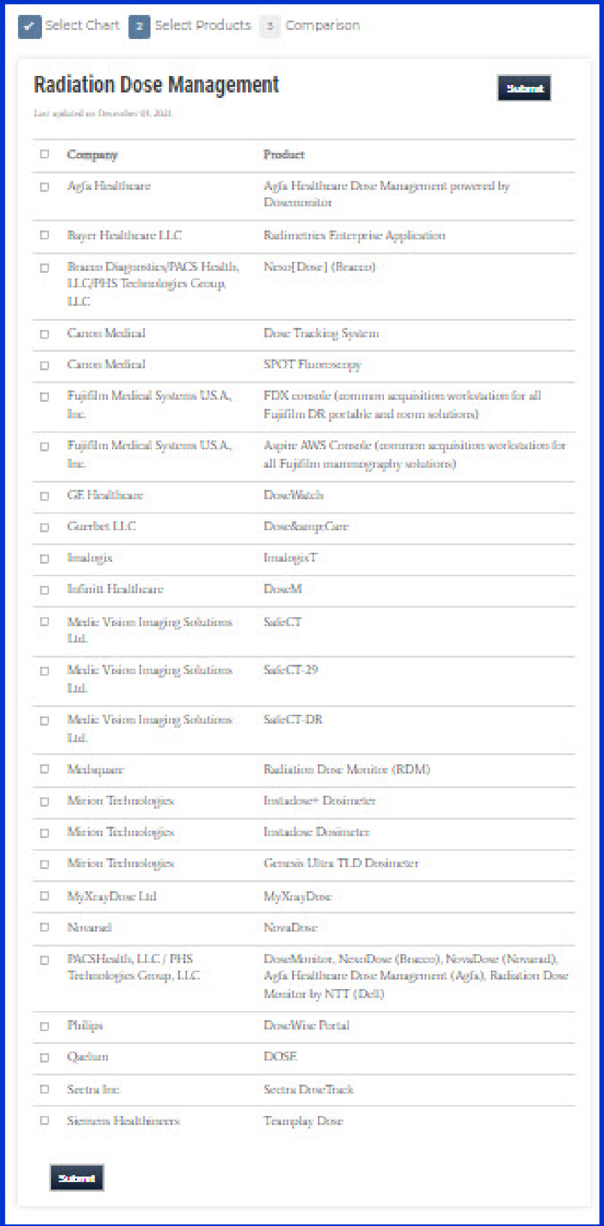
TABLE 1. MODALITY SPECIFIC RADIATION EXPOSURE METRICS

Quantity [27, 28]	Recommended symbols	Unit used in practice	Other common symbols used in literature	Closely related quantity	Modality
Incident air kerma	$K_{a,i}$	mGy	IAK		Diagnostic radiography and fluoroscopy, image guided interventional procedures, conventional radiation therapy simulators and imaging equipment for image guided radiotherapy, dental intraoral radiography, mammography and breast tomosynthesis
Incident air kerma rate	$\dot{K}_{a,i}$	mGy.s^{-1}			
Entrance surface air kerma	$K_{a,e}$	mGy	ESAK	Entrance-surface dose (ESD)*	
Air kerma at the patient entrance reference point**	$K_{a,r}$	mGy	CAK (Cumulative reference air kerma)		Fluoroscopy and fluoroscopy guided interventional procedures
Air kerma-area product	P_{KA}	mGy.cm^{2}***	KAP	Dose-area product (DAP)*	Radiography, fluoroscopy, image guided interventional procedures, dental panoramic radiography and dental CBCT
Weighted CT air kerma index	C_w	mGy [30]		Weighted CT dose index ($CTDI_w$)*	CT
Volume CT air kerma index	C_{vol}	mGy [30]		Volume CT dose index ($CTDI_{vol}$)*	CT
Air kerma-length product	P_{KL}	mGy.cm [30]		Dose-length product (DLP)*	CT
Activity of a radiopharmaceutical	A	Bq			Nuclear medicine
Activity of a radiopharmaceutical administered per unit body mass	A/body mass	Bq.kg^{-1}			Nuclear medicine

*Because "air kerma" and "dose in air" are numerically equal in diagnostic radiology energy range.
**Also names "cumulative dose", "reference air kerma" and "reference point air kerma" have been used in the literature.
***Further recommendation for the unit of 'air kerma-area product' of X-ray equipment for interventional procedures is provided in Ref. [29].

Medical Imaging Radiation Monitoring Products





Select Chart 2 Select Products 3 Comparison

Radiation Dose Management

Submit

Company	Product
Agfa Healthcare	Agfa Healthcare Dose Management powered by Dosemonitor
Bayer Healthcare LLC	Radimetrics Enterprise Application
Bracco Diagnostics/PACS Health, LLC/PHS Technologies Group, LLC	Nexo[Dose] (Bracco)
Canon Medical	Dose Tracking System
Canon Medical	SPOT Fluoroscopy
Fujifilm Medical Systems U.S.A., Inc.	FDX console (common acquisition workstation for all Fujifilm DR portable and room solutions)
Fujifilm Medical Systems U.S.A., Inc.	Aspire AWS Console (common acquisition workstation for all Fujifilm mammography solutions)
GE Healthcare	DoseWatch
Guerbet LLC	Dose&Care
Imalogix	ImalogixT
Infinitt Healthcare	DoseM
Medic Vision Imaging Solutions Ltd.	SafeCT
Medic Vision Imaging Solutions Ltd.	SafeCT-29
Medic Vision Imaging Solutions Ltd.	SafeCT-DR
Medsquare	Radiation Dose Monitor (RDM)
Mirion Technologies	Instadose+ Dosimeter
Mirion Technologies	Instadose Dosimeter
Mirion Technologies	Genesis Ultra TLD Dosimeter
MyXrayDose Ltd	MyXrayDose
Novarad	NovaDose
PACSHealth, LLC / PHS Technologies Group, LLC	DoseMonitor, NexoDose (Bracco), NovaDose (Novarad), Agfa Healthcare Dose Management (Agfa), Radiation Dose Monitor by NTT (Dell)
Philips	DoseWise Portal
Qaelum	DOSE
Sectra Inc.	Sectra DoseTrack
Siemens Healthineers	Teamplay Dose

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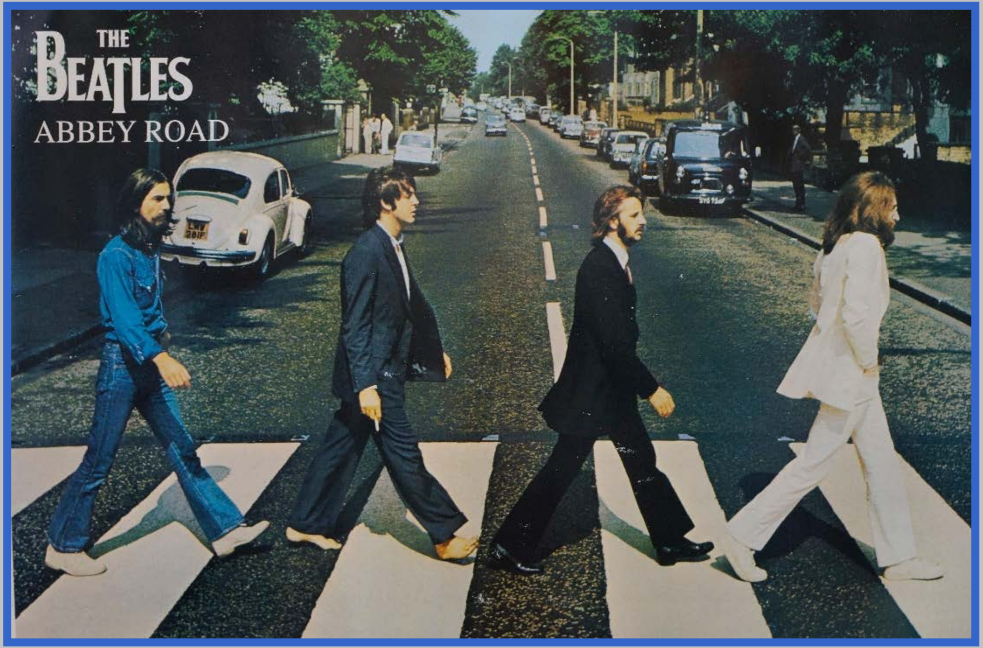
https://www.itnonline.com/chart/radiation-dose-management



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About Products Buy Support Contact

Radiation Passport

X-rays, CAT scans, fluoroscopy (including angiography/angioplasty), and nuclear medicine exams all cause ionizing radiation to be delivered to the body, which can cause cancer. Over the last 15 years, the use of medical imaging has been rapidly increasing. There have been recent estimates that up to 1.5-2% of all cancers within the US are caused by radiation from CAT (CT) scans.

The purpose of Radiation Passport is to educate about the radiation and cancer risks associated with medical imaging exams and procedures that physicians (and dentists) want you to undergo, to keep track of radiology and imaging-related exams and procedures, and to provide an estimate of risk of developing cancer because of this radiation.

The radiation exposure and associated risk numbers are based on published scientific journal papers, however, are in each case an estimate. There are different methods by which to estimate the associated risk.

Date	Exam	Facility Where Exam Performed

7678 10.10

FOLD HERE

Name: ___________________________

My Medical Imaging History

Use this handy record to track your imaging history

Before undergoing any X-ray exam or treatment procedure, remember to ask your doctor:

- Why do I need this exam?
- How will having this exam improve my health care?
- Are there alternatives that do not use radiation and which are equally as good?

Remember:

- Be sure to tell the doctor or technologist if you are, or might be, pregnant before having an exam.
- Don't insist on an imaging exam if the doctor explains there is no need for it.
- And, don't refuse an imaging exam if there's a clear need for it and the clinical benefit outweighs the small radiation risk.

For more information, go to www.ImageWisely.org and www.fda.gov/ForConsumers/ConsumerUpdates/ucm095505.htm

IMAGE WISELY FDA

Co-Sponsored by Image Wisely and the US Food and Drug Administration

North Carolina Department of Health and Human Services
Division of Medical Assistance
2501 Mail Service Center • Raleigh, N. C. 27699-2501 • Tel 919-855-4100 • Fax 919-733-6608

Beverly Eaves Perdue, Governor
Lanier M. Cansler, Secretary

Craigan L. Gray, MD, MBA, JD, Director

June 30, 2011

To: Jane Doe
555 Main Street
Anywhere, NC 12345

Dear Ms. Doe,

This letter is to inform you that you had 10 or more CT scans in 2010. This is more than most people get in a year. Medicaid records show that you went through a CT scanner _##_ times in 2010.

CT scans, sometimes called CAT scans, expose you to radiation while taking a picture of what is inside your body. Too much radiation can be bad for your health. It can increase your chances of getting some kinds of cancer.

Sometimes CT scans are important for doctors to see what is going on when you are sick or hurt. But sometimes there may be other ways to figure out what is wrong.

If a doctor treating you does not know you well or have your medical records, that doctor will not know how many CT scans you have had. It is important for you to remind them of this information. Showing your doctors this letter will help them treat you as safely as possible. **Please take this letter with you when you go to the emergency department or doctor's office.**

Call 1-800-662-7030 if you have any questions.

Please call [enrollment office number] for help finding a primary care doctor in your town.

Wishing you the best of health,

Please don't

The Joint Commission

In July 2015, TJC mandated that:

1. ***“The [hospital/practice] documents the radiation dose (CTDI$_{vol}$ or DLP) on every study produced during a computed tomography (CT) examination. The radiation dose must be exam specific, summarized by series or anatomic area, and documented in a retrievable format.”, and***

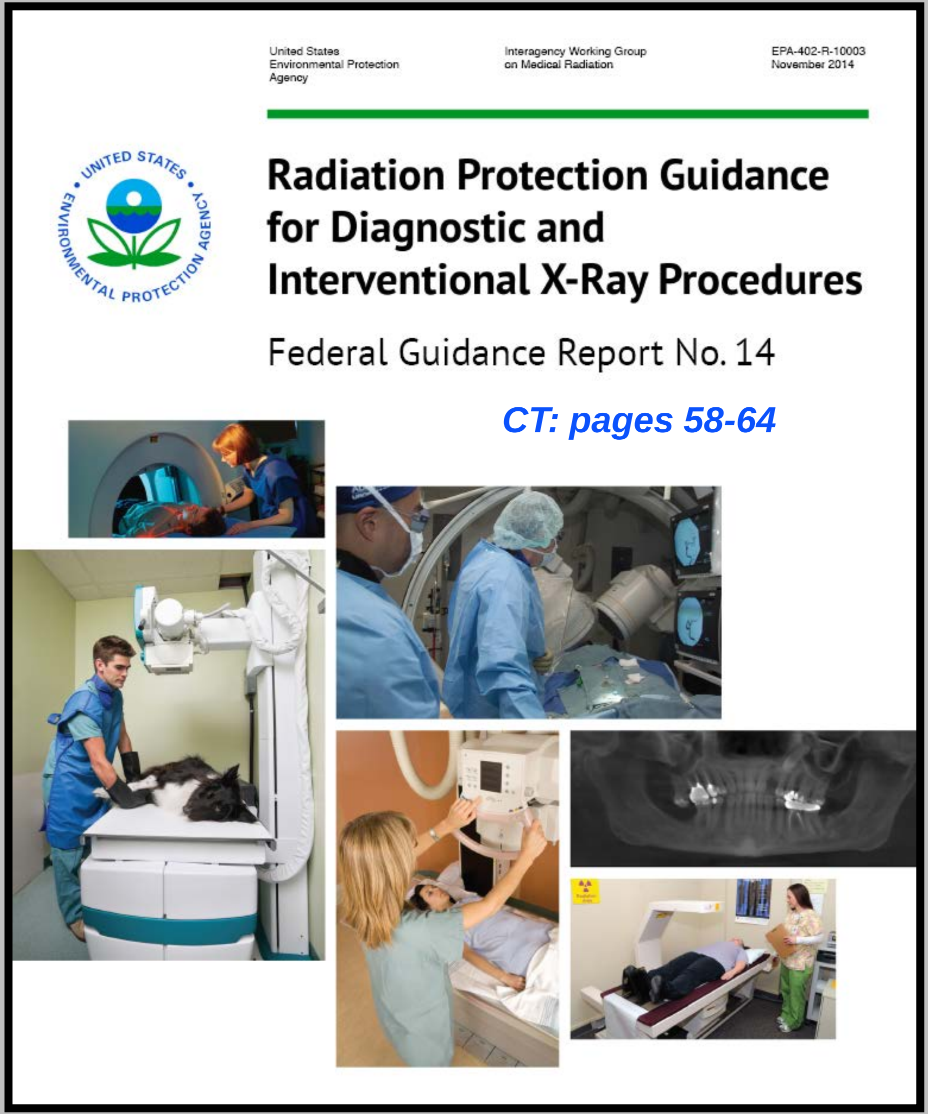
2. ***“The [hospital/practice] re***
where the radiation dose (
computed tomography (CT
diagnostic CT exams exce
identified in imaging proto

1. Retrievable format

2. Review exams exceeding expected ranges

3. Compare doses to benchmarks

4. Radiation safety designee



United States
Environmental Protection
Agency

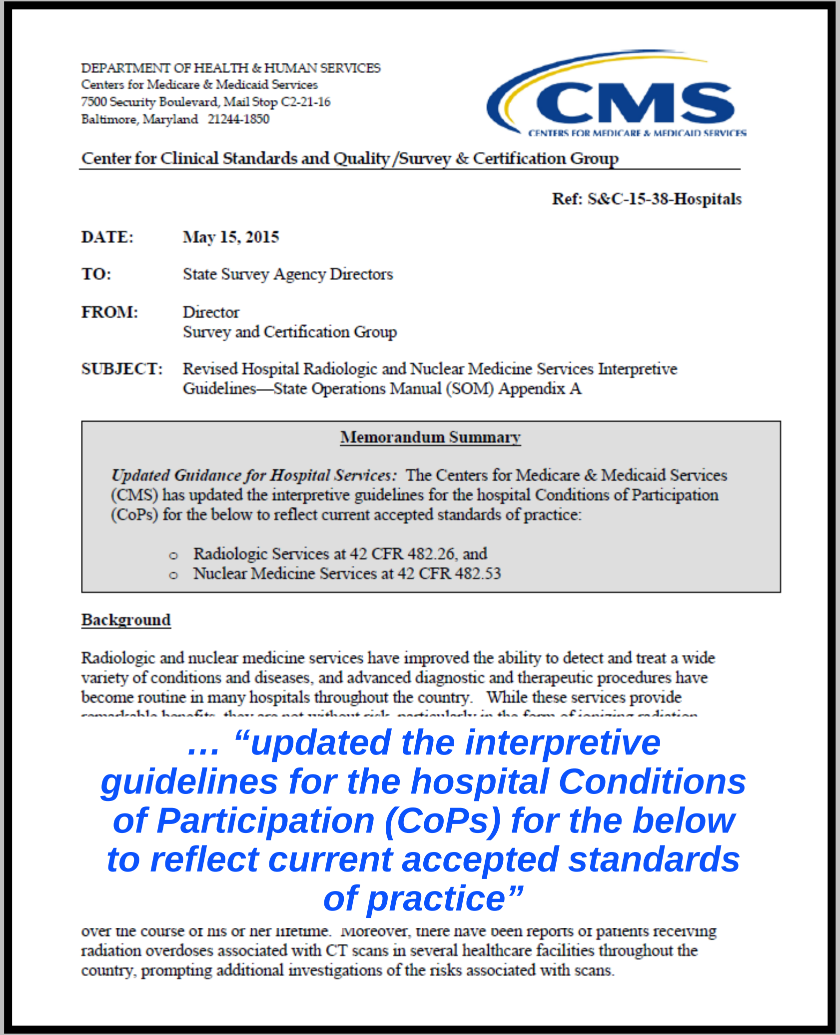
Interagency Working Group
on Medical Radiation

EPA-402-R-10003
November 2014

Radiation Protection Guidance for Diagnostic and Interventional X-Ray Procedures

Federal Guidance Report No. 14

CT: pages 58-64



DEPARTMENT OF HEALTH & HUMAN SERVICES
Centers for Medicare & Medicaid Services
7500 Security Boulevard, Mail Stop C2-21-16
Baltimore, Maryland 21244-1850

CMS
CENTERS FOR MEDICARE & MEDICAID SERVICES

Center for Clinical Standards and Quality/Survey & Certification Group

Ref: S&C-15-38-Hospitals

DATE: May 15, 2015

TO: State Survey Agency Directors

FROM: Director
Survey and Certification Group

SUBJECT: Revised Hospital Radiologic and Nuclear Medicine Services Interpretive Guidelines—State Operations Manual (SOM) Appendix A

Memorandum Summary

Updated Guidance for Hospital Services: The Centers for Medicare & Medicaid Services (CMS) has updated the interpretive guidelines for the hospital Conditions of Participation (CoPs) for the below to reflect current accepted standards of practice:

- Radiologic Services at 42 CFR 482.26, and
- Nuclear Medicine Services at 42 CFR 482.53

Background

Radiologic and nuclear medicine services have improved the ability to detect and treat a wide variety of conditions and diseases, and advanced diagnostic and therapeutic procedures have become routine in many hospitals throughout the country. While these services provide

… "updated the interpretive guidelines for the hospital Conditions of Participation (CoPs) for the below to reflect current accepted standards of practice"

over the course of his or her lifetime. Moreover, there have been reports of patients receiving radiation overdoses associated with CT scans in several healthcare facilities throughout the country, prompting additional investigations of the risks associated with scans.

Radiology

The Federal Government's Oversight of CT Safety:

Regulatory Possibilities[1]

H. Benjamin Harvey, MD, JD
Pari V. Pandharipande, MD, MPH

Computed tomography (CT) has become a routine part of medicine in the United States, with close to 70 million scans completed per year (1). While the clinical benefits of CT have always come hand-in-hand with the risk of radiation exposure, it is not until recently that this risk has reached the forefront of public awareness, prompting the federal government to take a renewed interest in tant for meaningful involvement, this body of knowledge is not at the fingertips of the practicing radiologist. In this report, we update the radiology community on the federal government's investigations of CT safety, deconstruct its authority and options for regulating CT practices, and examine current regulatory interventions as well as future possibilities.

Volume 262: Number 2—February 2012

MEDICAL ERROR

User Certification/Quality Assurance
- Standardization of certification/education requirements for CT technologists
- Mandatory quality assurance processes

Adverse Event Reporting
- Improved mechanisms for technologists and staff to report medical errors within institutions
- Improved reporting of adverse events to the FDA
- Provide better access to the adverse event database at the FDA

CT Scanner Design
- Warning or lock-out systems to prevent radiation overdoses, restricted log-in access to scanners, restricted access for changing CT protocols
- Standardization of CT terminology and protocol element names (eg, scout versus scanogram) to avoid user error
- Standardization of technical information provided to users

OVERUTILIZATION

Authorization Systems to Ensure Medical Appropriateness
- Decision support systems for ordering clinicians
- Benefits management companies performing preauthorization assessments

Legislation to Limit Self-referral

DOSE OPTIMIZATION

Diagnostic Reference Levels
- Diagnostic reference levels to distinguish between acceptable and inappropriate practices at the facility level

Dose-Reduction Techniques
- Improvement of current dose-reduction techniques and discovery of novel dose-reduction strategies
- Requirement for specific dose reduction features on forward production units (ie, tube current modulation, collimators)

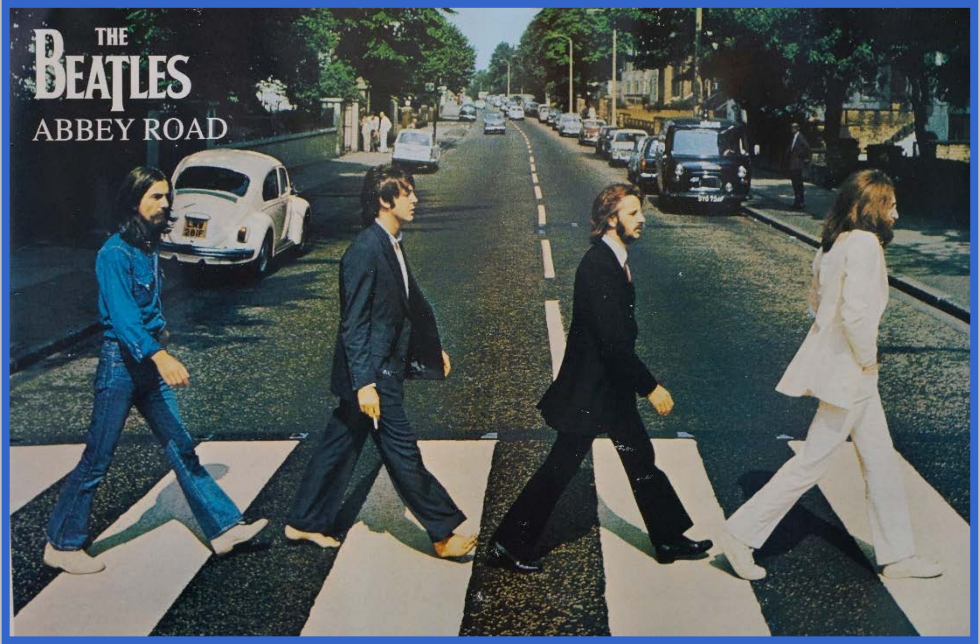
Dose Tracking
- Documentation/reporting of radiation dose for every CT study
- National dose registry to help define best practices and allow for interfacility comparisons of dose indexes.

Figure 1: Specific expert recommendations from congressional and FDA testimony on ways to address the issue of CT safety. Recommendations were extracted from the House congressional hearing, "Medical Radiation: An Overview of the Issues," held in February 2010 and the FDA public meeting, "Device Improvements to Reduce Unnecessary Radiation Exposure from Medical Imaging," held in March 2010 (14,15).

Principles of Radiation Protection

Regulatory oversight… and

- Advances in *what* (imaging technology)
  - Including artificial intelligence
- Advances in *how* (application)
  - e.g. limiting multiphase exams
- Advances in *when* (justification)
  - e.g. clinical decision support (NDSL CareSelect Imaging™)



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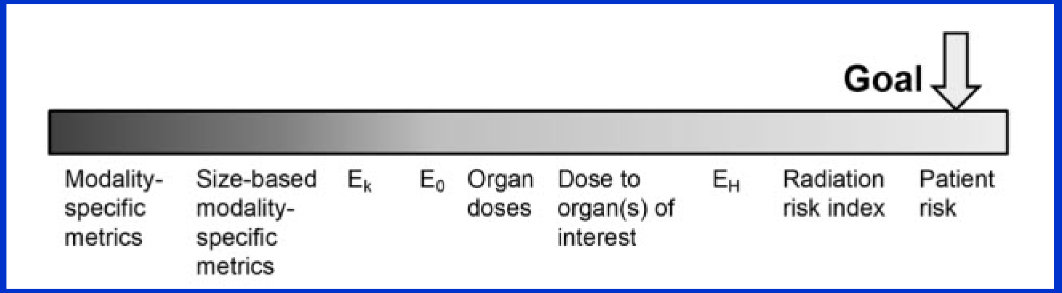
Coming Together

- Monitoring technology and programs that provide value
  - represent voices from multiple stakeholders
  - generic metrology, efficient, adaptable (avoid data-drowning)
  - beyond current dose indices: organ dose? risk? quality…
- Defining *what that value is* (how do we use this?)
  - including benchmarks
  - in context to current understanding of risk
  - promoting benefit of imaging



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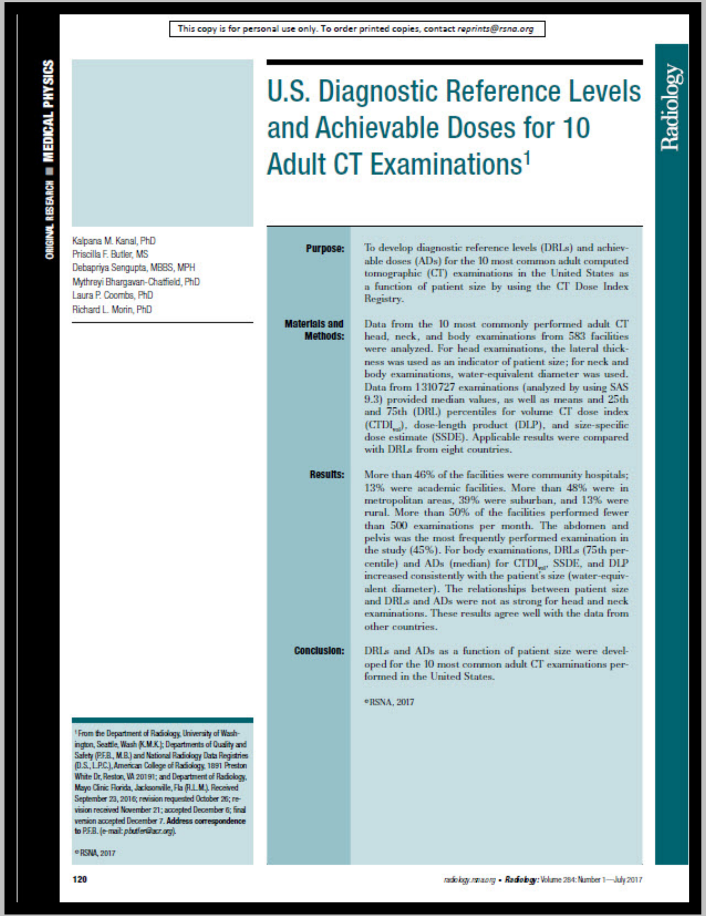
U.S. CT Diagnostic Reference Levels

Radiology 2017



ORIGINAL RESEARCH ■ MEDICAL PHYSICS

Radiology

U.S. Diagnostic Reference Levels and Achievable Doses for 10 Adult CT Examinations[1]

Kalpana M. Kanal, PhD
Priscilla F. Butler, MS
Debapriya Sengupta, MBBS, MPH
Mythreyi Bhargavan-Chatfield, PhD
Laura P. Coombs, PhD
Richard L. Morin, PhD

Purpose: To develop diagnostic reference levels (DRLs) and achievable doses (ADs) for the 10 most common adult computed tomographic (CT) examinations in the United States as a function of patient size by using the CT Dose Index Registry.

Materials and Methods: Data from the 10 most commonly performed adult CT head, neck, and body examinations from 583 facilities were analyzed. For head examinations, the lateral thickness was used as an indicator of patient size; for neck and body examinations, water-equivalent diameter was used. Data from 1310727 examinations (analyzed by using SAS 9.3) provided median values, as well as means and 25th and 75th (DRL) percentiles for volume CT dose index ($CTDI_{vol}$), dose-length product (DLP), and size-specific dose estimate (SSDE). Applicable results were compared with DRLs from eight countries.

Results: More than 46% of the facilities were community hospitals; 13% were academic facilities. More than 48% were in metropolitan areas, 39% were suburban, and 13% were rural. More than 50% of the facilities performed fewer than 500 examinations per month. The abdomen and pelvis was the most frequently performed examination in the study (45%). For body examinations, DRLs (75th percentile) and ADs (median) for $CTDI_{vol}$, SSDE, and DLP increased consistently with the patient's size (water-equivalent diameter). The relationships between patient size and DRLs and ADs were not as strong for head and neck examinations. These results agree well with the data from other countries.

Conclusion: DRLs and ADs as a function of patient size were developed for the 10 most common adult CT examinations performed in the United States.

[1] From the Department of Radiology, University of Washington, Seattle, Wash (K.M.K.); Departments of Quality and Safety (P.F.B., M.B.) and National Radiology Data Registries (D.S., L.P.C.), American College of Radiology, 1891 Preston White Dr, Reston, VA 20191; and Department of Radiology, Mayo Clinic Florida, Jacksonville, Fla (R.L.M.). Received September 23, 2016; revision requested October 26; revision received November 21; accepted December 6; final version accepted December 7. **Address correspondence** to P.F.B. (e-mail: *pbutler@acr.org*).

Radiology 2021

Radiology

ORIGINAL RESEARCH ▪ PEDIATRIC IMAGING

U.S. Diagnostic Reference Levels and Achievable Doses for 10 Pediatric CT Examinations

Kalpana M. Kanal, PhD ▪ *Priscilla F. Butler, MS* ▪ *Mythreyi B. Chatfield, PhD* ▪ *Jered Wells, PhD* ▪ *Ehsan Samei, PhD* ▪ *Michael Simanowith, MD* ▪ *Dan Golden, BA* ▪ *Dustin A. Gress, MS* ▪ *Judy Burleson, MHSA* ▪ *William F. Sensakovic, PhD* ▪ *Keith J. Strauss, MSc* ▪ *Donald Frush, MD*

From the Department of Radiology (K.M.K.), University of Washington, 1959 NE Pacific St, Box 357987, Seattle, WA 98195-7987; Department of Quality and Safety (P.F.B., M.B.C., M.S., D. Golden, D. Gress, J.B.), American College of Radiology, Reston, Va; Department of Radiology (J.W., E.S., D.F.), Duke University Medical Center, Durham, NC; Department of Radiology (W.S.), Mayo Clinic, Phoenix, Ariz; and Department of Radiology (K.S.), Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio. Received May 14, 2021; revision requested June 2; revision received August 5; accepted August 10. Address correspondence to K.M.K. (e-mail: [illegible]).

Conflicts of interest are listed at the end of this article.

Radiology 2021; 000:1–11 ▪ https://doi.org/10.1148/radiol.2021211241 ▪ Content codes: CT PD

Background: Diagnostic reference levels (DRLs) and achievable doses (ADs) were developed for the 10 most commonly performed pediatric CT examinations in the United States using the American College of Radiology Dose Index Registry.

Purpose: To develop robust, current, national DRLs and ADs for the 10 most commonly performed pediatric CT examinations as a function of patient age and size.

Materials and Methods: Data on 10 pediatric (ie, patients aged 18 years and younger) CT examinations performed between 2016 and 2020 at 1625 facilities were analyzed. For head and neck examinations, dose indexes were analyzed based on patient age; for body examinations, dose indexes were analyzed for patient age and effective diameter. Data from 1 543 535 examinations provided medians for AD and 75th percentiles for DRLs for volume CT dose index ($CTDI_{vol}$), dose-length product (DLP), and size-specific dose estimate (SSDE).

Results: Of all facilities analyzed, 66% of the facilities (1068 of 1625) were community hospitals, 16% (264 of 1625) were freestanding centers, 9.5% (154 of 1625) were academic facilities, and 3.5% (57 of 1625) were dedicated children's hospitals. Fifty-two percent of the patients (798 577 of 1 543 535) were boys, and 48% (744 958 of 1 543 535) were girls. The median age of patients was 14 years (boys, 13 years; girls, 15 years). The head was the most frequent anatomy examined with CT (876 655 of 1 543 535 examinations [57%]). For head without contrast material CT examinations, the age-based $CTDI_{vol}$ AD ranged from 19 to 46 mGy, and DRL ranged from 23 to 55 mGy, with both AD and DRL increasing with age. For body examinations, DRLs and ADs for size-based $CTDI_{vol}$, SSDE, and DLP increased consistently with the patient's effective diameter.

Conclusion: Diagnostic reference levels and achievable doses as a function of patient age and effective diameter were developed for the 10 most commonly performed CT pediatric examinations using American College of Radiology Dose Index Registry data. These benchmarks can guide CT facilities in adjusting pediatric CT protocols and resultant doses for their patients.

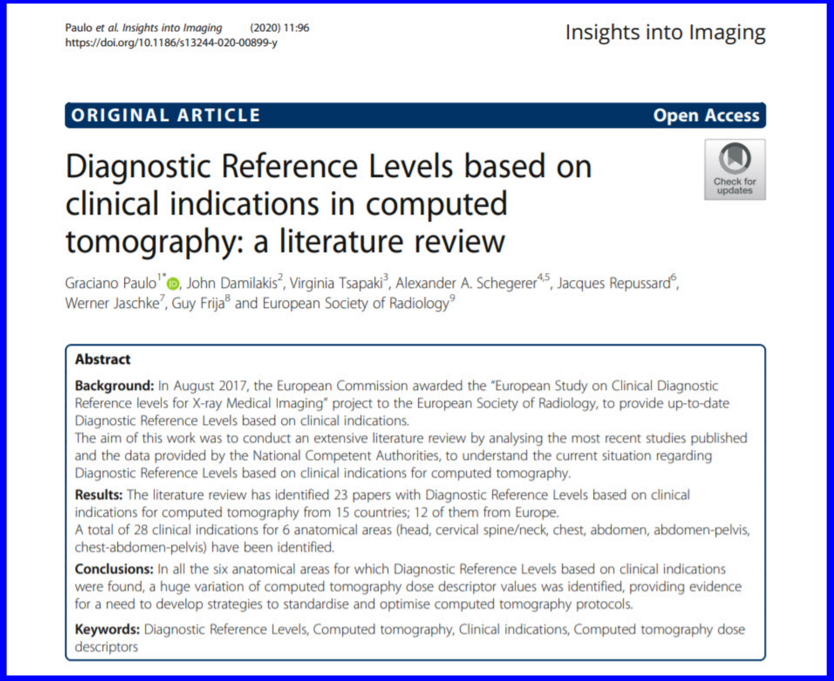
Diagnostic reference level (DRL) benchmarks for radiation protection and optimization of patient imaging were first mentioned by the International Commission on Radiological Protection (ICRP) in 1990 (1) and clarified further in 1996 (2). The DRL is used for identifying situations where the levels of patient dose are unusually high (2,3). The use of DRLs is endorsed by professional, advisory, and regulatory organizations. The ICRP emphasizes that DRL values "are not for regulatory or commercial purposes, not a dose restraint and not linked to limits or constraints" (4). DRLs are typically set at the 75th percentile of the dose distribution from a survey conducted across a broad user base using a specified dose measurement protocol. They are established both regionally and nationally, and considerable variations have been seen across regions and countries (4–6)

The concept of achievable dose (AD) was introduced in 1999 in a United Kingdom National Radiation Protection Board advisory group to recognize more typical values within a practice (7). In 2012, the National Council on Radiation Protection and Measurements proposed that ADs be set at the median, or 50th percentile, of a dose survey, on the basis that 50% of the facilities have already achieved doses at or below this value (8).

In 2017, DRLs were published for adult CT examinations in the United States using the American College of Radiology CT Dose Index Registry (DIR) (9–11). Few current U.S. recommendations exist for pediatric DRLs and ADs in CT. Some are based on phantom surveys, not clinical examinations (12,13). Other work in the United States has used clinical examinations from DIR data to provide age- or size-based dose index guidance for pediatric CT (14–16). In 2018, the European Commission summarized existing national DRLs from 17 countries in its Guidelines for Diagnostic Reference Levels for Pediatric Imaging based mainly on the anatomic region imaged; these are primarily presented in age groups and, in some cases, weight groupings (17). At this time, there are no national DRLs based on patient dimensions or size. The purpose of this study is to use the CT DIR to develop robust, current, national DRLs and ADs for the 10 most commonly performed pediatric CT examinations as a function of patient age and size. This is the first time these benchmarks have been developed in the United States.

Benchmarks: DRLs

EUCLID: pursue
indication-based DRLs



Paulo *et al. Insights into Imaging* (2020) 11:96
https://doi.org/10.1186/s13244-020-00899-y

Insights into Imaging

ORIGINAL ARTICLE — Open Access

Diagnostic Reference Levels based on clinical indications in computed tomography: a literature review

Check for updates

Graciano Paulo[1*], John Damilakis[2], Virginia Tsapaki[3], Alexander A. Schegerer[4,5], Jacques Repussard[6], Werner Jaschke[7], Guy Frija[8] and European Society of Radiology[9]

Abstract

Background: In August 2017, the European Commission awarded the "European Study on Clinical Diagnostic Reference levels for X-ray Medical Imaging" project to the European Society of Radiology, to provide up-to-date Diagnostic Reference Levels based on clinical indications.
The aim of this work was to conduct an extensive literature review by analysing the most recent studies published and the data provided by the National Competent Authorities, to understand the current situation regarding Diagnostic Reference Levels based on clinical indications for computed tomography.

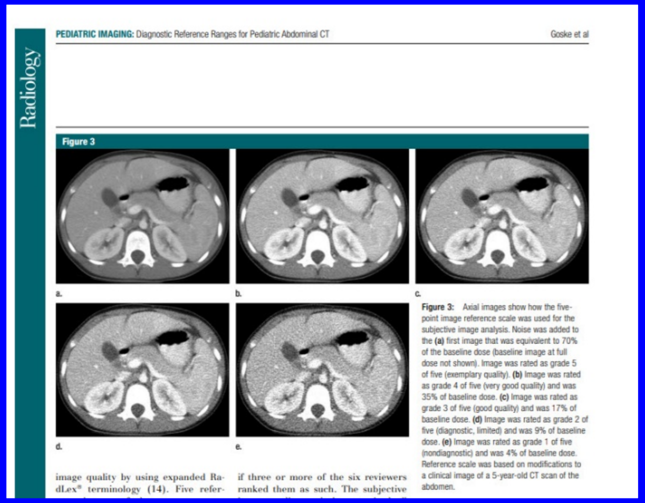
Results: The literature review has identified 23 papers with Diagnostic Reference Levels based on clinical indications for computed tomography from 15 countries; 12 of them from Europe.
A total of 28 clinical indications for 6 anatomical areas (head, cervical spine/neck, chest, abdomen, abdomen-pelvis, chest-abdomen-pelvis) have been identified.

Conclusions: In all the six anatomical areas for which Diagnostic Reference Levels based on clinical indications were found, a huge variation of computed tomography dose descriptor values was identified, providing evidence for a need to develop strategies to standardise and optimise computed tomography protocols.

Keywords: Diagnostic Reference Levels, Computed tomography, Clinical indications, Computed tomography dose descriptors

Goske et al
Radiology 2013 (268)

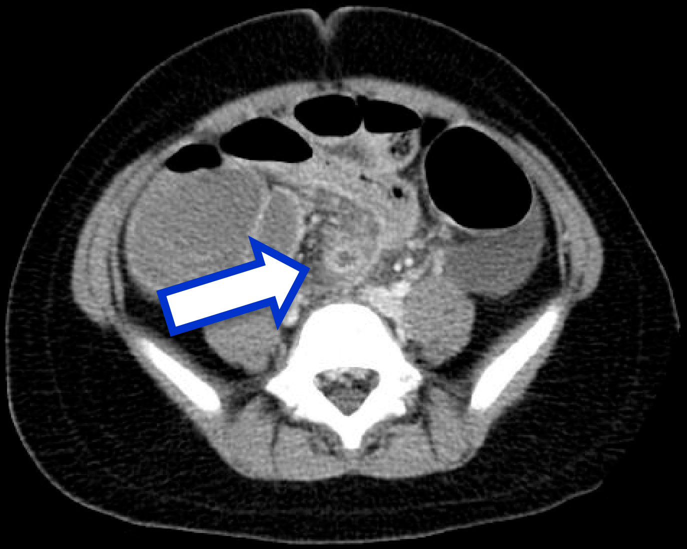
Diagnostic Reference Ranges
For Pediatric Abdominal CT



"The concept of DRRs addresses the balance between the patient's risk (radiation dose) and benefit (diagnostic image quality)."

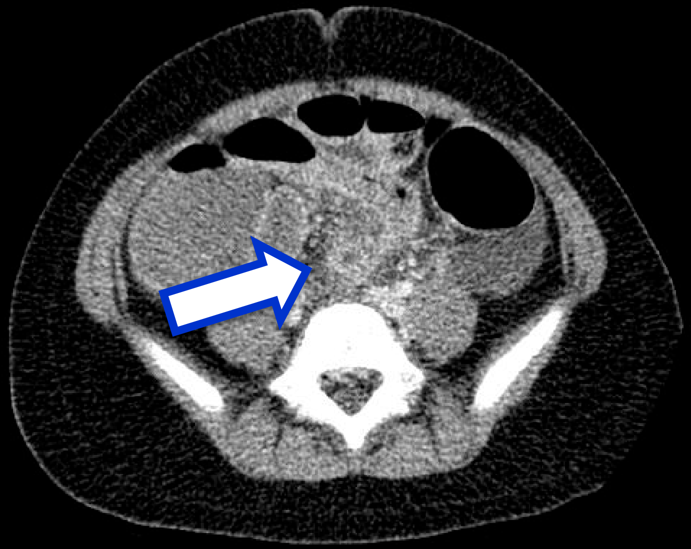
Appendicitis: Simulated Dose (mA) Reduction

There is a “Too Low…”



Original

50% mA Reduction



75% mA Reduction

Monitoring Beyond Dose

"DRLs have reached a stage where there is an **evident need of introducing image quality** evaluation process linked to dose evaluation as both go hand-in-hand"

European Radiology
https://doi.org/10.1007/s00330-019-06422-2

PHYSICS

Check for updates

Long-term experience and analysis of data on diagnostic reference levels: the good, the bad, and the ugly

Patrice Roch[1] · David Célier[1] · Cécile Dessaud[2] · Cécile Etard[1] · Madan M. Rehani[3]

Received: 26 May 2019 / Revised: 25 July 2019 / Accepted: 12 August 2019

Abstract

Objectives To analyze 11-year data of France for temporal trends in dose indices and dose optimization and draw lessons for those who are willing to work on creation and update of diagnostic reference levels (DRLs).

Methods The data from about 3000 radiology departments leading to about 750,000 imaging exams between 2004 and 2015 was analyzed, and patterns of reductions in dose for those below and above the DRLs were estimated and correlated with technology change.

Results Dose optimization achieved was important and significant in departments which were above or just below the DRL ($p = .006$) but not in those which were around half of the DRL values. The decrease in 75th percentile value of Kerma air product (KAP) for chest radiography by 27.4% between 2004 and 2015 was observed with the number of flat panel detectors increase from 6 to 43%. A good correlation between the detector type distribution and the level of patient radiation exposure is observed. Otherwise, setting DRLs for standard-sized patient excludes patients lower and higher weighted than "standard."

Conclusions The concept of DRL may become obsolete unless lessons drawn from the experience of users are taken into account. While establishing DRLs should be part of the regulations, setting up and updating values should be governed by bodies whose decision-making cycle is short, at the most 1 year. A local rather than national approach, taking into account body habitus and image quality, needs to be organized.

Key Points

- *The technology changes faster than regulations. Requirement of DRL establishment should be part of the regulations; however, setting and updating values should be the role of professional societies.*
- *The concept of DRL, highlighting the 75th percentile values and dedicated to standard-sized adult, misses optimization opportunities in the majority of patients who are below the 75th percentile value and outside the range of standard-sized adult.*
- *The ugly aspects of the DRL concept include its non-applicability to individuals, no customization to clinical indications, and lack of consideration of image quality.*

Keywords Diagnostic imaging · Radiation protection · Patient safety · Radiation exposure · Reference values

Radiology

REVIEWS AND COMMENTARY • EDITORIAL

Benchmarking CT Radiation Doses Based on Clinical Indications: Is Subjective Image Quality Enough?

Mahadevappa Mahesh, MS, PhD

Dr Mahesh is a professor of radiology and cardiology at the Johns Hopkins University School of Medicine and a medical physicist at Johns Hopkins Hospital. His research interests are in CT and radiation dose assessment in medical imaging. He is associate editor of the *Journal of the American College of Radiology* and serves as a subject matter expert for the United Nations International Atomic Energy Agency.

The number of CT examinations performed in the United States and worldwide has consistently grown since the introduction of multiple-row detector CT around the turn of the century. The advent of multiple-row detector CT paved new ways for diagnosis, treatment, and post-treatment evaluation because of fast data acquisition, high spatial and temporal resolution, and better three-dimensional image acquisitions. The dramatic increase in the number of CT examinations performed drew considerable attention to the radiation doses associated with CT studies. According to the National Council on Radiation Protection and Measurements, or NCRP, Report 160 (1) published in 2009, CT doses were the largest contribu-

In addition, all CT examinations of a specific anatomic area, such as the head, do not all need to have the same image quality—all may not require the same radiation dose levels. For example, head CT for sinus evaluation can be performed with a lower radiation dose than head CT performed for evaluating stroke. This provides an opportunity to optimize CT protocols based on clinical indications. Similarly, scanning of the heart (ie, calcium scoring studies) does not need the same level of radiation dose as cardiac CT angiography because the clinical indications, such as calcifications, are readily visible even with a noisy image due to a lower radiation dose.

The advent of radiation dose management systems, or dose registries, has allowed for the establishment of diagnostic reference levels for CT examinations (4). Registries can be used to describe "typical" radiation doses for a specific type of CT examination. Despite registries, we still see a wide range of radiation doses, up to three- to 10-fold variation, for the same type of CT examination. Thus, there remains a need to optimize CT protocols by considering both image quality and radiation dose levels.

In this regard, Smith-Bindman and colleagues (5) present an image quality–based framework for CT radiation dose in this issue of *Radiology*. In their study, the authors

"… there remains a need to optimize CT protocols by considering **both image quality and radiation dose levels** … In my opinion, such image quality **metrics must be quantitative and not subjective**."

Competitive Landscape 2019

Leading market radiation dose monitoring products focus on dose and basic analytics ONLY: NOT QUALITY (

Product name	Data Access	Data Integrity	Analysis Used	Metrics and Informatics	
				Dose	Quantitative Quality Assessment
Bayar Radimetrics	Yes	Limited	Basic	Basic	None
GE DoseWatch	Yes	Limited	Basic	Basic	None
Imalogix	Yes	Limited	Basic	Basic	None
DoseM	Yes	Limited	Basic	Basic	None
NovaDose	Yes	Limited	Basic	Basic	None
DoseMonitor	Yes	Limited	Basic	Basic	None
DoseTrack	Yes	Limited	Basic	Basic	None

Courtesy Ehsan Samei

Noise, dose, resolution reference levels and ranges: L = median; R = Range 25% - 75%

Chest CT	Noise		Dose		Resolution	
Size Range (cm)	NRL	NRR	DoRL	DoRR	RRL	RRR
21-25	10.8	7.6	3.3	2.1	0.46	0.06
25-29	9.8	6.8	5.2	2.5	0.47	0.06
29-33	10.2	5.7	7.7	3.7	0.48	0.08
33-37	10.5	6.4	11.1	7.3	0.48	0.10
37-41	10.6	7.6	15.0	12.4	0.47	0.10
Abd-Pelvis CT	Noise		Dose		Resolution	
Size Range (cm)	NRL	NRR	DoRL	DoRR	RRL	RRR
21-25	6.9	2.1	5.3	1.6	0.46	0.08
25-29	7.7	2.4	6.7	2.5	0.46	0.09
29-33	8.2	2.7	8.8	3.6	0.46	0.10
33-37	8.4	3.3	11.8	5.0	0.46	0.11
37-41	8.0	3.9	14.7	8.0	0.45	0.12

true CT *diagnosis reference* is dose + quality

Smith et al, JMI 2021

Recurrent Imaging and Cumulative Effective Dose (CED): Generating Dialogue

JOINT POSITION STATEMENT AND CALL FOR ACTION FOR STRENGTHENING RADIATION PROTECTION OF PATIENTS UNDERGOING RECURRENT RADIOLOGICAL IMAGING PROCEDURES

This Position Statement was developed by the International Atomic Energy Agency (IAEA) jointly with the European Federation of Organizations for Medical Physics (EFOMP), European Society of Radiology (ESR), Global Diagnostic Imaging, Healthcare IT and Radiation Therapy Trade Association (DITTA), Heads of European Radiological Competent Authorities (HERCA), Image Gently Alliance, International Organization for Medical Physics (IOMP), International Society of Radiology (ISR), International Society of Radiographers and Radiological Technologists (ISRRT), in collaboration with the World Health Organization (WHO).

INTRODUCTION

Medical imaging is immensely beneficial in the diagnosis and management of many health conditions. Benefits of a given medical imaging procedure far outweigh inherent radiation risks when the procedure is both clinically indicated and correctly performed, using the minimum necessary radiation exposure to achieve the diagnostic or interventional objective. The Bonn Call for Action, jointly issued by the IAEA and WHO, emphasized the need for enhanced implementation in clinical practice of the principles of *justification and optimization*, the right procedure performed right, spotlighting radiation protection and safety for each patient exposure.

AMERICAN ASSOCIATION *of* PHYSICISTS IN MEDICINE

Proper Use of Radiation Dose Metric Tracking for Patients Undergoing Medical Imaging Exams

Frequently Asked Questions

Introduction
In August of 2021, the American Association of Physicists in Medicine (AAPM), the American College of Radiology (ACR), and the Health Physics Society (HPS) jointly released the following position statement advising against using information about a patient's previous cumulative dose information from medical imaging exams to decide the appropriateness of future imaging exams. This statement was also endorsed by the Radiological Society of North America (RSNA).

> *It is the position of the American Association of Physicists in Medicine (AAPM), the American College of Radiology (ACR), and the Health Physics Society (HPS) that the decision to perform a medical imaging exam should be based on clinical grounds, including the information available from prior imaging results, and not on the dose from prior imaging-related radiation exposures.*
>
> *AAPM has long advised, as recommended by the International Commission on Radiological Protection (ICRP), that justification of potential patient benefit and subsequent optimization of medical imaging exposures are the most appropriate actions to take to protect patients from unnecessary medical exposures. This is consistent with the foundational principles of radiation protection in medicine, namely that patient radiation dose limits are inappropriate for medical imaging exposures. Therefore, the AAPM recommends against using dose values, including effective dose, from a patient's prior imaging exams for the purposes of medical decision making. Using quantities such as cumulative effective dose may, unintentionally or by institutional or regulatory policy, negatively impact medical decisions and patient care.*
>
> *This position statement applies to the use of metrics to longitudinally track a patient's dose from medical radiation exposures and infer potential stochastic risk from them. It does not apply to the use of organ-specific doses for purposes of evaluating the onset of deterministic effects (e.g., absorbed dose to the eye lens or skin) or performing epidemiological research.*

https://www.iaea.org/sites/default/files/position_statement_final_endorsed.pdf
https://www.aapm.org/org/policies/documents/EffectiveDose_FAQ.pdf

Contemporary issues in radiation protection in medical imaging: BJR Sept 2021
https://www.birpublications.org/toc/bjr/current

Recurrent Imaging and CED[1]

- General threshold discussed is $\geq$ 100 mSv
- Recent reports in adults vary:
  - "0.6–3.4%"
  - "Up to 1.9%"
  - "0.5%"
- Children:
  - "0-0.08%"
- In adults and children, oncology population most often
- In children, migration of imaging to MR and US
- "Bang for the buck"?

[1] Br J Radiol 2021; 94: 20210478

Recurrent Imaging and CED and

- **What above and beyond current RP requirements and recommendations?**
- **Investment in designing guidelines for situations where recurrent imaging is likely: beyond current justification?**
- **Use at the individual patient point of care?**

"There is no simple or uniformly applicable approach to these challenging and often nuanced clinical decisions. The complexity and variability of the underlying disease states and trajectories *argues against alerting mechanisms based on a simple cumulative dose threshold.*

Awareness of imaging history may [encourage] physicians and patients to … identify those populations of frequent flyers that might benefit from alternative imaging strategies."

BJR

https://doi.org/10.1259/bjr.20210543

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Sodickson AD. Radiation concerns in frequent flyer patients: should imaging history influence decisions about recurrent imaging?. *Br J Radiol* 2021; **94**: 20210543.

CONTEMPORARY ISSUES IN RADIATION PROTECTION IN MEDICAL IMAGING SPECIAL FEATURE: REVIEW ARTICLE

Radiation concerns in frequent flyer patients: should imaging history influence decisions about recurrent imaging?

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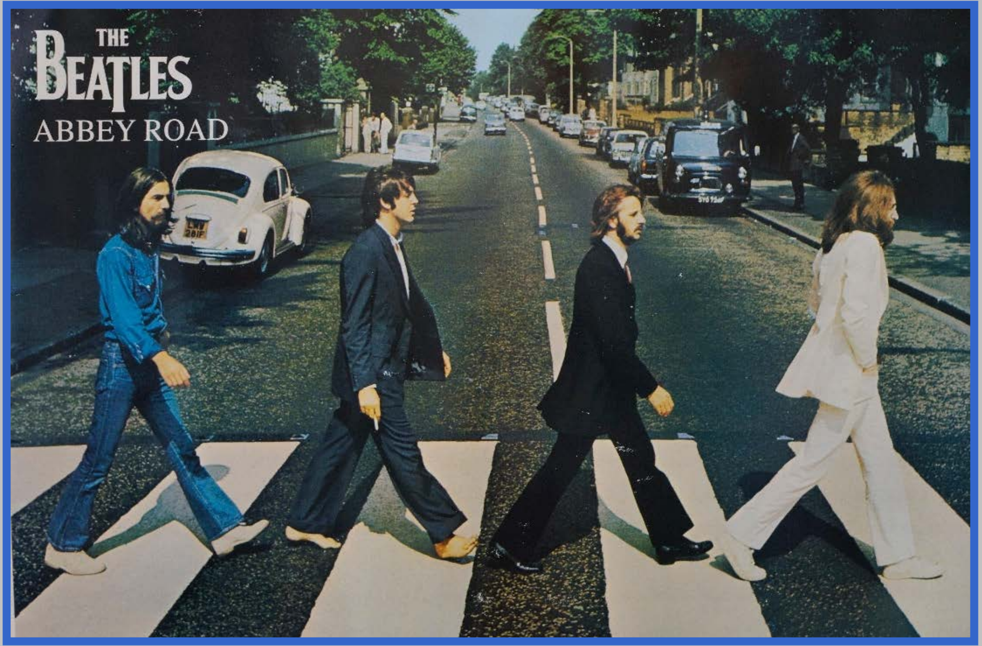

https://postermuseum.com/collections/rock-music/products/the-beatles-abbey-road-crossing-753

He say, "one and one and one is three"

- U.S. doses have fallen
- Monitoring impact: attribution?
- Opportunities and challenges with how to do this, avoiding…

https://mccartney.com/?p=16520


Thank You