

Computed Tomography (CT): Cumulative doses

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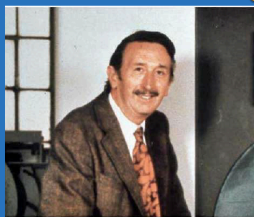
There has been s much
talk about radiation
dose in CT. Is there still
something to do?

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CT – The beginning



Sir Godfrey Hounsfield (1919-2004)
EMI Research Division
Nobel Prize - 1979

Oct. 1, 1971

1st Clinical scan – Atkinson Morley's
Hospital, London

EMI - Electric and Musical Industries Ltd
formed March 1931 by merger of
UK Columbia Graphophone and
Gramophone Company



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CT

- **1970's and 1980's: Several generations of CT scanner**
 - How to measure and express dose in CT
- **1980's: Possible death of CT**
- **Early 1990's: CT is going to stay**
- **Late 1990's: Radiation dose in CT**

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In comes CTDI circa 1980 ~ 8 years from 1st CT

A method for describing the doses delivered by transmission x-ray computed tomography^{a)}

Thomas B. Shope, Robert M. Gagne, and Gordon C. Johnson

Bureau of Radiological Health, Food and Drug Administration, 5600 Fishers Lane, Rockville, Maryland 20857
(Received 23 September 1980; accepted for publication 3 October 1980)

A method for describing the absorbed dose delivered by x-ray transmission computed tomography (CT) is proposed which provides a means to characterize the doses resulting from CT procedures consisting of a series of adjacent scans. The dose descriptor chosen is the average dose at several locations in the imaged volume of the central scan of the series. It is shown that this average dose, as defined, for locations in the central scan of the series can be obtained from the integral of the dose profile perpendicular to the scan. This method for estimating the average dose of the number of scans in the series is suggested.

480 Shope, Gagne, and Johnson: Doses delivered by transmission x-ray computed tomography

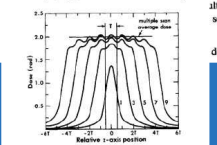


Fig. 3. Simulated dose profiles for multiple scan series consisting of 1, 3, 5, 7, or 9 scans. Curves are separated by the distance T equal to the slice thickness. Single scan profile is representative of extreme dose profiles.

II. SUGGESTED DOSE DESCRIPTOR FOR COMPUTED TOMOGRAPHY

The dose descriptor we propose is the computed tomography dose index (CTDI) denoted as C and defined by

$$C = (1/T) \int_{-T}^{+T} D_z(x) dx, \quad (1)$$

where $D_z(x)$ is the dose as a function of position along the z axis coordinate for a single scan dose profile at a given point (x, y) . T is the slice thickness as stated by the manufacturer or selected by the CT system operator. The CTDI will be shown below to be equal to the average dose along the z direction at the point (x, y) over the central scan of a series of

Medical Physics, Vol. 9, No. 4, July/August 1981

1998: Review of situation in ICRP

- There were no cases of skin injuries from CT
- There was no momentum on cancer risk estimates from CT scans
- Manufacturers not really concerned about patient doses, as hardly customers asked for it
- Most emphasis on faster and faster CT scanners

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Rehani_Brazil_CT dose ICRP INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

ICRP Task Group (1998)

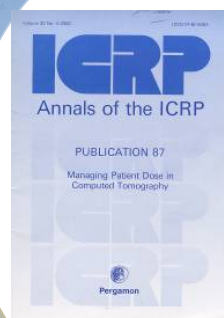
- M.M. Rehani (Chairman)
- Members:
 - G. Bongartz (Switzerland); S.J. Golding (UK); L. Gordon (Sweden); W. Kalender (Germany); T. Murakami (Japan); P. Shrimpton (UK)
- Corresponding members:
 - R. Albrecht (USA) and K. Wei (China)

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ICRP Publication 87 (2000)

Free Download
From ICRP Website



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**CT is going to be a major
source of radiation exposure
to population**

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Question: Should safety be

- A. built into the system
- B. be a matter of choice as users can be trained effectively

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Approach

Safety is best achieved when it is **built
into the system** rather than a **matter
of choice for users**

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Approach

- The example of a collision avoidance systems which started with automobile industry.
- When collision **has to be avoided through education, training, instructions**, the results cannot be the same.
- Both detection and avoidance should be automatic.

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ICRP 87 (2000)

- Forecasting
- Warning
- Actions needed by
 - Industry
 - Users

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Editorial in Br Med J in March 2000

Journal List > BMJ > v.320(7235); Mar 4, 2000 > PMC1117635

BMJ

helping doctors make better decisions

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BMJ. Mar 4, 2000; 320(7235): 593-594.

P

Radiation doses in computed tomography

The increasing doses of radiation need to be controlled

Madan M Rehani, additional professor of medical physics

Manorma Berry, professor of radiodiagnosis

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Reactions- USA

Diagnostic Imaging Online

April 13, 2000

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CT radiation dose questions draw international attention

Radiation dosage from CT scans could become a matter of debate if international calls for reduced radiation levels move forward.

Writing last month in the British Medical Journal, Dr. Madan Rehani, chairperson of an international task force on safer dosage standards for CT scans, made the case for a closer look at CT radiation levels.

"The increasing doses of radiation need to be controlled worldwide," he said.

The task force was established by the International Commission on Radiological Protection (ICRP). The organization meets in Zurich this month to discuss safer dosage recommendations.

While the ICRP believes that there is cause for concern about high radiation dosage in CT scans, some physicians claim that there is no basis for this.

"The FDA approves a technology only after due research. Radiation is used discerningly in our country. America is one of the most conscious medical communities when it comes to radiation safety, and radiation is used wisely by physicians only after weighing cost and benefit, keeping in mind safety of the patients," said Dr. Jonathan Goldin, an assistant professor of radiology at the University of California, Los Angeles, who studies

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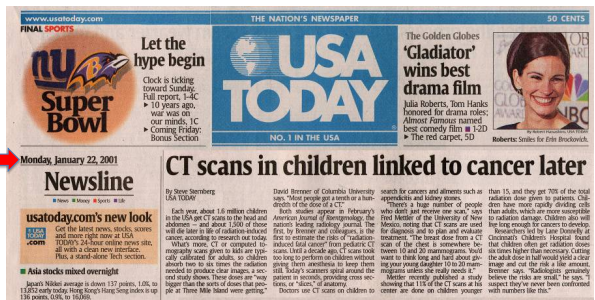
Other actions that gave thrust

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AJR issue with many articles & Editorial



Brenner, Lee Rogers, Paterson, Donolly, Nickloff, Haaga

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Era on ATTENTION to dose in CT

Manufacturers vying with each other on Radiation Dose

Role of Steve Sternberg
in making patients & staff safer

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Enjoying being with the wave or create wave

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After ICRP 87

- Spiral CT 1999-2000
- 2000-2003: Doses in MDCT are higher
- Newer applications
- Potential for
 - Steep increase in usage
 - Multiple CT examination
- Watched literature on patient doses

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2005: ICRP

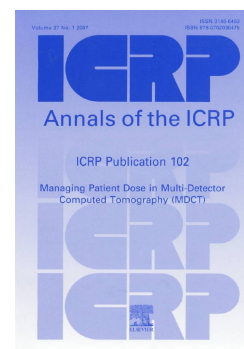
- Established another TG on Patient dose Management in MDCT
- **Chair: Madan Rehani**
- Other members:
 - M.K. Kalra, USA
 - C.H. McCollough, USA
 - H.D. Nagel, Germany
- Corresponding members
 - L. Collins, NSW, Australia
 - W. Kalender, Erlangen, Germany

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ICRP Publication 102, 2007



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Single most important point in new document

Be aware!!

About image quality that you are using

Guidance on HOW to optimize

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A check on PubMed for the number of papers on CT dose optimization in 2018 shows **three to five** papers every week

Was it so in early 2000?

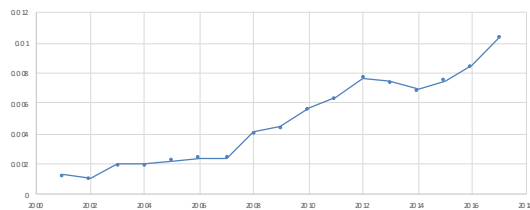
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Normalized to "radiology" publications

"radiation dose" AND "computed tomography"



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2001-2005

International Action Plan (IAEA)

Cancer risk from CT scan

First skin injury from CT and DSA combined

2011-2015

BONN CALL FOR ACTION
10 Actions to Improve Radiation Protection
in Medicine in the Next Decade

Choosing Wisely

2006-2010



image genitly

World Health Organization
Global Initiative



2016-

Several regional and national campaigns

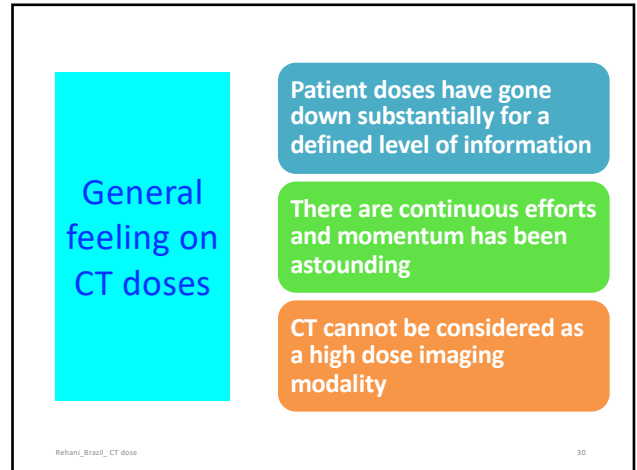
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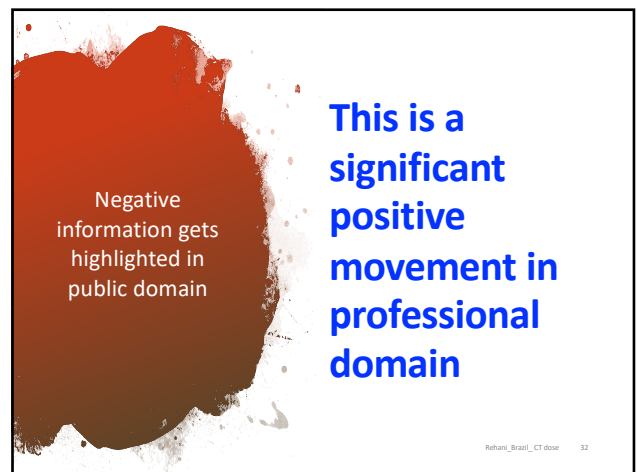
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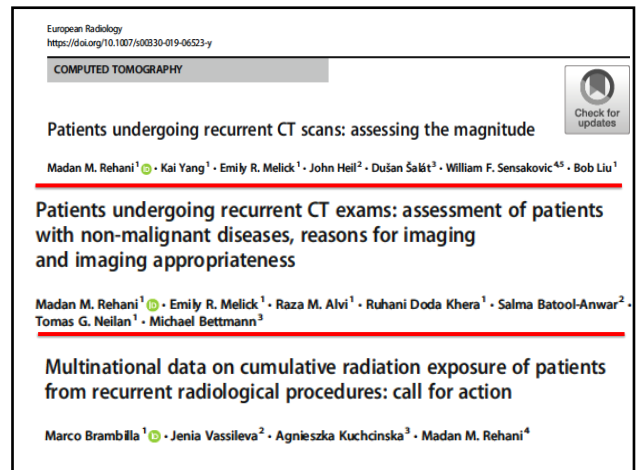
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**Data from
Rehani et
al. Eur
Radiol. Apr
2020**

**Data from 344 hospitals
>500 CT scanners
20 Countries**

**3.3 million patients and
>5 million CT exams**

**≈ 0.9 Million patients are likely
getting added every year globally
with CED ≥ 100 mSv only from
recurrent CT exams.**

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Rehani et al. Eur Radiol. April 2020; 30(4):1828-1836

Institute	Duration (Years & months)	Number of Hospitals	Number of CT scanners	Total number of patients undergoing CT
A in USA	5 yrs	5 sites	19	267,013
B in USA	2 yrs 7 m	16 sites	35	430,049
C National data Europe	5 yrs	70	108	807,526
D USA	1 yr 1 m	252	326	999,997
Total		324	488	2,504,585

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Rehani et al. Eur Radiol. April 2020; 30(4):1828-1836

Data on cohort with cumulative effective dose (CED) ≥ 100 mSv

Institution	Total number of patients with CED ≥ 100 mSv (%)	Maximum CED mSv	Median CED mSv	Mean number of CT exams per patient	Median number of CT exams per patient	Maximum number of CT exams in any patient
A	8,952 (3.4%)	1185	146.9	21	19	109
B	5888 (1.4%)	785.7	129.9	12	11	57
C	12,198 (1.5%)	864.7	130.7	6.3	6	67
D	6,369 (0.64%)	800.3	125.5	7	6	89
	33,407 (1.33%)					

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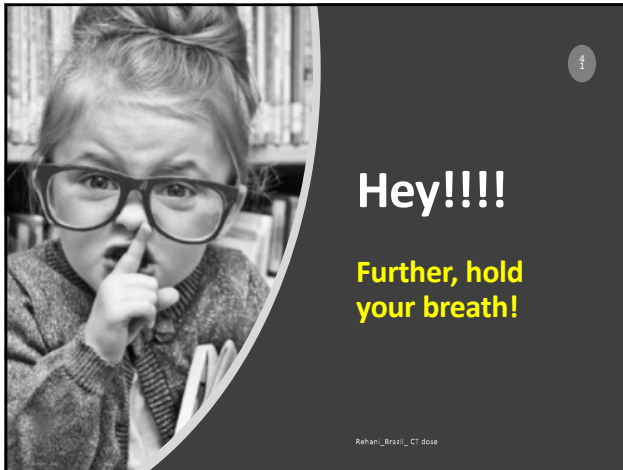


"You gotta be kidding me."

NO Sir/Madam, I am serious

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Rehani et al. Eur Radiol. April 2020; 30(4):1828-1836

Institution	Minimum days needed to get 100 mSv
A	1
B	1
C	1
D	1

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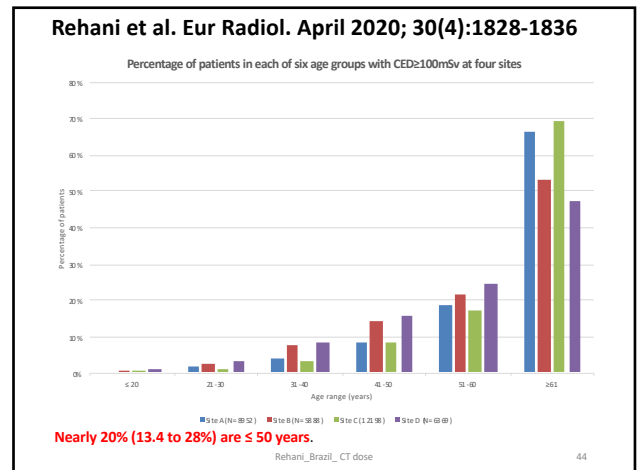
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Typical arguments

1. Patients may be over 50 years of age with a significantly lower probability of radiation effects
2. Patients may have malignant or other serious disease with short life expectancy
3. CT scans may be clinically justified and needed to save the patient's life.

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Rehani et al. Eur Radiol. April 2020; 30(4):1828-1836

Institution	CT Chest without contrast	CT Head/brain without contrast	CT abdomen/pelvis without contrast	CT abdomen/pelvis with contrast	CT Chest angio heart with and without contrast
American College of Radiology Dose Index Registry	339	869	669	682	541
A	254	772	561	476	204
B	425	1027	703	675	N/A
D	336	903	600	615	N/A

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Imaging Appropriateness in a small sub-set of patients
Rehani et al. Dec 2019

Clinical decision support (CDS)

ACR and clinical professional societies appropriateness use criteria

Manual review by clinicians

Red rate <2%, yellow 38%, clinically 80-100% appropriate

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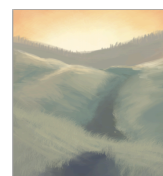
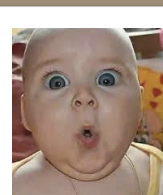
Important points

- Utility of CT is not questioned
- We are **NOT** saying that CT was used in these patients without justification or optimization
- We are not getting into the territory of effects, but as medical physicists talking about Dose
- Perhaps this may be the first time when imaging appropriateness in such patients was seriously studied
- Can anyone think of a time in last century when there was a similar situation?

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Even though CT is one of the safest imaging modalities, and its contribution to patient benefit is unquestionable, it seems that we have a real point for patients who need recurrent imaging.

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Remember: This is what we felt



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Sorry.
No chance to
sit back and
relax, but need
to act further



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Do you agree
that there is
need for
contributions
by

- Medical
Physicists
- Industry
- Users

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Med Phys 2019 Dec 28.
doi: 10.1002/mp.14000

POINT/COUNTERPOINT

Suggestions for topics suitable for these Point/Counterpoint debates should be addressed to Habib Zaidi, Geneva University Hospital, Geneva, Switzerland; habib.zaidi@unige.ch; Jing Cai, The Hong Kong Polytechnic University, Hong Kong; jing.cai@polyu.edu.hk; and/or Gerald White, Colorado Associates in Medical Physics; gerald.white@mindspring.com. Persons participating in Point/Counterpoint discussions are selected for their knowledge and communication skills. Their positions for or against a proposition may or may not reflect their personal opinions or the positions of their employers.

CT is still not a low-dose imaging modality

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(Tel. Tel: 608-263-3729; E-mail: tszczepietowski@wisc.edu)

Habib Zaidi, Ph.D., Moderator

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Paper Just published
Phys Med. 2020
Mar;71:176-177

Is it possible to kill the radiation risk issue in computed tomography?

M Kachelrieß,
M. Rehani

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Items that will impact

- More powerful X-ray tubes, thicker prefilters, in a filter changer
- Use of tunable tube voltage settings
- AEC not only to include mA modulation but also kV and filter thickness modulation
- Adaptive bow-tie filters
- Photon counting detector technology
- Deep learning

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Future

There will be a need to include the concept of cumulative dose in Standards and regulations

We foresee that with industry acting CED of >100 mSv will become a thing of the past at least in CT

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With the concept of Cumulative Dose

Total dose to patient will include not only from CT, but NM, interventional and imaging dose from RT

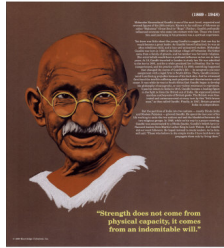

Holistic approach of patient protection rather than collective dose based approach

Protection of individual patient

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“Whatever you do will be insignificant, but it is very important that you do it”



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To myself I am only a child playing on the beach, while vast oceans of truth lie undiscovered before me.

-Isaac Newton



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Thank You

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