Radiation Issues for the Pediatric Patient

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Acknowledgement

- Thanks to the SPR (Society for Pediatric Radiology) and the ImageGently campaign for the generous, permitted use of some of their images and charts

Topics

- Radiation Physics And Biology
- Radiology History
- Current Knowledge
- How To Respond

Radiation Physics And Biology

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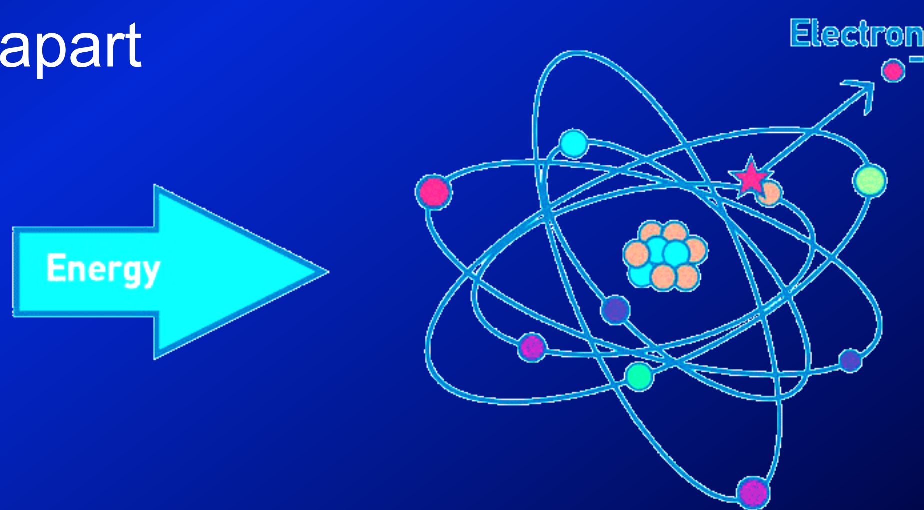
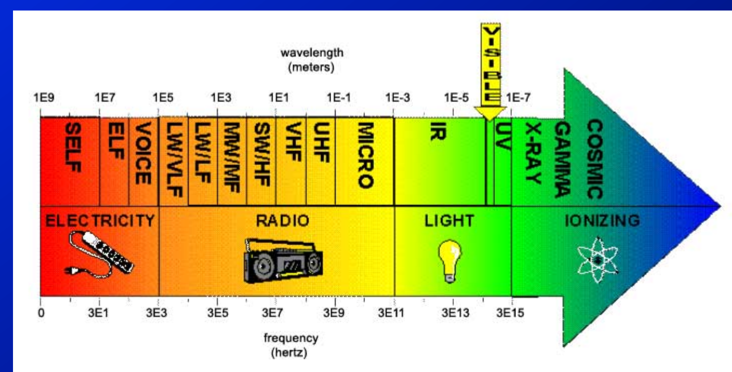
Radiation Physics

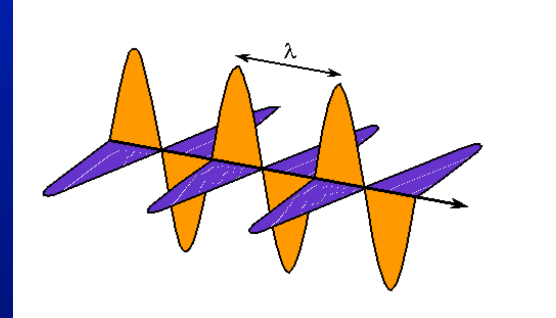
- Ionizing radiation
  - High-energy particles or waves that can detach – or ionize – electrons from an atom or molecule
    - For electrons shared by two atoms within a molecule, the bond is broken and the molecule falls apart



Ionizing Radiation

- Particles
  - Alpha (ie, He nucleus)
  - Beta
    - Electrons
    - Positrons
  - Neutrons
- Photons
  - Cosmic rays
  - Gamma rays
  - Xrays





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Ionizing Radiation

- Diagnostic imaging which uses it
  - Radiography
    - Chest xray
    - VCUG
    - Upper GI
  - Nuclear medicine
    - DMSA
    - PET
  - CT
    - CT angiography
- Diagnostic imaging which does not use it
  - Ultrasound
    - Doppler
    - Duplex
  - MRI
    - MR angiography
    - MR spectroscopy
    - Functional MRI

Radiation Biology

- ▲Ionization can occur anywhere in living tissue, both intracellular and extracellular
  - ►Intracellular chromosomal damage is the major concern
    - ▼Chromosomes contains the instructions required for cells to perform their functions
    - ▼Allows cells to copy themselves
  - ►Very effective mechanisms exist which constantly repair cellular damage

Radiation Biology

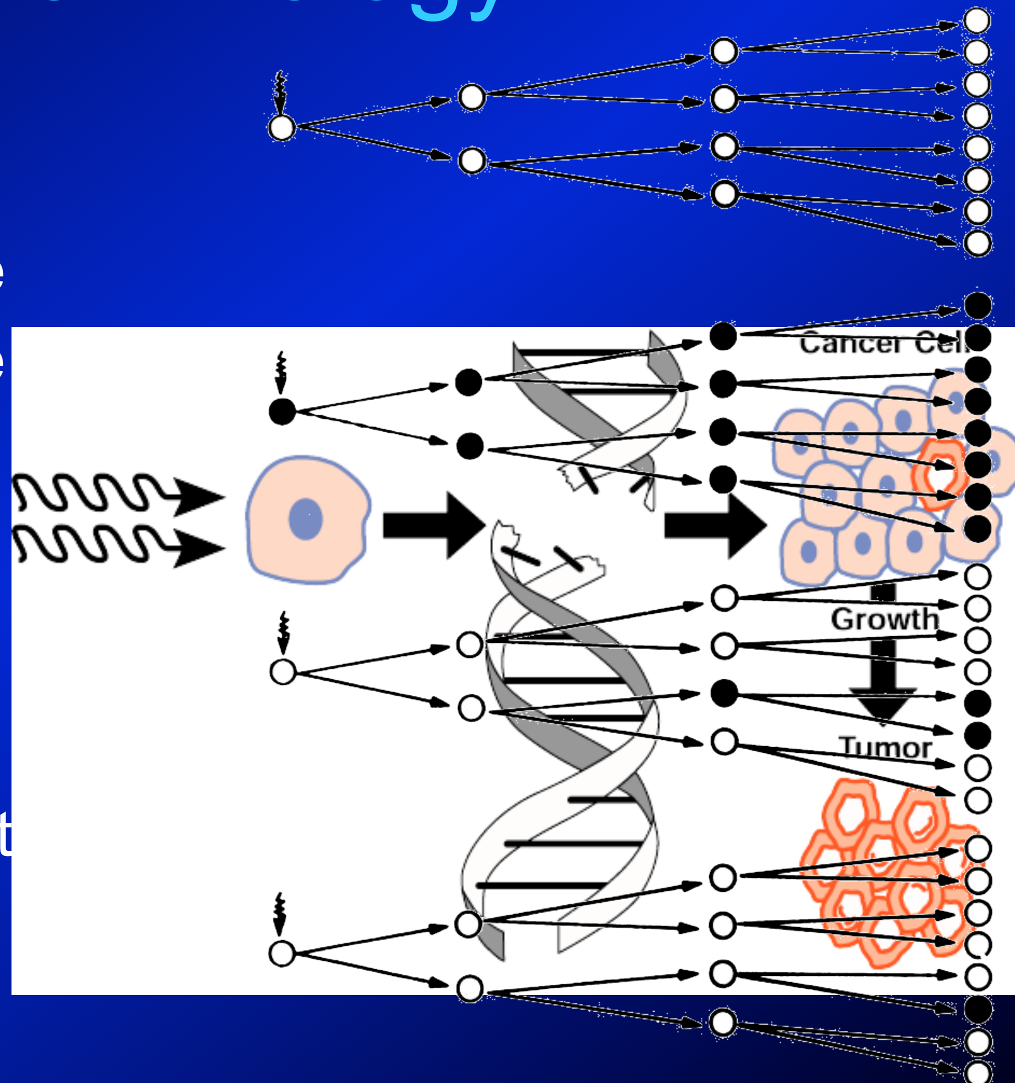
- Possible effects of ionizing radiation
  - No cell damage
  - Cell damage which is repaired
    - Operate normally
    - Operate abnormally
      - Unable to reproduce
      - Reproduce at uncontrolled rate
        - Can lead to malignancy
  - Cell death

Radiation Biology

- ▲Deterministic effects
  - ►Depends upon dose
  - ►Threshold
  - ►Examples
    - ▼Erythema
    - ▼Tissue burns
    - ▼Cataracts
  - ►Forms basis of Radiation Oncology

Radiation Biology

- ▲ Stochastic effects
  - ► Independent of dose
  - ► Threshold debatable
    - ▼ Risk proportional to dose
  - ► Examples
    - ▼ Malignancy
    - ▼ Genetic mutation
  - ► May not show up unt
    future generations



Radiation Doses

- Radioactivity
  - Rate of radiation released over time
- Exposure
  - Strength of a radiation field at a defined point
- Absorbed dose
  - Amount of energy imparted to matter
- Dose equivalent
  - Biological effect of an absorbed dose
    - Most important
    - Hardest to determine

Radiation Doses

	Radio-activity	Exposure	Absorbed Dose	Dose Equiv-alent
Common Units	Curie (Ci)	Roentgen (R)	rad	rem
SI Units	Becquerel (Bq)	Coulombs/ kg	Gray (Gy)	Sievert (Sv)

Radiation Doses

- Definitions
  - Absorbed dose
    - 1 rad = 0.01 Gy = 1 cGy = 10 mGy
  - Dose equivalent
    - Absorbed dose x QF
      - QF = quality factor
        - Takes into account the relative effectiveness of the particular radiation in producing a biological effect
    - 1 rem = 0.01 Sv = 1 cSv = 10 mSv

Radiation Doses

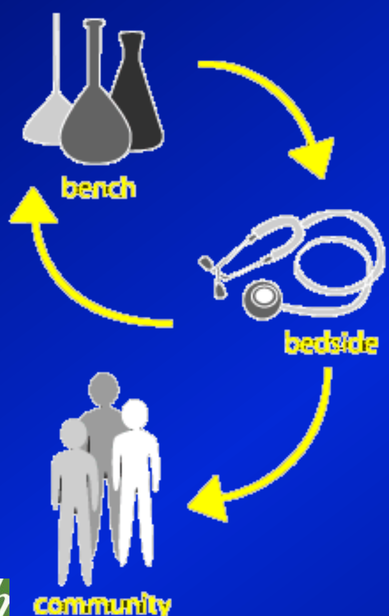
- All physicists are now encouraged to leave the room
  - For practical purposes (ie, for simple minded radiologists)
    - 1 rad = 1 rem = 1 cGy = 1 cSv = 1 R

Radiology History

Wilhelm Conrad Röentgen (1845 – 1923)

Translational Medicine

- Current "buzzword" in medical research
- Attempts to more directly connect basic research to patient care



JOURNAL OF TRANSLATIONAL MEDICINE

www.translational-medicine.com

Development Of Xrays

- Arguably both the first and fastest example of translational medicine
  - 12/28/1895
    - Röentgen submits a manuscript on his discovery to the Physical Medical Society of Wurzburg
  - 12/31/1895
    - Manuscript printed and distributed
  - 01/09/1896
    - Article appears in Vienna Press
  - 01/23/1896
    - Article appears in *Nature* (England)
    - Presents paper to Physical Medical Society of Wurzburg
  - Mid 1896
    - Xrays being used in clinical practice

1895

- First xray of the human body
  - Mrs. Röentgen's hand
  - She exclaimed upon first seeing the image, "Oh my God! It makes me somehow feel that I'm looking at my own death!"

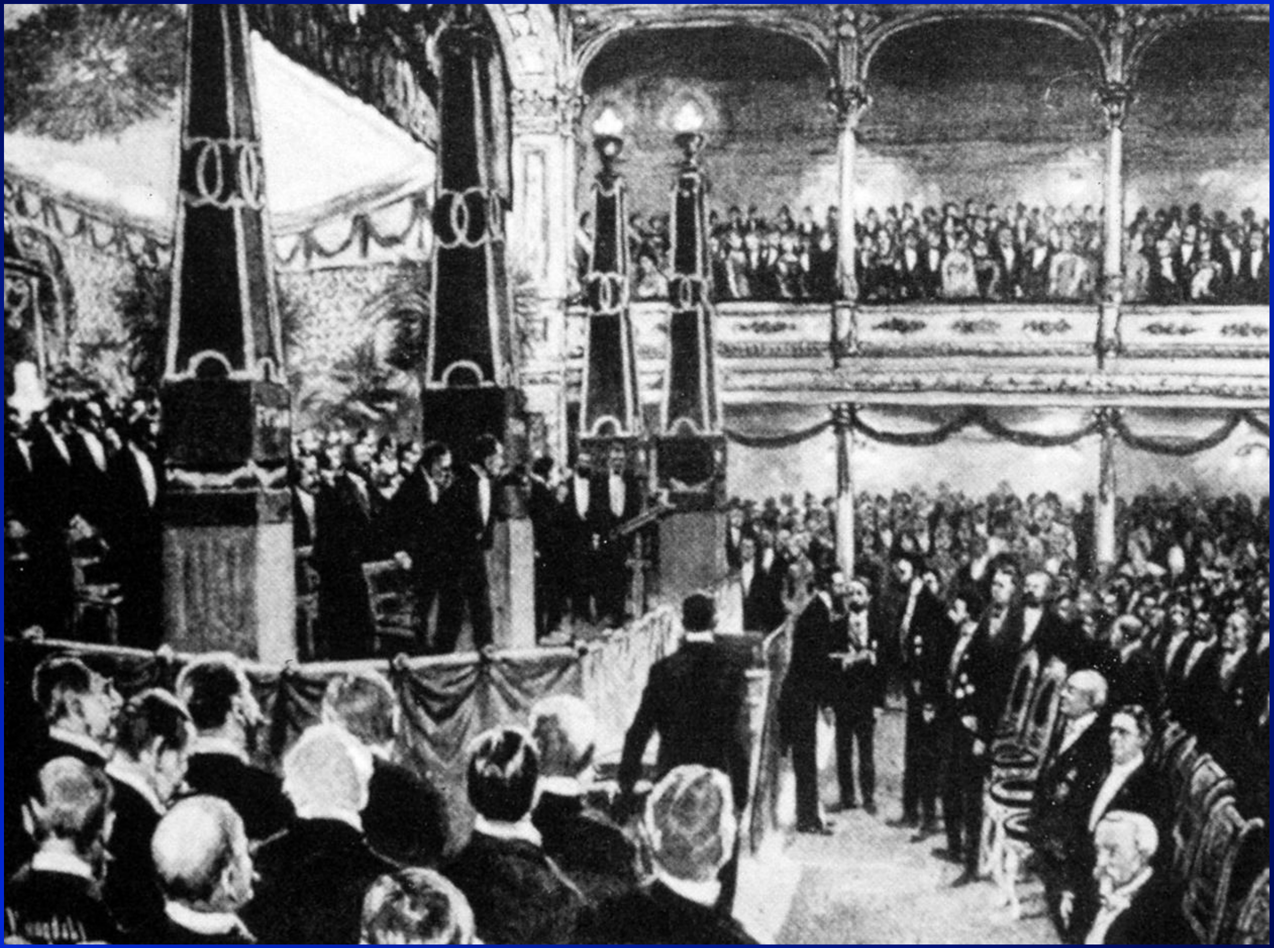
1896

- First pediatric xray
  - Required 14 minutes of fluoroscopy time
    - How could any child have remained motionless for that long?
      - World's greatest sedation?
      - Deceased?
      - Did s/he have a situs anomaly?

1896

- Fluoroscope invented by Thomas Edison
  - Marketed it as the "Vitascope"
  - Proclaimed that one day xrays would be routinely taken in every home around the world
- Portrait of Edison "basking in xray light"

1901



Röentgen receives first Nobel Prize in Physics

Early "Radiologists"

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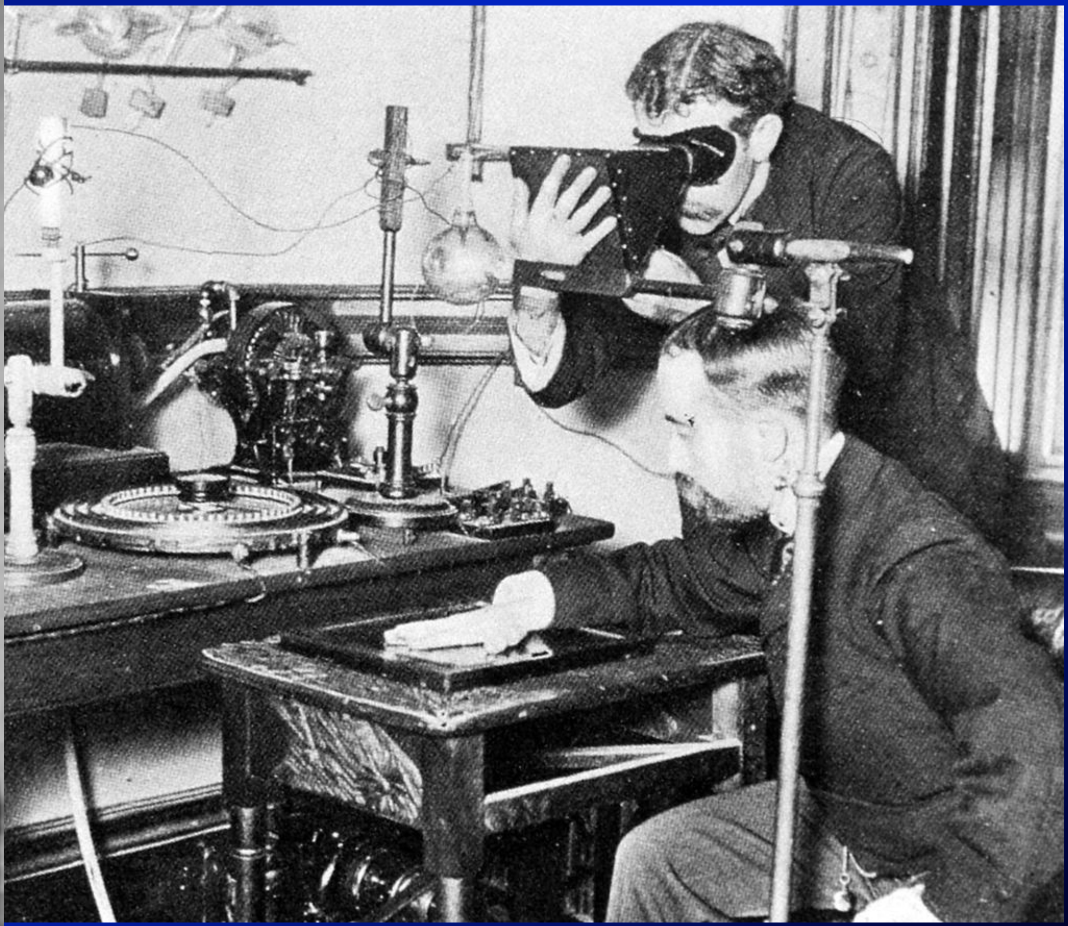
Early Radiation Safety



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Early Radiation Safety

- Adverse effects began showing up within 3 months of Röentgen's initial report
  - Thomas Edison described having "sore eyes" after looking into his fluoroscope in 03/1896
- "Like-for-like" philosophy
  - Belief in healing properties of radiation
    - If radiation could cause injury, it could also cure it
      - Application of radium to the skin in an attempt to heal radiation burns

Berry RJ. *J R Soc Med* **1986**

Early Deterministic Radiation Injuries
Dermatitis

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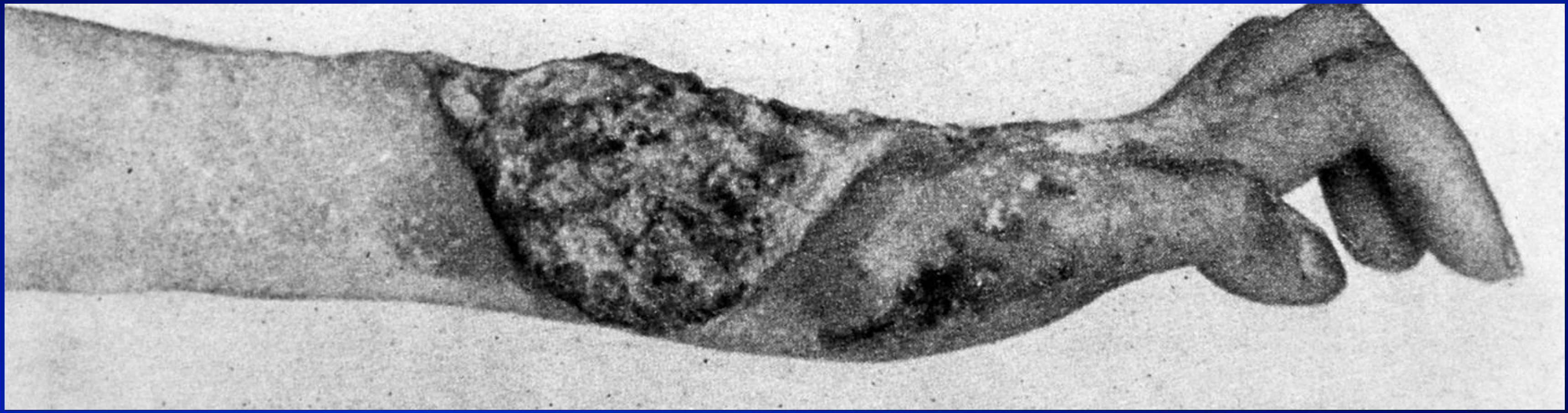
Early Deterministic Radiation Injuries

Hair Loss

40 minutes exposure

3 months later

Early Stochastic Radiation Injuries
Malignancy



Radiologist who developed skin cancer

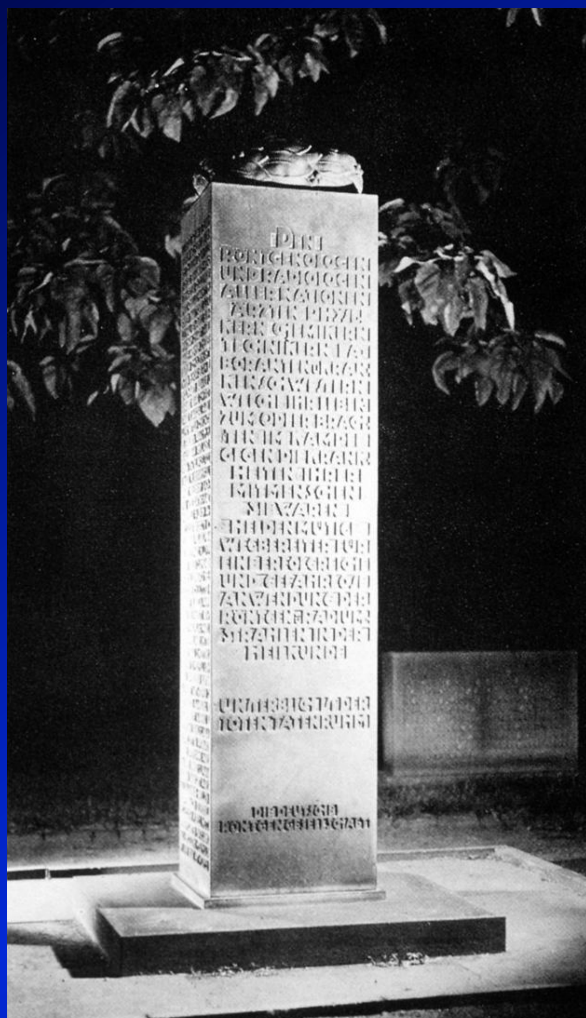
Early Stochastic Radiation Injuries
Fatal Malignancy

- Early radiologists
  - 1946 – leukemia rate reported as 8 times higher than that of other physicians
  - 1956 – lifespan reported as 5.2 years less than other physicians

Ulrich H. *N Engl J Med* **1946**

National Academy of Science **1956**

Early Stochastic Radiation Injuries
Fatal Malignancy



- Monument to Xray and Radium Martyrs
  - Hamburg, Germany
  - Dedicated in 1936 with 159 names
  - Hundreds more have been added since

Early Radiology Entrepreneurs

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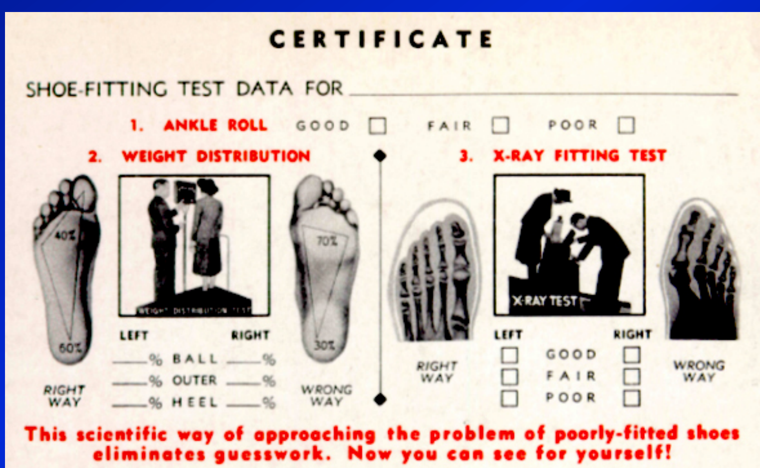
Early Radiology Entrepreneurs

- Shoe fitting fluoroscope
  - Patented in 1920s
  - Directly from the Installation Instructions: "Of course, it should face the ladies' and children's departments by virtue of the heavier sales in these departments"


CERTIFICATE

SHOE-FITTING TEST DATA FOR ______

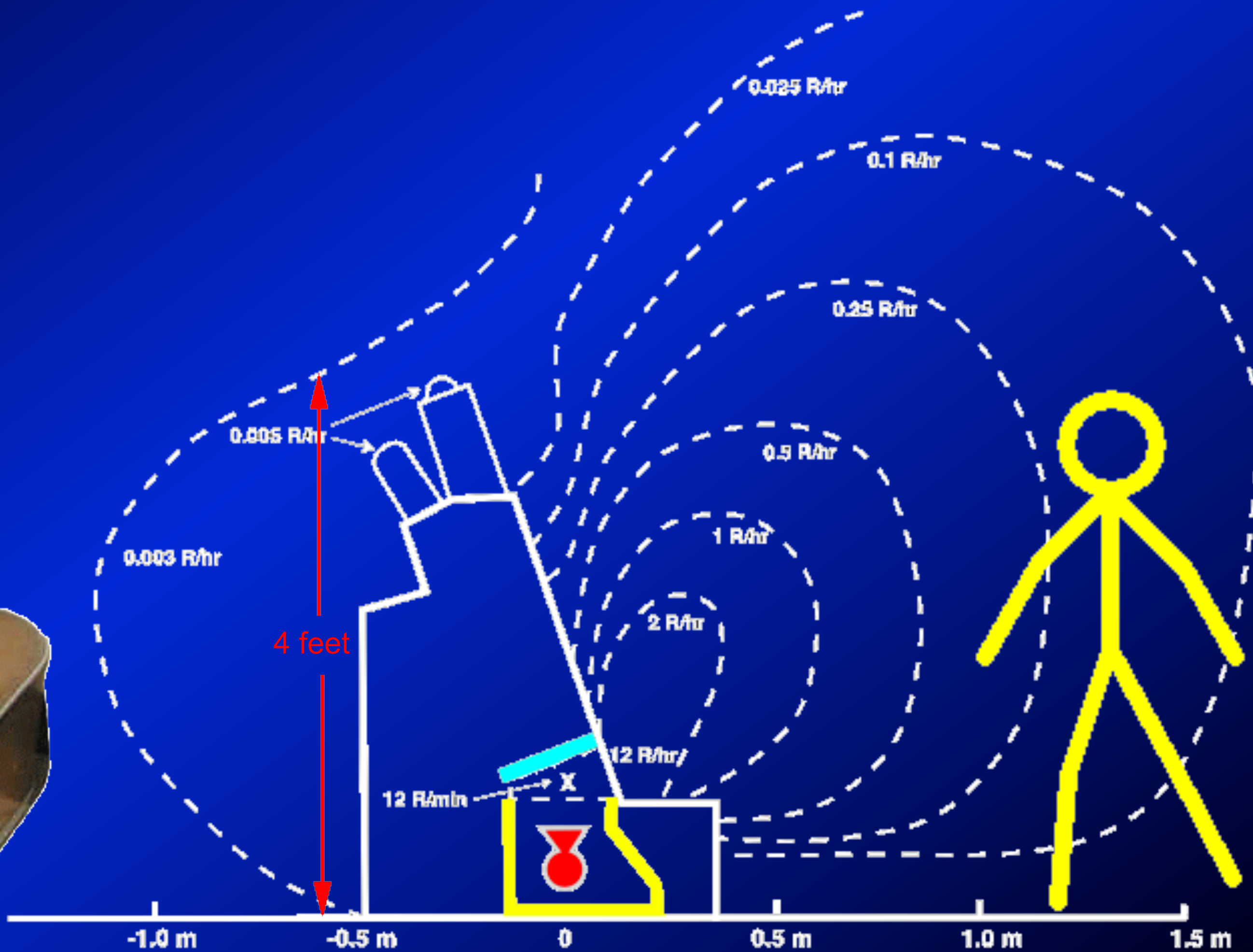
1. ANKLE ROLL GOOD ☐ FAIR ☐ POOR ☐

2. WEIGHT DISTRIBUTION

3. X-RAY FITTING TEST

This scientific way of approaching the problem of poorly-fitted shoes eliminates guesswork. Now you can see for yourself!

Shoe Fitting Fluoroscope



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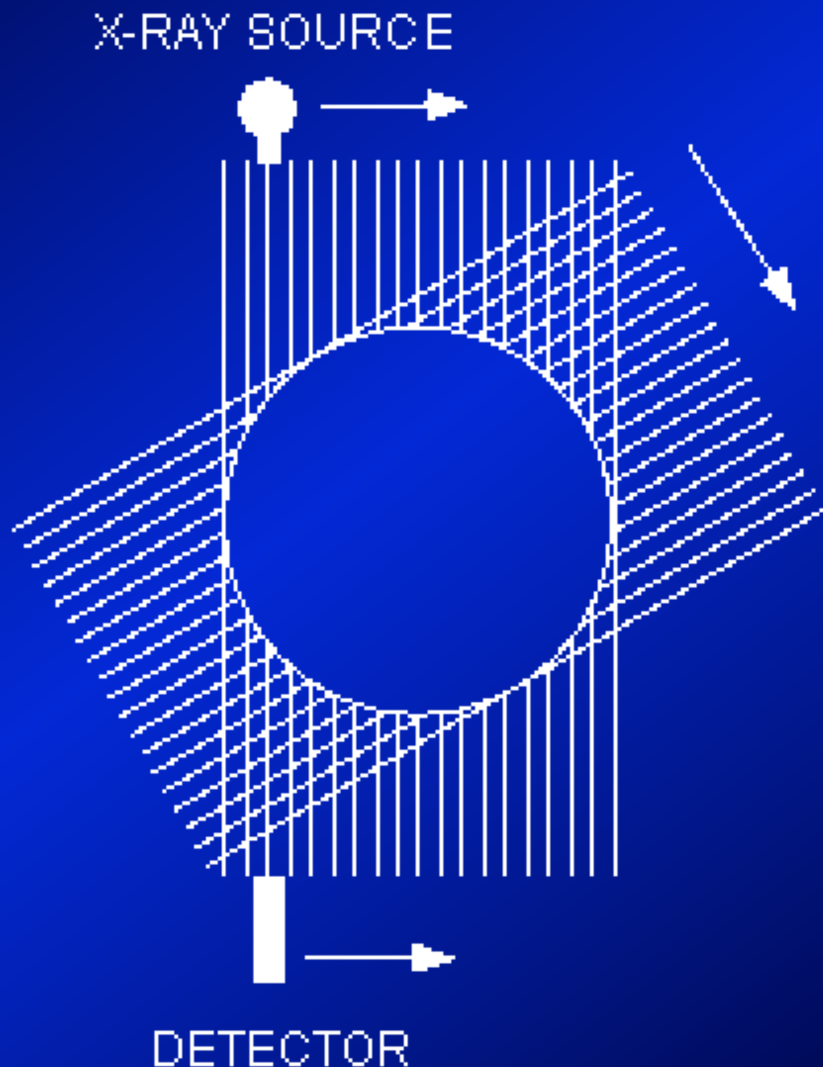
Shoe Fitting Fluoroscope

- RSNA (Radiological Society of North America)
  - One of the most important and influential radiology and radiologist organizations
  - Instrumental in banning these devices
    - Wrote letters to several manufacturers stating that the devices "lowered the dignity of the profession of radiology“
- Began to be phased out in 1950s
- Prohibited by US federal law in 1963

Here Comes CT



The Great CT And MRI Race

- CT
  - Utilizes xrays
  - Xray source(s) and detector(s) rotate around patient
  - Computer processing creates cross-sectional image based upon differing degrees of xray beam attenuation within tissue
- MRI
  - Utilizes NMR (nuclear magnetic resonance)
    - First described in 1938
  - Protons excited within high magnetic field relax differently depending upon local tissue properties
  - Computer processing transforms received signals into cross-sectional image

The Great CT And MRI Race

- CT
  - 1960s – various competing research efforts
  - 1971 – first documented image
  - 1972 – scanners commercially introduced
- MRI
  - 1960s – various competing research efforts
  - 1973 – first documented image
  - 1980 – scanners commercially introduced

The Great CT And MRI Race

- CT
  - Godfrey Hounsfield
    - 1919 – 2004
    - Research performed at EMI, Ltd. in England
    - Shared Nobel in 1979

- MRI
  - Paul Lauterbur
    - 1929 – 2007
    - Research performed at SUNY in Stony Brook
    - Shared Nobel in 2003

The Great CT And MRI Race

Cocktail Party Trivia

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The Great CT And MRI Race

- What is the single most important reason that CT was in widespread use nearly a decade before MRI?

EMI CT

- ▲Electronic and Musical Industries
  - ►Invested four straight years of Beatles' record sale profits into Hounsfield's research and subsequent scanner development
  - ►First commercially available CT scanners
    - ▼1972 – brain
    - ▼1976 – body
  - ►Sold over half of all CT scanners through 1976

EMI CT

- Electronic and Musical Industries
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    - 1972 – brain
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  - Sold over half of all CT scanners through 1976

EMI CT

- Rapid decline and fall in late 1970s
  - Strong competition from companies better established in radiology and healthcare
  - 1978
    - EMI CT operations acquired by Thorn Electrical
  - 1979
    - Thorn sold all but its US CT operations to GE (DOJ prevented US sale)
    - Thorn sold its US CT operations to Omnimedical
      - Went bankrupt in 1984

CT Resurgence

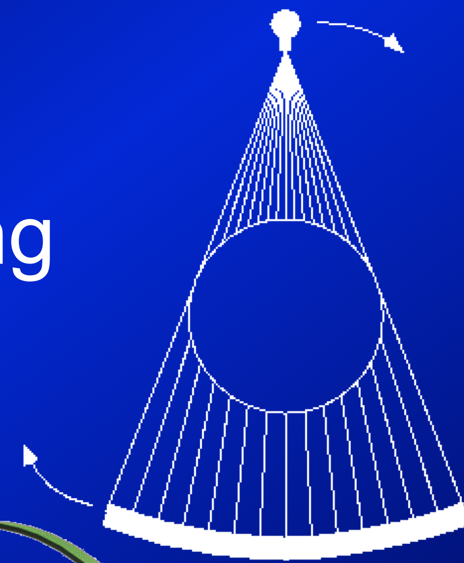
- Conventional wisdom in 1980s was that MRI would soon permanently eclipse and ultimately replace CT
  - Never happened and probably never will
- CT growth has continued to outpace that of MRI to this day
  - Why?
    - Speed , speed , speed

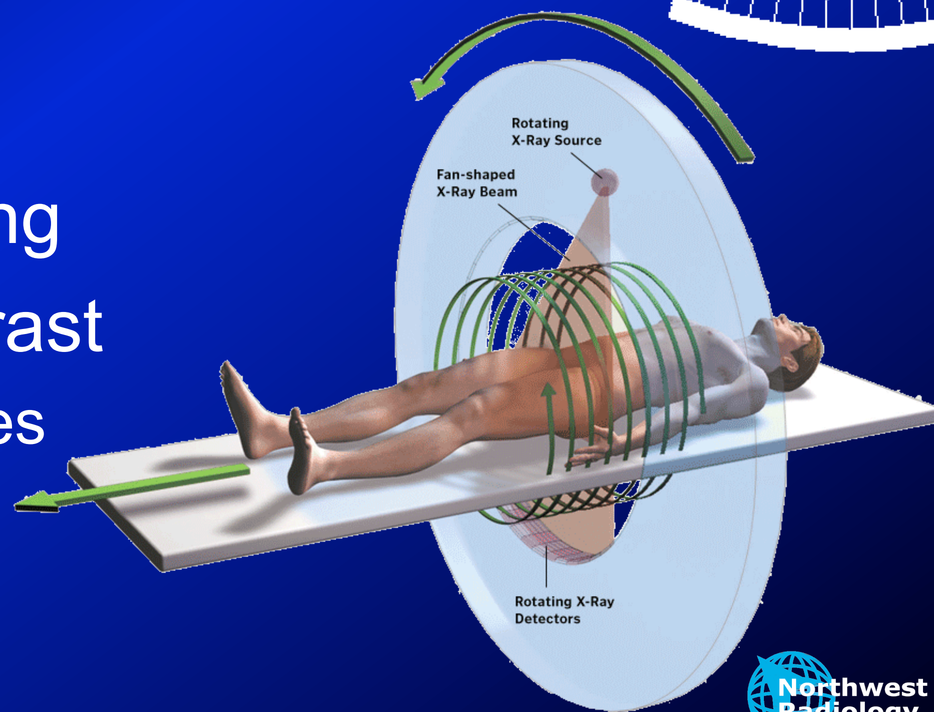
CT Resurgence

- ▲1970s - single line beams
  - ►EMI scanner
    - ▼5 minutes to acquire single "slice"
    - ▼2.5 hours of computer processing per slice
- ▲1980s – fan beams and array detectors
- ▲1990s – helical/spiral
- ▲2000s – multidetector and multisource
  - ►NCH Siemens SOMATOM® Definition scanner
    - ▼64 detectors, 2 xray sources
    - ▼Seconds to acquire and process images of the entire body

CT Resurgence

- Advantages of faster CT scanning
  - Increased patient throughput
    - Patient comfort and convenience
    - Rapid diagnoses
    - $
  - Volumetric imaging
  - Intravenous contrast
    - Multiphase images
    - CT angiography





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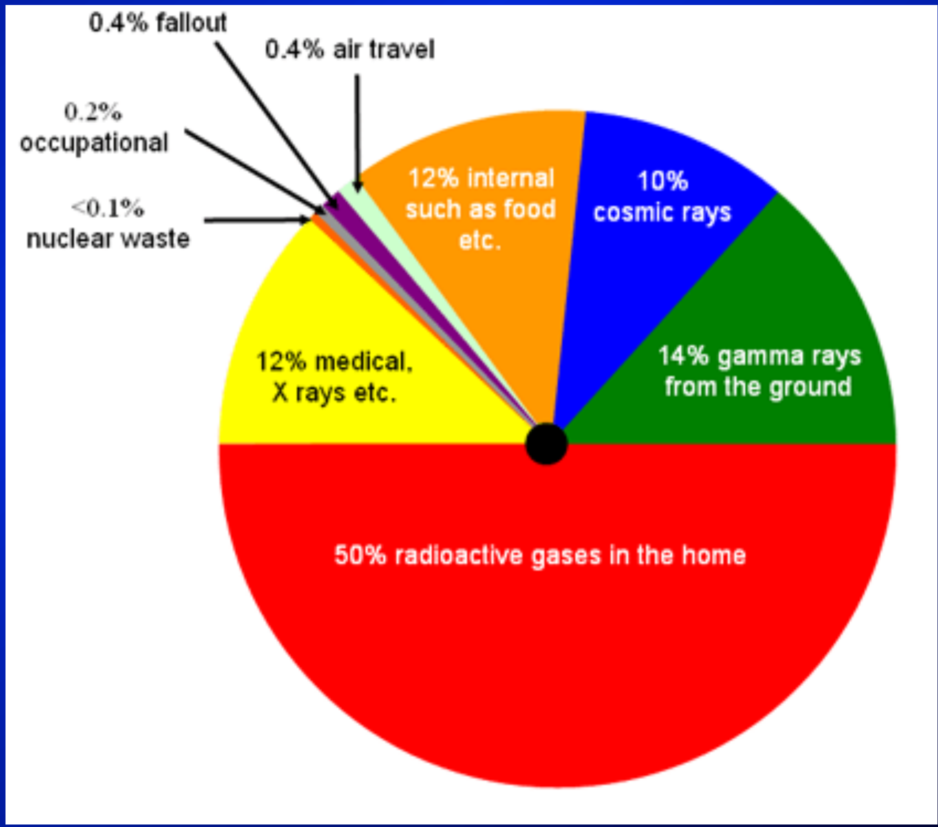
Multiphasic Imaging

- Possible phases
  - Noncontrast
  - Pulmonary arterial
  - Systemic arterial
  - Portal venous
  - Systemic venous
  - Various delays
- Uses
  - Chest
    - "Triple rule out"
      - Noncontrast
      - Pulmonary arterial
      - Systemic arterial
  - Abdomen
    - "Dedicated liver"
      - Noncontrast
      - Arterial phase
      - Portal venous phase
      - 3-10 minute delay

Current Knowledge

Radiation Exposure

- ▲Background radiation
  - ►Natural > manmade sources
  - ►Per person average
    - ▼~3 mSv/yr in US
    - ▼Increases with elevation
      - ◄~6 mSv/yr in Denver



Brody AS. *Pediatrics* **2007**

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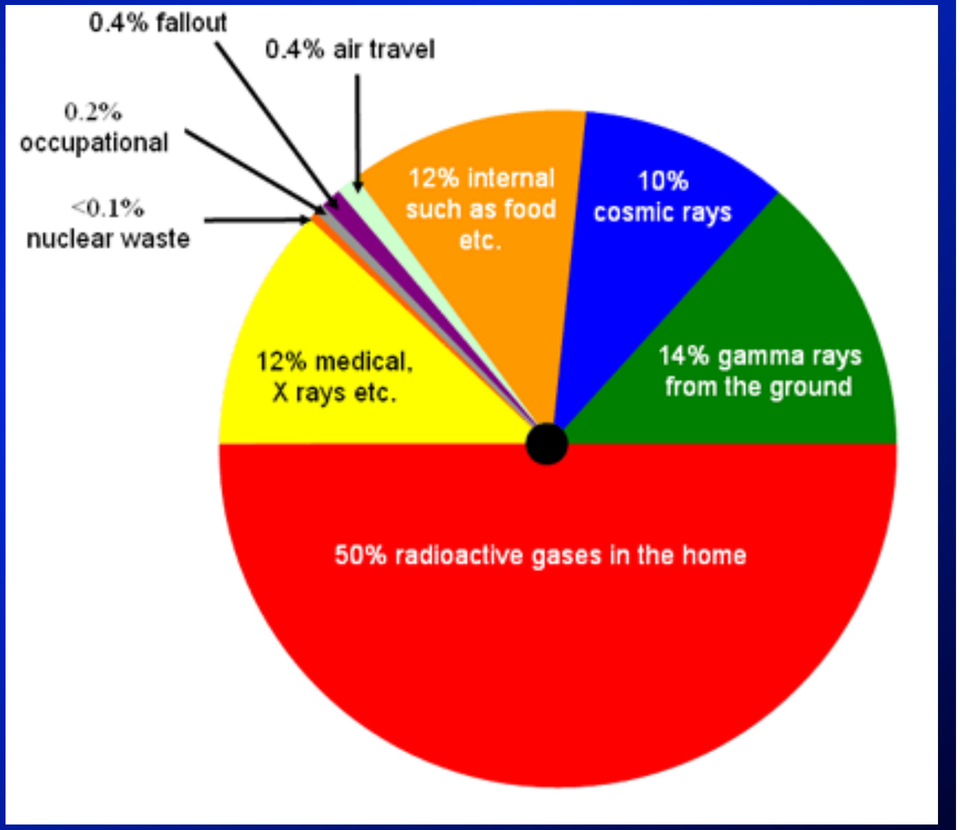
Radiation Exposure

- Medical sources
  - 12% of total exposure
  - CT
    - 11% of all imaging examinations which utilize ionizing radiation
    - 67% of exposure from medical sources



Brody AS. *Pediatrics* **2007**

Radiation Exposure

Estimated Medical Radiation Doses for a 5-Year-Old Child

Imaging Area	Effective Dose, mSv	Equivalent No. of CXRs
3-view ankle	0.0015	1/14th
2-view chest	0.02	1
Anteroposterior and lateral abdomen	0.05	2½
Tc-99m[2] radionuclide cystogram	0.18	9
Tc-99m radionuclide bone scan	6.2	310
FDG PET[3] scan	15.3	765
Fluoroscopic cystogram	0.33	16
Head CT	4	200
Chest CT	3	150
Abdomen CT	5	250

CXR indicates chest radiograph; Tc-99m, technetium 99m; FDG PET, fluorodeoxyglucose positron emission tomography.

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Brody AS. *Pediatrics* **2007**

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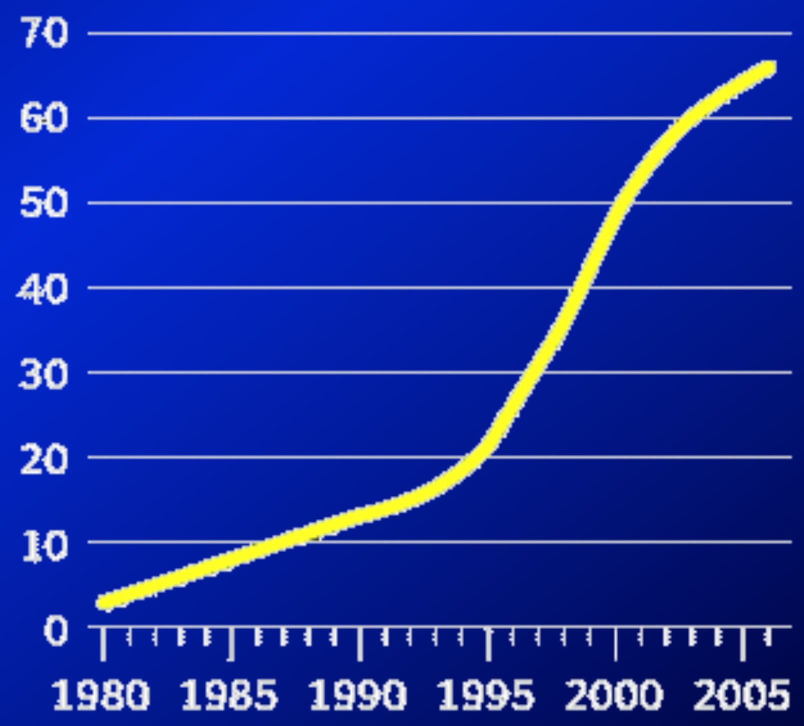
CT Issues

- Rapid US growth
  - 1980: 2 million exams
  - 2006: 67 million exams
    - 7 million in children
- Potential for overuse
  - Physician driven
    - 24/7 availability
    - Medicolegal
    - Substitute for physical exam
    - Lack of radiation knowledge
  - Patient driven
    - "High tech" care expectations



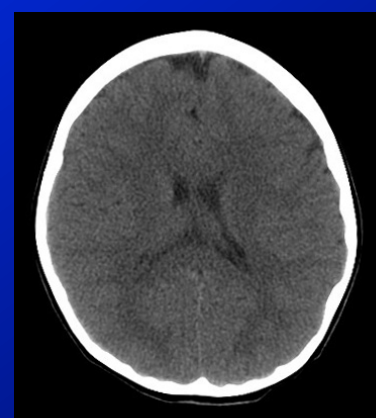
Washington Post **01/15/2008**

CT Issues

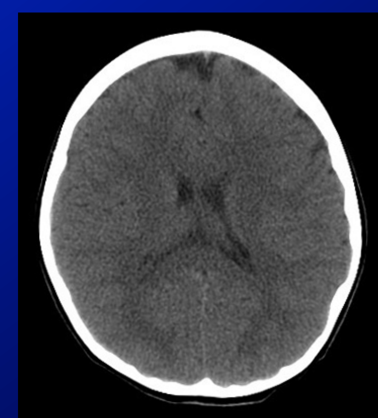
- ▲ Radiography
  - ► Image quality penalty for using too much radiation
- ▲ CT
  - ► No penalty (?mild benefit) for using more radiation than needed

Correct

Overexposed



Correct



"Overexposed"

Radiation Induced Cancers

- "No published studies have directly attributed cancer to CT scanning"
- Described risks usually based on studies of Japanese atomic bomb survivors
  - Epidemiological studies have documented radiography induced cancers
- Prospective study of CT induced cancer
  - Exceedingly difficult to perform
  - Serious ethical concerns

Brody AS. *Pediatrics* **2007**

Radiation Induced Cancers

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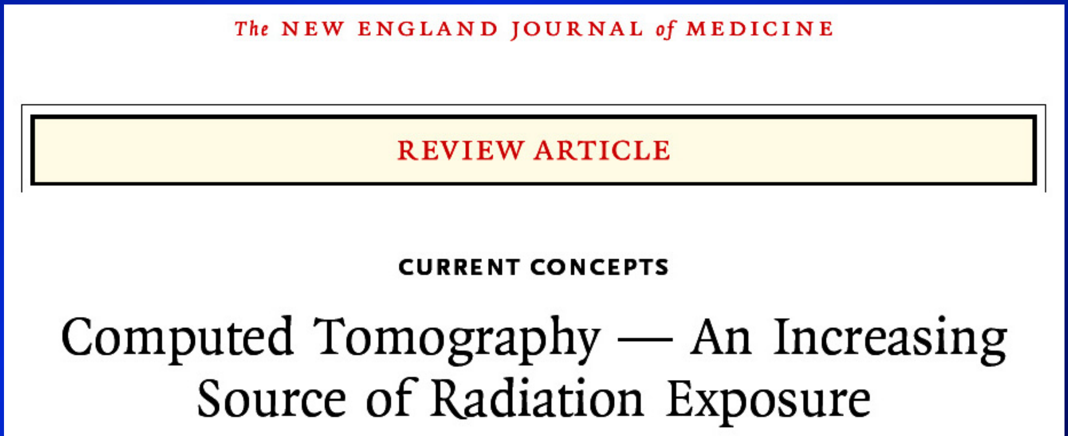
Radiation Induced Cancers


The NEW ENGLAND JOURNAL of MEDICINE

REVIEW ARTICLE

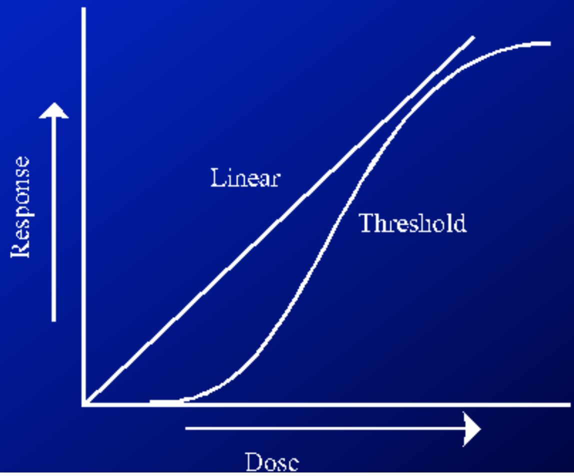
CURRENT CONCEPTS

Computed Tomography — An Increasing Source of Radiation Exposure

Brenner DJ. *N Engl J Med* **2007**

NEJM Article Findings

- ▲Key – and debatable – points
  - ►Up to 2% of all cancers in the US may be caused by radiation received from CT scans
  - ►Exposure to low level radiation (< 100-150 mSv) may be a greater risk than thought
  - ►The linear, no threshold theory is correct



Brenner DJ. *N Engl J Med* **2007**

NEJM Article Findings

- Other – and less debatable – points
  - Up to 1/3 of all currently performed CT studies are either unnecessary or repetitive
    - 1 million children radiated unnecessarily per year
  - Greatest increases in CT use
    - Pediatric patients
    - Screening of healthy adults
  - Children are at greater risk than adults
    - Rapidly growing tissues are more radiosensitive
    - Effects of radiation are cumulative
    - Longer time for cancers to develop

Brenner DJ. *N Engl J Med* **2007**

NEJM Article Criticisms

- Radiation doses and CT techniques used to calculate risks are not those recommended by the ACR (American College of Radiology) or the SPR that are widely accepted and applied
- Overlooked that CT equipment companies have been responsive in developing dose reduction techniques for children
- Failed to deal with the risk/benefit ratio of CT, particularly in life-threatening conditions

NEJM Article Criticisms

- Epidemiological studies that find positive results are more likely to be published – and gain publicity – than those that do not
- The linear, no threshold theory has both supporters and critics

Atomic Bomb Survivor Data

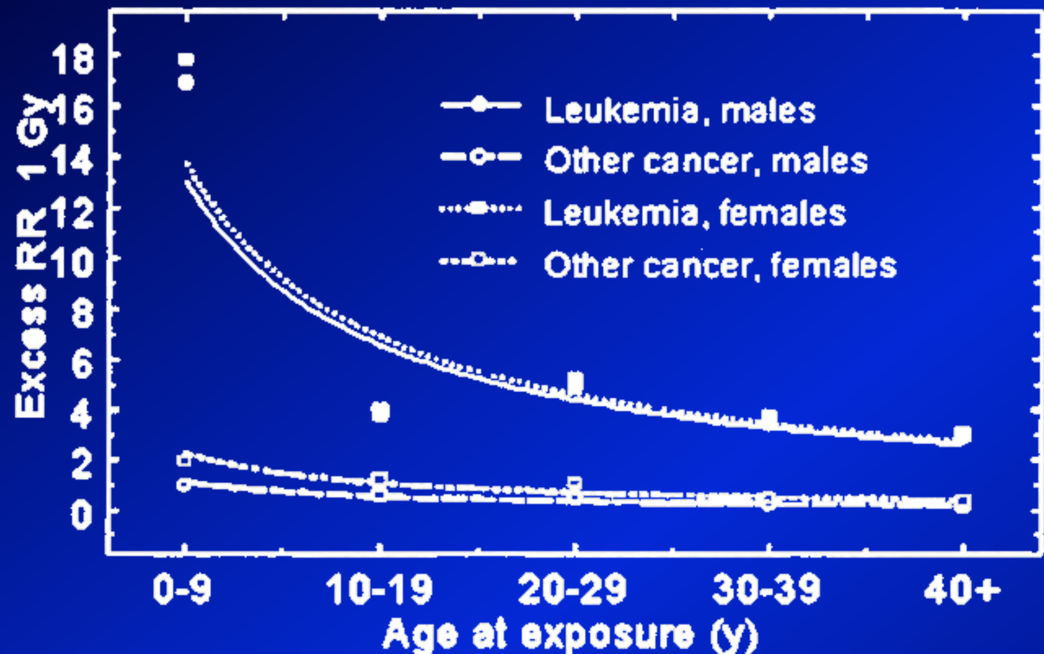
Cancer in Japanese Atomic Bomb Survivors*
1950-1985

Cancer type or site	cases[a] Total	Excess
Leukemia	202	78
Esophagus	176	11
Stomach	2,007	72
Colon	232	19
Lung	638	44
Female breast	155	22
Ovary	82	19
Urinary tract	133	8
Multiple myeloma	36	8
Other[a]	2,275	61
Total	5,936	344

*Data source:
Shimizu Y, Kato H, Schull WJ. Life span study report 11, part 2. "Cancer mortality in the years 1950-1985 based on the recently revised doses" (DS86). RERF Technical Report 5-88. Radiation Effects Research Foundation, Hiroshima, 1988.
[a]76,000 individuals in study sample

- Most radiosensitive cancers
  - Bone marrow
    - Leukemia
    - Multiple myeloma
  - Breast
  - Ovary

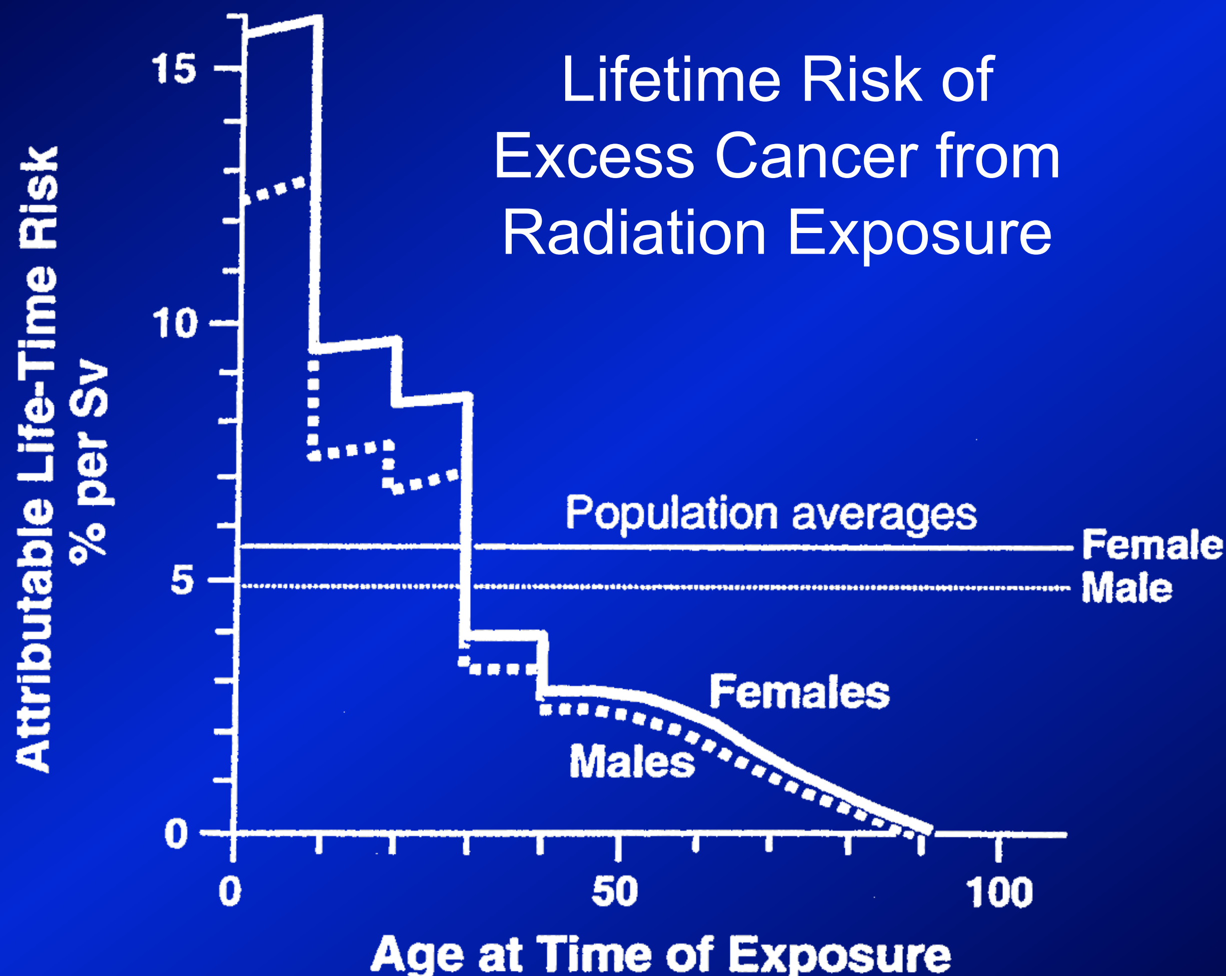
Atomic Bomb Survivor Data



Excess relative risk of cancer by age and sex at exposure in Japanese atomic bomb survivors, dose 1 Gy (100 rad). Leukemia risk is strongly dependent on age but only weakly dependent on sex; it is maximum in those exposed as children and declines with age. Risks of other cancers show similar age dependence but are greater in females than males, basically because of breast and ovarian cancer. Relative risk of leukemia is substantially greater than that of other cancers, related to the low spontaneous incidence of leukemia in the Japanese population. An excess relative risk of 1.0 means that incidence in the exposed population is 100 percent greater than that in unexposed controls.

American College of Radiology **1996**

Atomic Bomb Survivor Data



Hall EJ. *Pediatr Radiol* **2002**

Unique Pediatric Concerns

- Breast radiation received as a result of scoliosis radiography

Breast cancer mortality and diagnostic X-rays for scoliosis (*ERR* excess relative risk)

4,822 Exposed; 644 nonexposed
Mean age at exposure, 10.6 years
Mean dose, 0.11 Gy
70 Observed cancers; 35.7 expected
ERR at 1 Sv = 5.4 (95% CI = 1.2–14)
Results similar to A-bomb survivors

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Doody MM. *Spine* **2000**

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Unique Pediatric Concerns

- Bone marrow radiation received as a result of skeletal radiography

Childhood leukemia (*ALL*) risks and diagnostic X-ray exams

Population-based, Quebec 1980–1993
491 ALL cases (0–9 years); 491 controls
Mostly bone X-rays

	Exams	OR[a]	95% CI
Results	0	1.00	–
	1	1.08	0.7–1.6
	2+	1.78	1.2–2.6

[a]Excludes X-rays 3 months before diagnosis

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Infante-Rivard C. *Environ Health Perspect* **2000**

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Physician Knowledge

- ▲Nonradiologist physician survey
  - ►University and private facilities
  - ►177 responders
    - ▼54 (30.5%) pediatricians
      - ◄Data not broken down by specialty
  - ►Questionnaire
    - ▼Estimate radiation doses of several imaging examinations in “chest xray equivalents”
    - ▼Do ultrasound and MRI utilize ionizing radiation?

Arslanoğlu A. Diagn Interv *Radiol* **2007**

Physician Knowledge

Examination Type	Answers Compared To Actual Exposures		
	Less Than	Equal To	More Than
Abdominal Radiograph	95.3%	0%	4.7%
Upper GI	93.6%	1.7%	4.7%
Abdominal CT	83.6%	8.2%	8.2%

Arslanoğlu A. Diagn Interv *Radiol* **2007**

Physician Knowledge

Examination Type	Answers Regarding Exposure To Ionizing Radiation	
	Present	Absent
Ultrasound	4.0%	96.0%
MRI	27.4%	72.6%

Arslanoğlu A. Diagn Interv *Radiol* **2007**

Physician Knowledge

- Pediatrician survey
  - Toronto Hospital for Sick Children
  - 220 responders to multiple choice questionnaire
    - Exam dose estimates (chest xray equivalents)
      - 87% overall underestimation
      - 94% CT underestimation
    - Parental questioning regarding radiation doses
      - 31% noticed increase

Thomas KE. *Pediatr Radiol* **2006**

Physician Knowledge

▲ Radiologists may also need education

Increased Cancer Risk Question

Survey Question	Patients	ED Physicians	Radiologists	χ^2 Test Result
Lifetime risk of cancer believed to be increased by CT scan	2 of 76 (3)	4 of 45 (9)	18 of 38 (47)	41.45, $P < .001$

Note.—Data are the number of respondents. Numbers in parentheses are percentages.

Lee CI. *Radiology* **2004**

Putting It All In Perspective

- Nonradiologist physician survey regarding most important medical innovations

Rank	Innovation
1	MRI and CT scanning
2	ACE inhibitors
3	Balloon angioplasty
4	Statins
5	Mammography
6	CABG
7	Proton pump inhibitors and H2 blockers
8	SSRIs and recent non-SSRI antidepressants
9	Cataract extraction and lens implant
10	Hip and knee replacement

Fuchs VR. *Health Aff* **2001**

Putting It All In Perspective

Probability of Death from Radiation Induced Cancer and Other Causes

Activity	*Probability per 10,000 Population Exposed/per Year*
Smoking (all causes)	30
CT of kidneys or liver	12.5
Smoking (only cancer)	12
Mining	6.0
Construction	3.9
Farming	3.6
Cardiac catheterization	3.3
Driving a car	2.4
Anesthesiology (elderly patient)	2.0
Excretory urogram	2.0
Boating	0.5
Anesthesiology (all patients)	0.3
Hunting	0.3
Anesthesiology (outpatients)	0.2
Ionic contrast media	0.2
AP lumbar spine	0.06
Non-ionic contrast media	0.05
Chest (PA and lateral)	0.02
Commercial airline flight (one flight only)	0.002

American College of Radiology **1996**

- Based upon either
  - 1 year of activity
    - eg, smoking, mining, farming, construction
  - 1 event
    - eg, CT, anesthesia, airline flight

What We Know

- ▲CT is a fast and accurate method to diagnose many pediatric conditions, some of which may be life-threatening
- ▲When CT is indicated, the benefits far outweigh the potential radiation risks
- ▲The vast majority of the public's radiation exposure comes from nonmedical sources
- ▲More CT examinations are being performed than are necessary

What We Know

- CT radiation dose is approximately two orders of magnitude greater than that from a radiograph of the same anatomic area
  - Further increased by multiphasic imaging
- Children are more sensitive (> 2 times) to the carcinogenic effects of radiation than are adults
- Effects of radiation are cumulative over an individual's lifetime

What We Still Debate

- Is there a threshold dose required for radiation to induce malignancy, or does exposure to any amount of radiation carry a stochastic risk?
  - Is the linear, no threshold theory correct?
- Is exposure to what is generally considered low level (< 100-150 mSv) radiation safe?

How To Respond

"Children Are Not Small Adults"

ImageGently.org

- Alliance for Radiation Safety in Pediatric Imaging
  - American Academy of Pediatrics
  - American Association of Physicists in Medicine
  - American College of Radiology
  - American Osteopathic College of Radiology
  - American Registry of Radiologic Technologists
  - American Roentgen Ray Society
  - American Society of Radiologic Techologists
  - Association of University Radiologists
  - Conference of Radiation Control Program Directors
  - National Council for Radiation Protection and Measurements
  - Radiological Society of North America
  - Society of Computed Body Tomography and Magnetic Resonance
  - Society of Radiologists in Ultrasound
  - Society for Pediatric Radiology

ImageGently.org

ONE SIZE DOES NOT FIT ALL...

This site offers information for every audience interested in radiation safety in pediatric imaging

Parents

Community Radiologists

Pediatricians

Radiologic technologists

Medical Physicists

Press

Pediatric CT Protocol Guidance and worksheet

How To Respond

- Equipment manufacturers
- Radiologists
- Pediatricians

Equipment Manufacturers

- The major manufacturers of imaging equipment have developed dose reduction techniques, particularly for children
  - Radiography
  - Fluoroscopy
  - CT

Equipment Manufacturers

Reduction in Radiographic Doses
from 1920 to 1990

Although these data are for an AP lumbar spine examination, all procedure doses have been reduced by this amount. This dose reduction resulted from the adoption of new technology and techniques.

Year	*Relative exposure*	*AP lumbar spine entrance dose mGy*[a]	*AP lumbar spine entrance dose mrad*
1920	6.5	14.3	1,430
1930	5.5	12.1	1,210
1940	5.5	12.1	1,210
1950	4.0	8.8	880
1960	2.5	5.5	550
1970	2.5	5.5	550
1980	1.0	2.2	220
1990	1.0	2.2	220

[a] 1mGy = 100 mrad

American College of Radiology **1996**

Equipment Manufacturers

- Pulsed fluoroscopy
  - Fluoroscopy technique where the radiation is delivered in intermittent pulses rather than continuously
    - Intensity, duration and spacing of pulses can all be varied
  - Resultant decrease in dose/time

Cohen MD. *J Am Coll Radiol* **2008**

Equipment Manufacturers

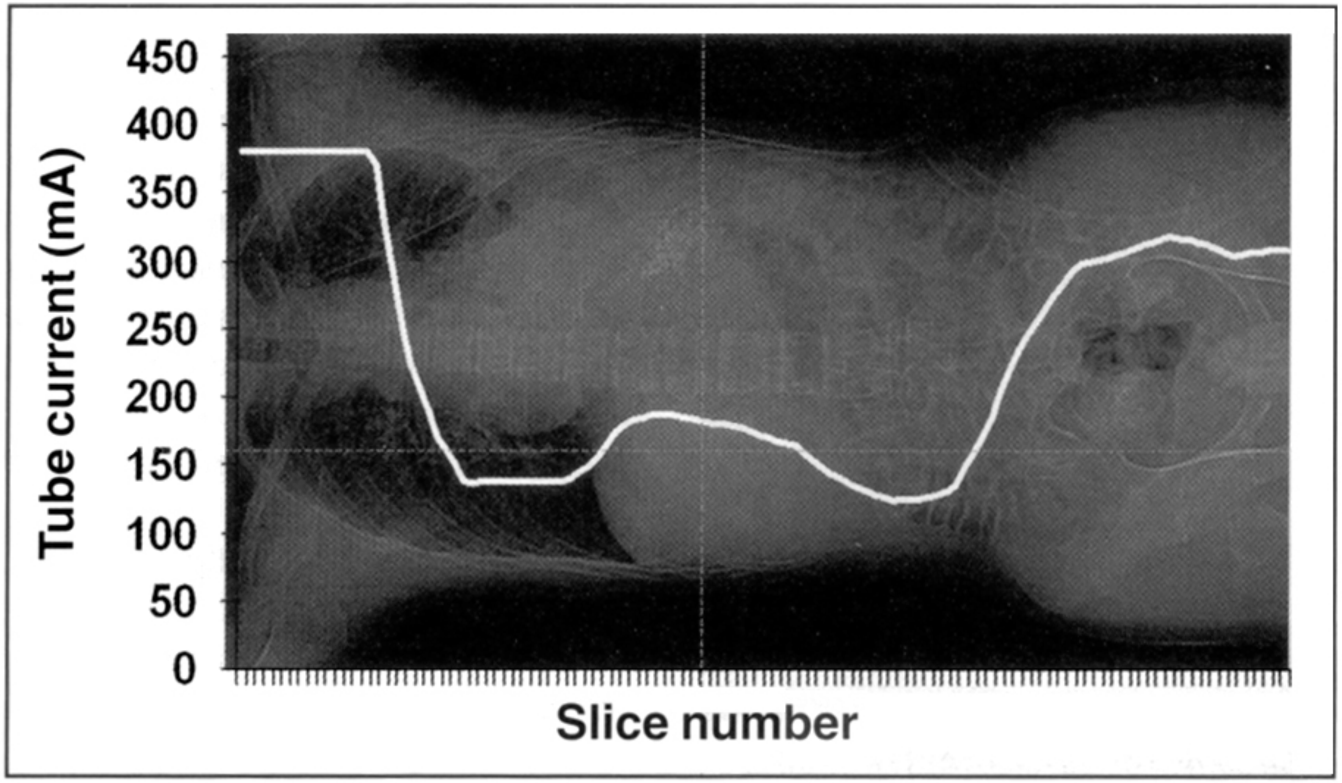


FIGURE *Tube currents delivered with automatic tube current modulation in an older teenager using a 16-slice CT scanner (LightSpeed CT scanner, GE Healthcare, Waukesha, WI), which modulates tube current along the z-axis (kVp 140, pitch 1.375:1, slice thickness 5 mm). Note the relatively higher tube currents through the shoulders and pelvis and the lower tube currents through the midthorax and lower abdomen.*

Coursey CA. *Appl Radiol* **2008**

Equipment Manufacturers

- CT dose reports routinely generated and in PACS
  - CTDIvol = volume CT dose index
  - DLP = dose length product
  - Effective dose (mSv) = DLP x conversion factor

Exam Description: CT ABD/PELVIS STRAIGHT

Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	S4.000-I331.000	9.16	328.05	Body 32
		Total Exam DLP:		328.05	

9-year-old boy

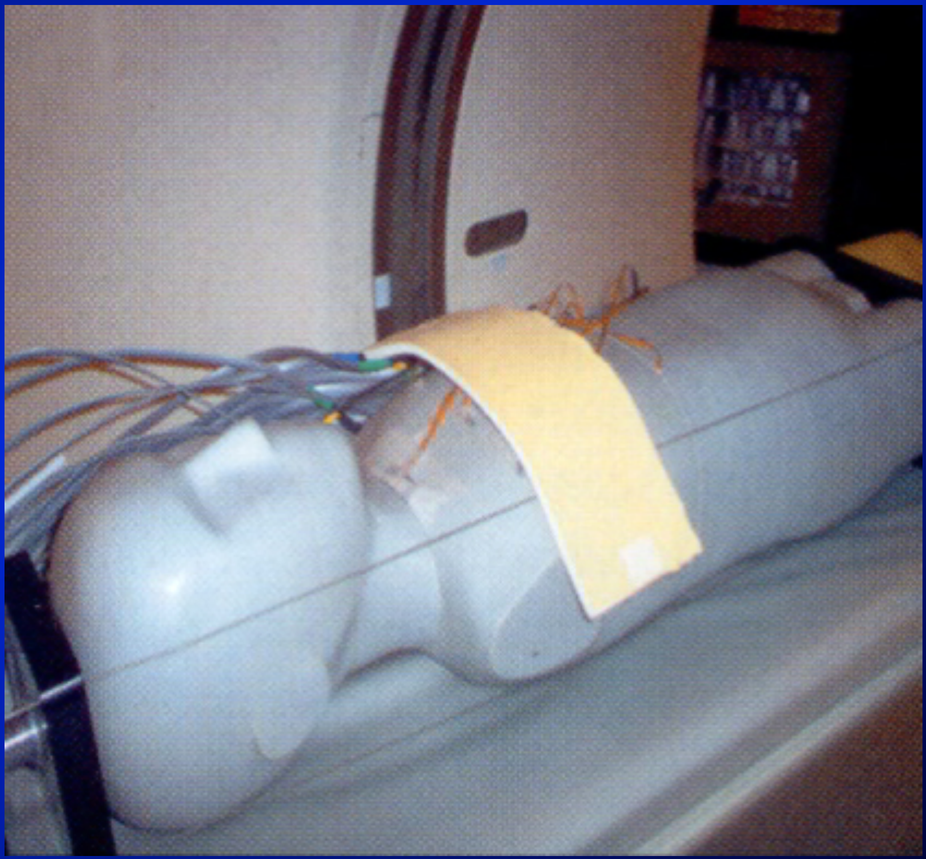
Region of body	Normalised effective dose, E_{DLP} (mSv mGy^{-1} cm^{-1})
Head	0.0023
Neck	0.0054
Chest	0.017
Abdomen	0.015
Pelvis	0.019

- Effective dose = 328.05 x 0.015 = 4.92 mSv

http://www.drs.dk/guidelines/ct/quality/Page032.htm

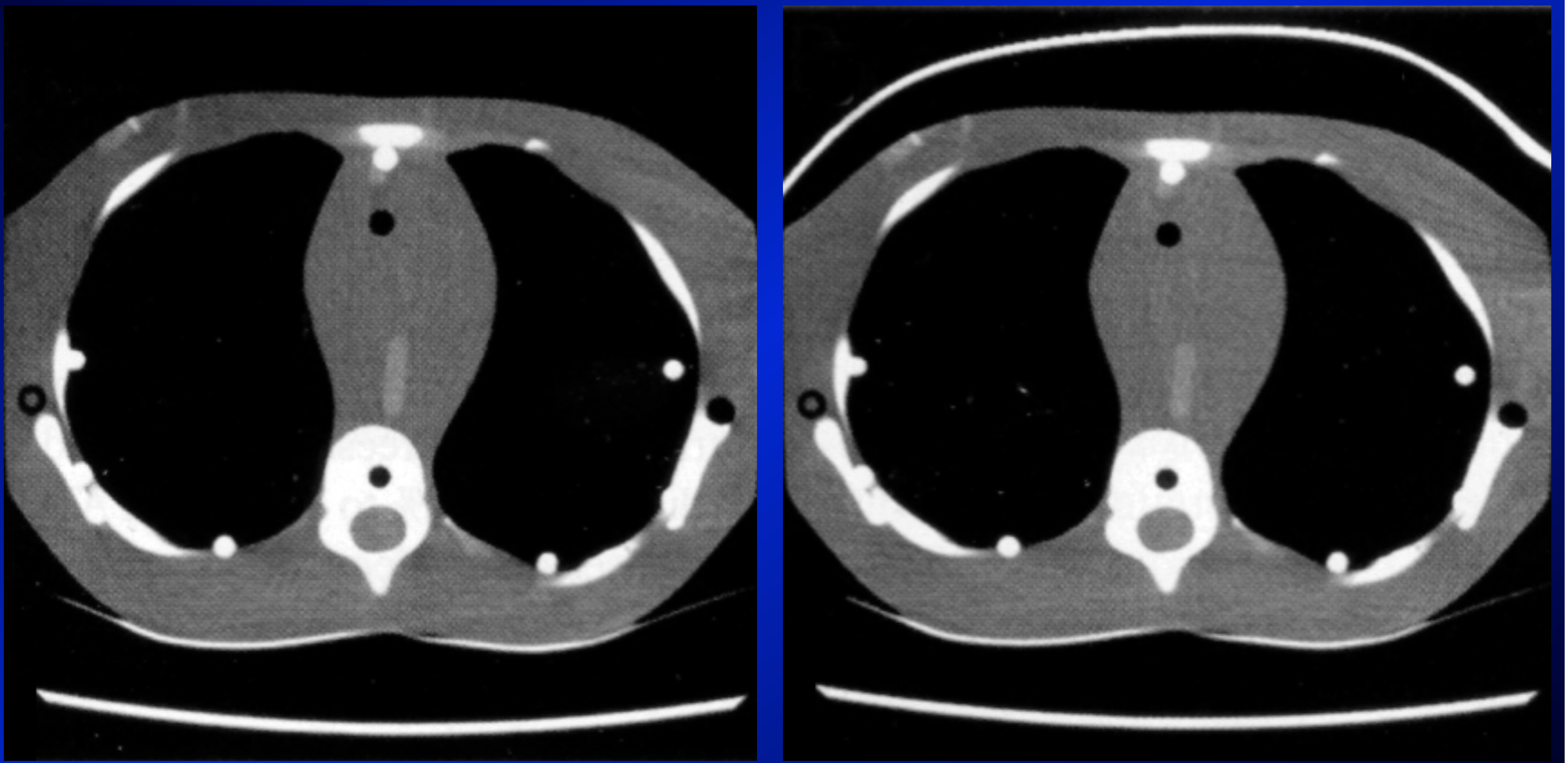
Equipment Manufacturers

- Bismuth shields
  - Breasts
    - Can reduce dose by 29% in pediatric patients
  - Orbits
    - Can reduce dose by 34%



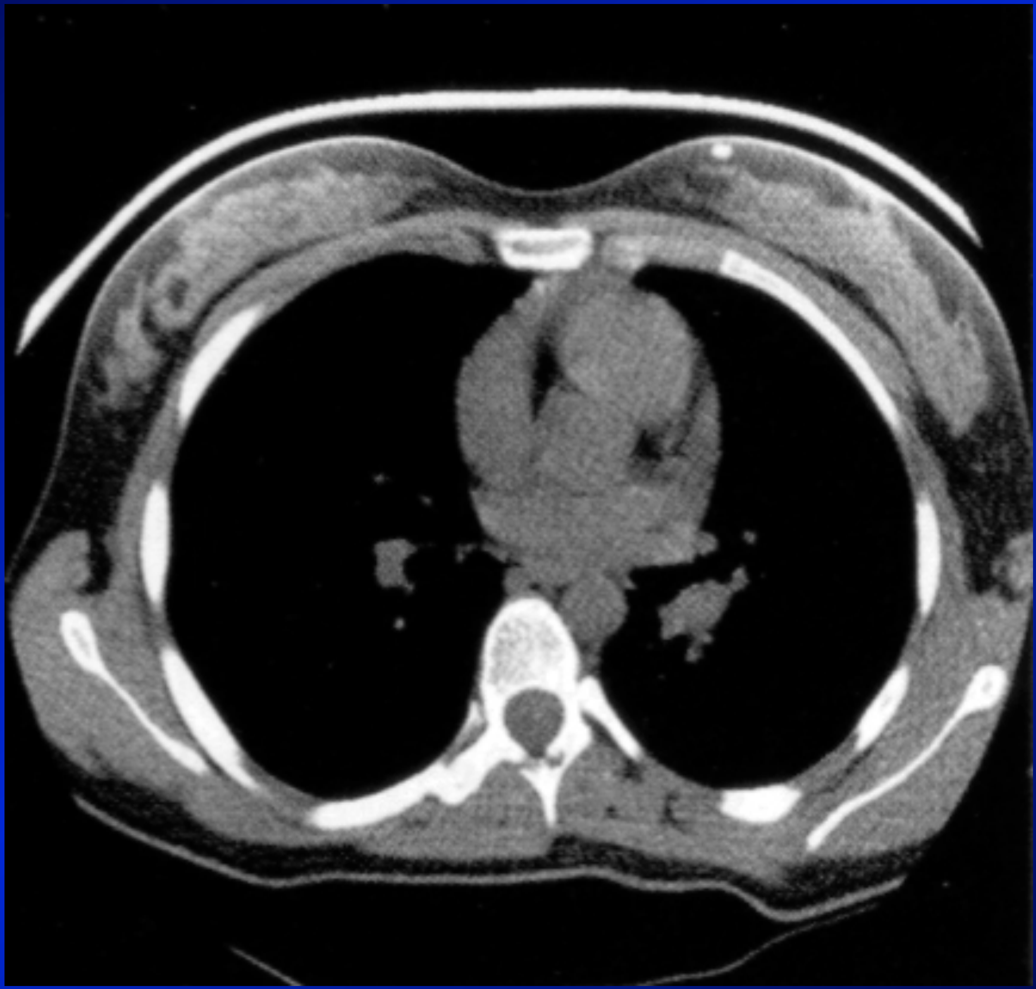
Coursey CA. *Appl Radiol* **2008**

Equipment Manufacturers



Coursey CA. *Appl Radiol* **2008**

Equipment Manufacturers



Coursey CA. *Appl Radiol* **2008**

Radiologists

- General
  - Have a strong fundamental knowledge of radiation doses and safety
  - Follow ALARA principle
    - As Low As Reasonably Achievable
    - Use only as much radiation as necessary to obtain a diagnostic quality examination
  - Review requests for high dose studies
    - Discuss with ordering clinicians

Radiologists

- Fluoroscopy
  - Think with foot off the pedal
  - Utilize last film save
- CT
  - Limit imaging
    - Single phase only
      - Multiphase studies rarely of use in pediatrics
    - Restrict imaged anatomy
      - Only scan areas of concern
    - Use appropriate parameters

Radiologists

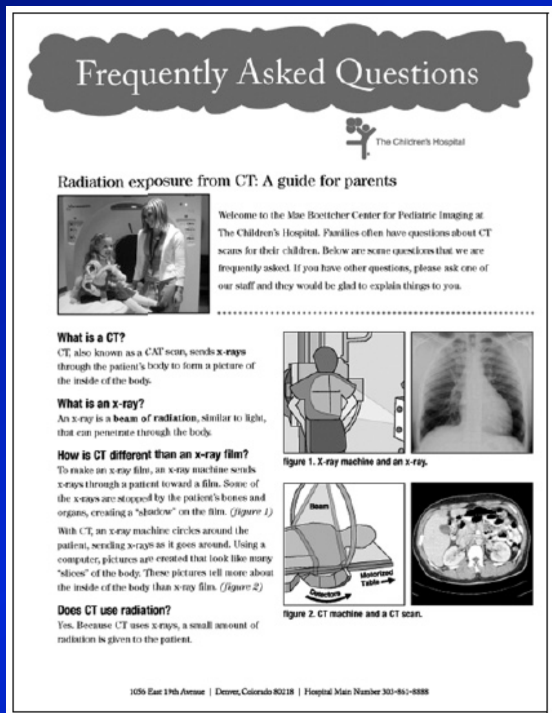
CT Parameters And Effects On Radiation Dose	
Parameter	Relationship
Tube current (mA)	Direct, linear
Gantry cycle time	Direct, linear
Kilovoltage (kVp)	Direct, nonlinear
Pitch	Indirect, linear

Pediatricians

- Be certain the test is necessary
- Use the least invasive modality which gives a high certainty of success
- Have a basic understanding of the radiation doses of imaging modalities
- Order examinations on medical indications, not parental or legal pressure
- Discuss case and imaging options with radiologist as needed

Pediatricians

- ▲Consider informing parents
  - ►Study of 100 parents who received a two page informational handout prior to their child's CT



Frequently Asked Questions

The Children's Hospital

Radiation exposure from CT: A guide for parents

Welcome to the Mae Boettcher Center for Pediatric Imaging at The Children's Hospital. Families often have questions about CT scans for their children. Below are some questions that we are frequently asked. If you have other questions, please ask one of our staff and they would be glad to explain things to you.

What is a CT?
CT, also known as a CAT scan, sends **x-rays** through the patient's body to form a picture of the inside of the body.

What is an x-ray?
An x-ray is a **beam of radiation**, similar to light, that can penetrate through the body.

How is CT different than an x-ray film?
To make an x-ray film, an x-ray machine sends x-rays through a patient toward a film. Some of the x-rays are stopped by the patient's bones and organs, creating a "shadow" on the film. *(figure 1)*

With CT, an x-ray machine circles around the patient, sending x-rays as it goes around. Using a computer, pictures are created that look like many "slices" of the body. These pictures tell more about the inside of the body than x-ray film. *(figure 2)*

Does CT use radiation?
Yes. Because CT uses x-rays, a small amount of radiation is given to the patient.

figure 1. X-ray machine and an x-ray.

figure 2. CT machine and a CT scan.

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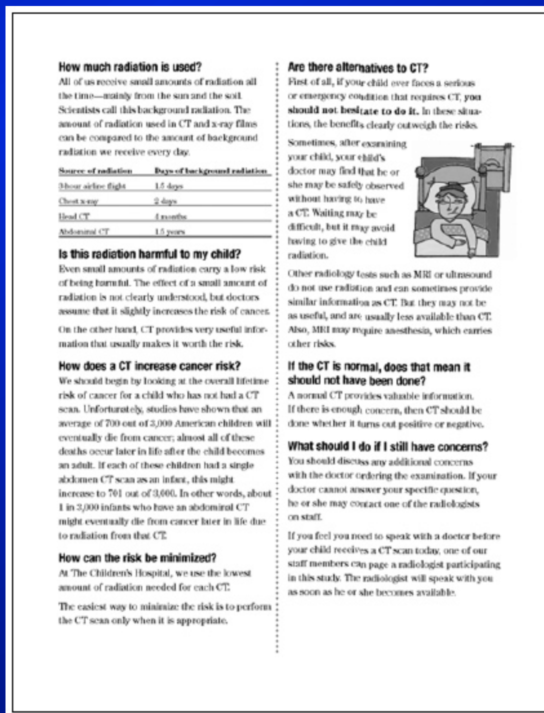


How much radiation is used?
All of us receive small amounts of radiation all the time—mainly from the sun and the soil. Scientists call this background radiation. The amount of radiation used in CT and x-ray films can be compared to the amount of background radiation we receive every day.

Source of radiation	Days of background radiation
3-hour airline flight	1.5 days
Chest x-ray	2 days
Head CT	4 months
Abdominal CT	1.5 years

Is this radiation harmful to my child?
Even small amounts of radiation carry a low risk of being harmful. The effect of a small amount of radiation is not clearly understood, but doctors assume that it slightly increases the risk of cancer.

On the other hand, CT provides very useful information that usually makes it worth the risk.

How does a CT increase cancer risk?
We should begin by looking at the overall lifetime risk of cancer for a child who has not had a CT scan. Unfortunately, studies have shown that an average of 700 out of 3,000 American children will eventually die from cancer; almost all of these deaths occur later in life after the child becomes an adult. If each of these children had a single abdomen CT scan as an infant, this might increase to 701 out of 3,000. In other words, about 1 in 3,000 infants who have an abdominal CT might eventually die from cancer later in life due to radiation from that CT.

How can the risk be minimized?
At The Children's Hospital, we use the lowest amount of radiation needed for each CT.

The easiest way to minimize the risk is to perform the CT scan only when it is appropriate.

Are there alternatives to CT?
First of all, if your child ever faces a serious or emergency condition that requires CT, **you should not hesitate to do it.** In these situations, the benefits clearly outweigh the risks.

Sometimes, after examining your child, your child's doctor may find that he or she may be safely observed without having to have a CT. Waiting may be difficult, but it may avoid having to give the child radiation.

Other radiology tests such as MRI or ultrasound do not use radiation and can sometimes provide similar information as CT. But they may not be as useful, and are usually less available than CT. Also, MRI may require anesthesia, which carries other risks.

If the CT is normal, does that mean it should not have been done?
A normal CT provides valuable information. If there is enough concern, then CT should be done whether it turns out positive or negative.

What should I do if I still have concerns?
You should discuss any additional concerns with the doctor ordering the examination. If your doctor cannot answer your specific question, he or she may contact one of the radiologists on staff.

If you feel you need to speak with a doctor before your child receives a CT scan today, one of our staff members can page a radiologist participating in this study. The radiologist will speak with you as soon as he or she becomes available.

nch Northwest Community Hospital

Larson DB. *AJR* **2007**

Northwest Radiology Associates | The Right Direction for Imaging

Pediatricians

Question	Before Reading Handout	After Reading Handout
Does CT involve exposure to radiation?	66%	99%
Does CT increase the lifetime risk of developing cancer?	13%	86%
Are you more concerned about your child having a CT?	N/A	38%
Will you allow your child to have the CT ordered by your physician?	100%	100%

Larson DB. *AJR* **2007**

Pediatricians

- Consider alternatives to CT that do not utilize ionizing radiation
  - MRI
  - Ultrasound
  - No imaging

Pediatricians

- MRI
  - No known adverse risks
    - Magnetic fields may induce electric fields and possibly even currents
    - Tissue heating can occur as a result of the RF frequency pulses
  - Intravenous contrast (gadolinium) issues
    - NSF (nephrogenic systemic sclerosis)
      - Absolute contraindication under age 1 year
  - May require sedation

Pediatricians

- Ultrasound
  - No known adverse risks
    - Tissue heating can occur
  - No need for sedation
  - Perhaps the ideal cross sectional imaging modality in pediatrics
- No imaging
  - Clinical judgment
  - Serial physical examinations

Pediatricians

- Issues where CT will be the preferred cross-sectional imaging modality
  - Trauma
  - Acute hemorrhage
    - Intracranial, retroperitoneal, etc.
  - Lung assessment
  - Bowel assessment
  - When MRI should alternatively be used but is contraindicated or cannot be easily obtained

Pediatricians

- ▲ Appendicitis: the continuing controversy
  - ► Both CT and ultrasound have significant diagnostic limitations in pediatric patients
    - ▼ Ultrasound may only perform better than CT at

Pediatricians

- ▲Appendicitis: the continuing controversy
  - ►History, physical examination and laboratory findings should probably remain the mainstay

Google "appendicitis is a clinical diagnosis" Search

Web Books Results **1** - **10** of about **178**

article | discussion | edit this page | history

WIKIPEDIA
The Free Encyclopedia

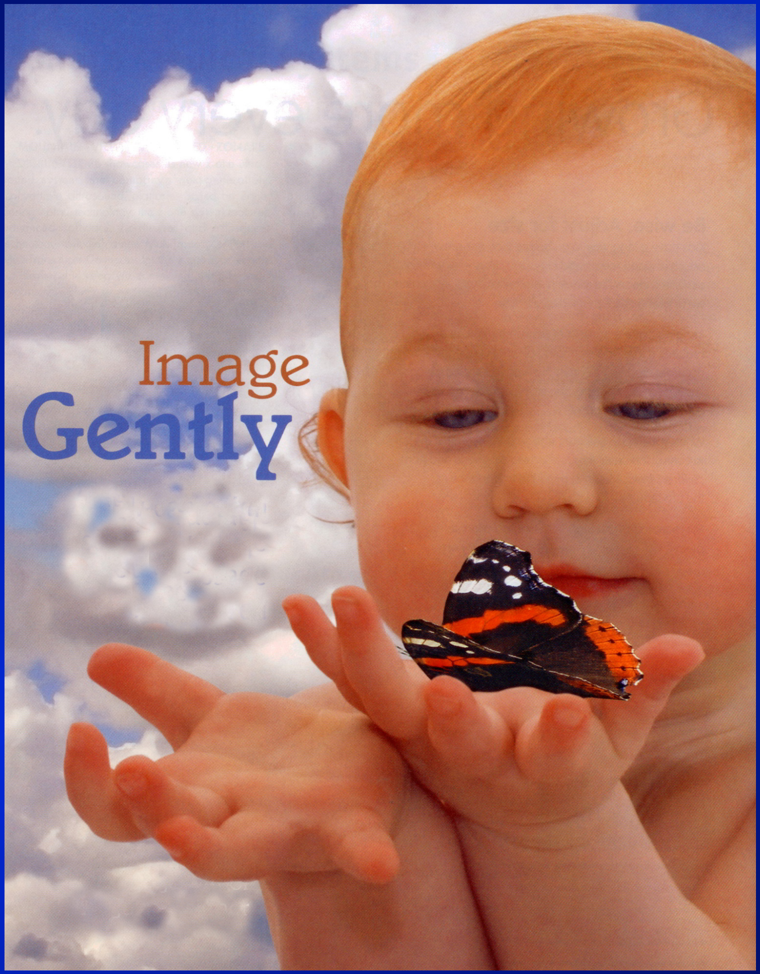
Appendicitis

From Wikipedia, the free encyclopedia

Appendicitis (or **epityphlitis**) is a condition characterized by inflammation of the appendix. While mild cases may resolve without treatment, most require removal of the inflamed appendix, either by laparotomy or laparoscopy. Untreated, mortality is high, mainly due to peritonitis and shock.[1] Reginald Fitz first described acute appendicitis in 1886,[2] and it has been recognized as one of the most common causes of acute abdomen pain worldwide.

Diagnosis is based on patient history (symptoms) and physical examination backed by an elevation of neutrophilic white blood cells. Atypical histories often require imaging with ultrasound and/or CT scanning.[1]

Take Home Message



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