Radiation Risk from Medical Imaging

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DISCLOSURES

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EB 017095	Mayo Discovery Translation Award
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DK 100227	Siemens Healthcare
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RR 018898	

Off Label Usage

None

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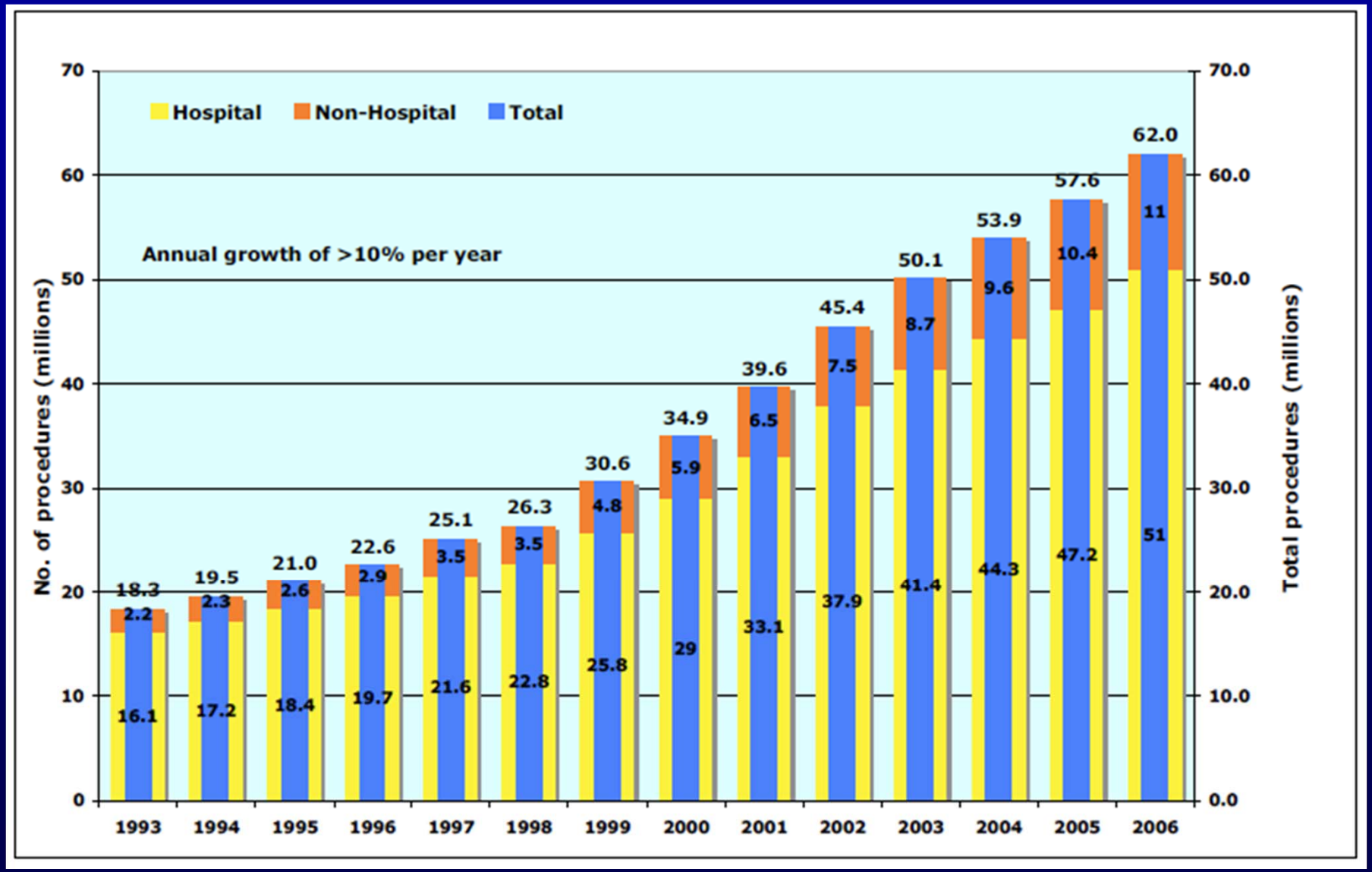
Growth in CT imaging



National Council on Radiation Protection. IONIZING RADIATION EXPOSURE OF THE POPULATION OF THE UNITED STATES in 2006, Report 16. (2009)

Growth driven by increased benefit

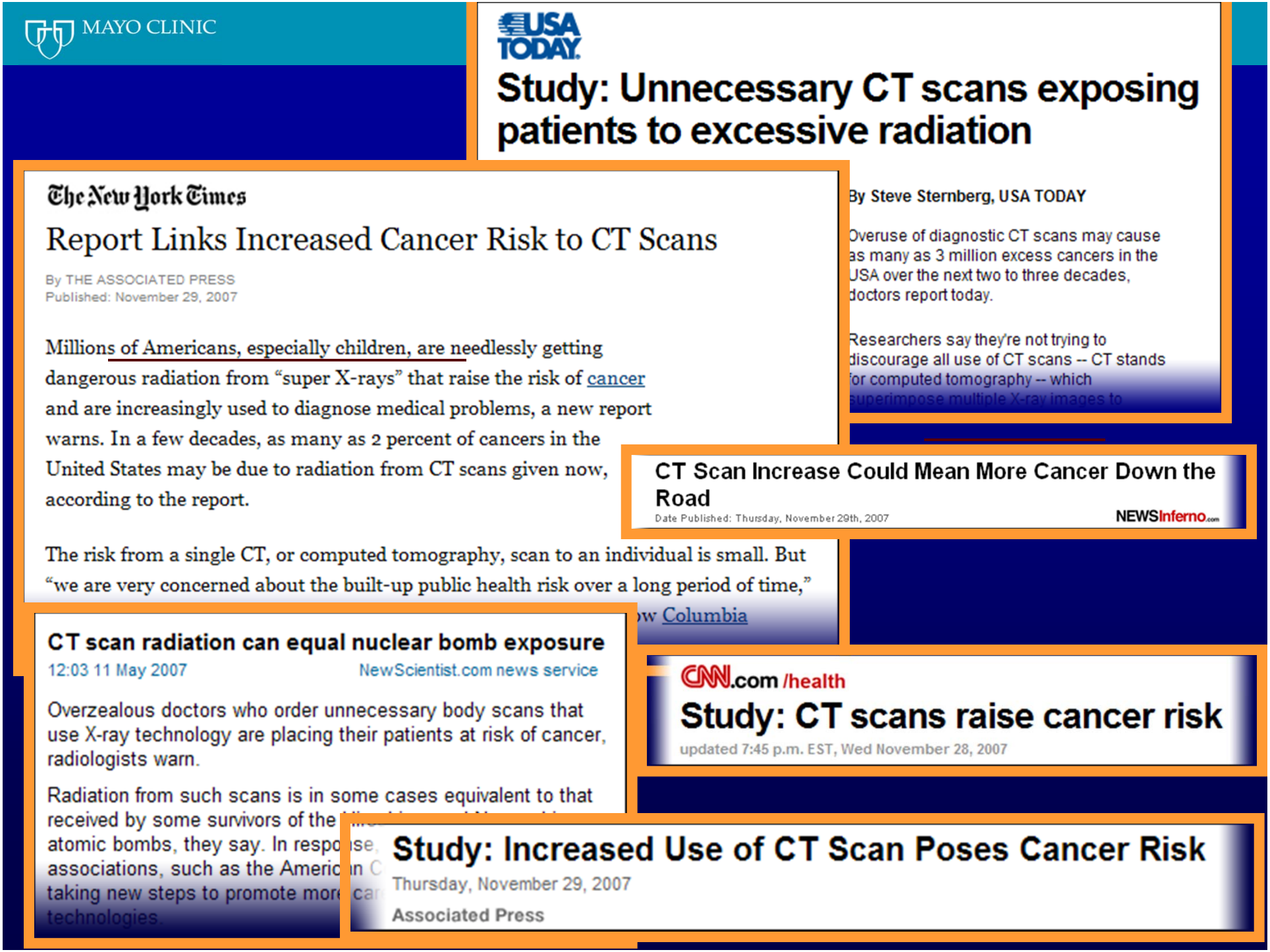
- Faster exams with finer anatomic detail
- New CT technology can address an ever increasing number of conditions and indications
  - CT angiography, colonography, enterography
  - Cardiac CT, dual-energy and perfusion CT
- CT replaced less accurate or more invasive exams

Benefits of CT in Urologic Imaging

- Highest sensitivity (95%-96%) and specificity (98%) for stone detection of any imaging technique
- Replaced invasive angiography for the evaluation of renal arteries
- American College of Radiology Appropriateness Criteria for *Urologic Imaging* : 50 clinical variants
  - (e.g. acute flank pain – new onset vs. known stone former)
  - 29 variants in which CT is a most appropriate exam (“tie”)
  - 20 variants in which CT is the single most appropriate exam

Radiation Risk

- There is a perception among some physicians and patients that the doses of ionizing radiation associated with medical imaging exams, particularly CT, is dangerous
- Where does this fear come from?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USA TODAY
Study: Unnecessary CT scans exposing patients to excessive radiation
By Steve Sternberg, USA TODAY
Overuse of diagnostic CT scans may cause as many as 3 million excess cancers in the USA over the next two to three decades, doctors report today.
Researchers say they're not trying to discourage all use of CT scans -- CT stands for computed tomography -- which superimpose multiple X-ray images to
The New York Times
Report Links Increased Cancer Risk to CT Scans
By THE ASSOCIATED PRESS
Published: November 29, 2007
Millions of Americans, especially children, are needlessly getting dangerous radiation from "super X-rays" that raise the risk of cancer and are increasingly used to diagnose medical problems, a new report warns. In a few decades, as many as 2 percent of cancers in the United States may be due to radiation from CT scans given now, according to the report.
The risk from a single CT, or computed tomography, scan to an individual is small. But "we are very concerned about the built-up public health risk over a long period of time,"
w Columbia
CT Scan Increase Could Mean More Cancer Down the Road
Date Published: Thursday, November 29th, 2007
NEWSInferno.com
CT scan radiation can equal nuclear bomb exposure
12:03 11 May 2007
NewScientist.com news service
Overzealous doctors who order unnecessary body scans that use X-ray technology are placing their patients at risk of cancer, radiologists warn.
Radiation from such scans is in some cases equivalent to that received by some survivors of the
atomic bombs, they say. In respo se,
associations, such as the Americ n C
taking new steps to promote mor ca
technologies.
CNN.com /health
Study: CT scans raise cancer risk
updated 7:45 p.m. EST, Wed November 28, 2007
Study: Increased Use of CT Scan Poses Cancer Risk
Thursday, November 29, 2007
Associated Press

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Arch Intern Med. 2009;169(22):2078-2086

ORIGINAL INVESTIGATION

Projected Cancer Risks From Computed Tomographic Scans Performed in the United States in 2007

Amy Berrington de González, DPhil; Mahadevappa Mahesh, MS, PhD; Kwang-Pyo Kim, PhD; Mythreyi Bhargavan, PhD; Rebecca Lewis, MPH; Fred Mettler, MD; Charles Land, PhD

Authors calculate potential cancers using published radiation risk data

Conclude that 29,000 future cancers could be related to CT scans performed in the U.S. in 2007 (>70 million)…
and could translate into about 14,500 cancer deaths.

Methods

Take a small hypothetical risk estimate
(e.g. 1 in 2000)

and multiply by a large population
(e.g. 70 Million)

Tylenol Analogy

Take a small hypothetical risk estimate
(e.g. risk of death from 2 Tylenol tablets)

and multiply by a large population
(e.g. 10% of 250 Million adults in US)

Assume risk is linearly proportional to dose

# of deaths from 200 tablets x 250 thousand adults

same as

# of deaths from 2 tablets x 25 million adults

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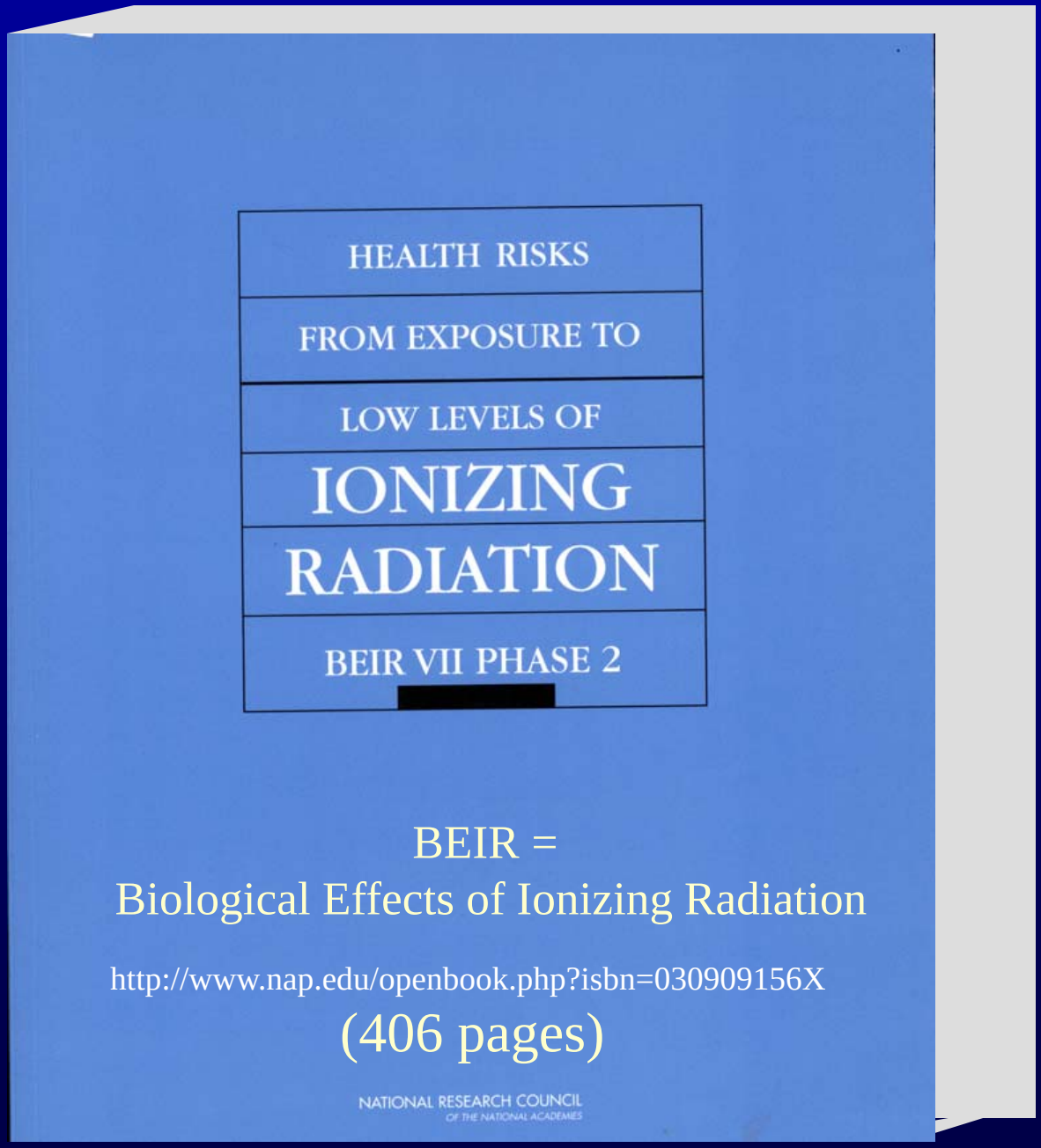

BEIR =
Biological Effects of Ionizing Radiation

http://www.nap.edu/openbook.php?isbn=030909156X

(406 pages)

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TABLE 12D-1 Lifetime Attributable Risk of Cancer Incidence[a]

Cancer Site	Age at Exposure (years) 0	5	10	15	20	30	40	50	60	70	80
Males											
Stomach	76	65	55	46	40	28	27	25	20	14	7
Colon	336	285	241	204	173	125	122				
Liver	61	50	43	36	30	22	21				
Lung	314	261	216	180	149	105	104				
Prostate	93	80	67	57	48	35	35				
Bladder	209	177	150	127	108	79	79				
Other	1123	672	503	394	312	198	172				
Thyroid	115	76	50	33	21	9	3	1	0.3	0.1	0.0
All solid	2326	1667	1325	1076	881	602	564	507	407	270	126
Leukemia	237	149	120	105	96	84	84	84	82	73	48
All cancers	2563	1816	1445	1182	977	686	648	591	489	343	174
Females											
Stomach	101	85	72	61	52	36	35				
Colon	220	187	158	134	114	82	79				
Liver	28	23	20	16	14	10	10				
Lung	733	608	504	417	346	242	240				
Breast	1171	914	712	553	429	253	141				
Uterus	50	42	36	30	26	18	16				
Ovary	104	87	73	60	50	34	31	25	18	11	5
Bladder	212	180	152	129	109	79	78	74	64	47	24
Other	1339	719	523	409	323	207	181	148	109	68	30
Thyroid	634	419	275	178	113	41	14	4	1	0.3	0.0
All solid	4592	3265	2525	1988	1575	1002	824	678	529	358	177
Leukemia	185	112	86	76	71	63	62	62	57	51	37
All cancers	4777	3377	2611	2064	1646	1065	886	740	586	409	214

NOTE: Number of cases per 100,000 persons exposed to a single dose of 0.1 Gy.

100,000 women aged 30

Single dose of 100 mSv

Incidence over their lifetime

2006 BEIR VII report

- "At doses of 100 mSv or less, statistical limitations make it difficult to evaluate cancer risk in humans."
- "… at relatively low doses, there is still uncertainty as to whether there is an association between radiation and disease, and if there is an association, there is uncertainty about whether it is causal or not."

Consensus Statements

- US and international radiation protection organizations repeatedly caution that risk estimates below 100 mSv are meaningless
  - Long-term effects are either too small to be observed or are non-existent
- United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)
  - 2012 report to United Nations General Assembly states “an increase in the incidence of health effects in populations cannot be attributed to exposure to radiation doses typical of background levels of radiation, i.e. 1-10 mSv/yr.”

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Typical Effective Doses in Medical Imaging

	Exam	Effective Dose
Radiography & Fluoroscopy	Hand radiograph	<0.1 mSv
	Dental bitewing	<0.1 mSv
	Chest radiograph	0.1-0.2 mSv
	Mammogram	0.3-0.6 mSv
	Lumbar spine radiograph	0.5-1.5 mSv
	Barium enema	3-6 mSv
	Diagnostic coronary angiogram	5-10 mSv
Computed Tomography	Head CT	0.5-2 mSv
	Chest CT	2-6 mSv
	Abdomen CT	2-7 mSv
	Pelvis CT	2-4 mSv
	Coronary artery calcification CT	0.1-2 mSv
	Coronary CT angiogram	1-15 mSv
Radionuclide Imaging	Lung scan	2-3 mSv
	Bone scan	3-5 mSv
	Myocardial perfusion	12-14 mSv

Fundamental Flaw of Cancer Risk Predictions

Assuming risk is linearly proportional to dose

Risk of cancer from 1 mSv x 10 million adults

same as

Risk of cancer from
100 mSv x 100,000 adults
or
1,000 mSv (1 Sv) x 10,000 adults

Universal agreement that this is wrong

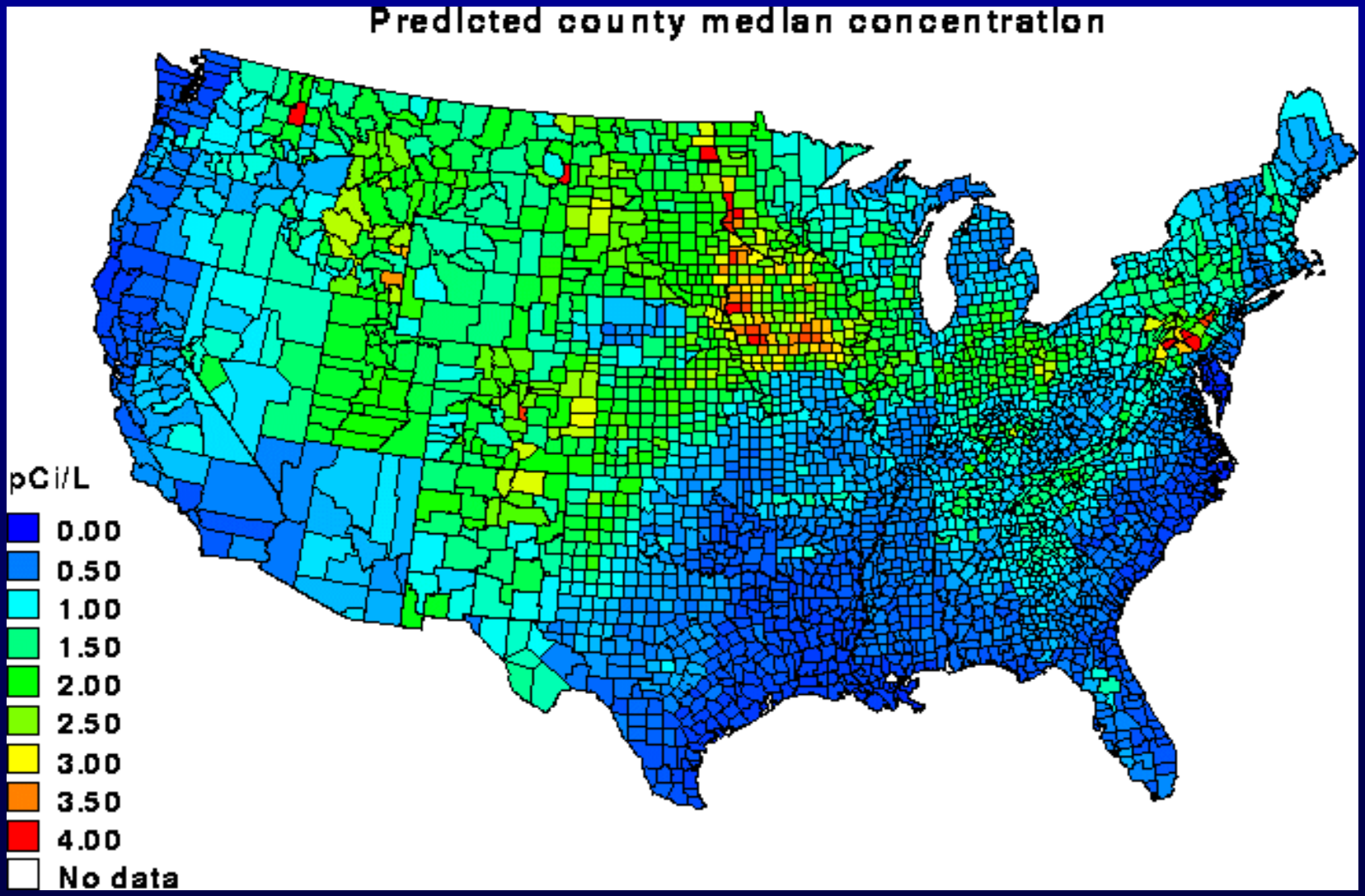
- United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)
- International Commission on Radiation Protection
- National Council on Radiation Protection
- Health Physics Society
- American Association of Physicists in Medicine
- Academie Nationale de Medicine (France)

Where does Table 12D come from?

- Epidemiology
- Studies of
  - medically exposed individuals
  - individuals lining in high background radiation areas
  - occupationally exposed individuals
  - survivors of the atomic bombings in Japan

  have demonstrated increased risk of cancer only for doses above 100 - 250 mSv
- Such doses are far greater than the dose levels used in medical imaging

Radiation Doses from Radon



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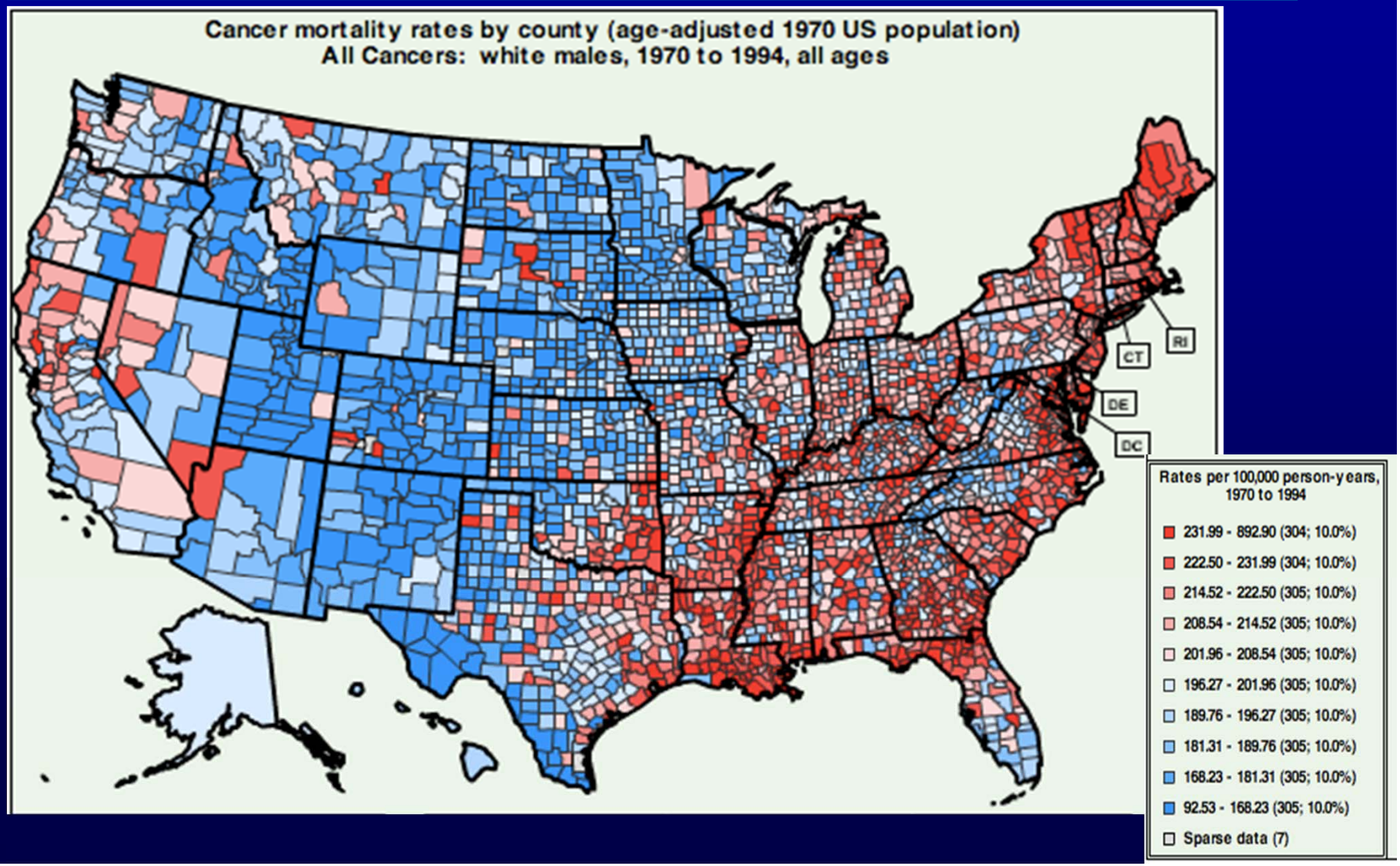
US Cancer Rates



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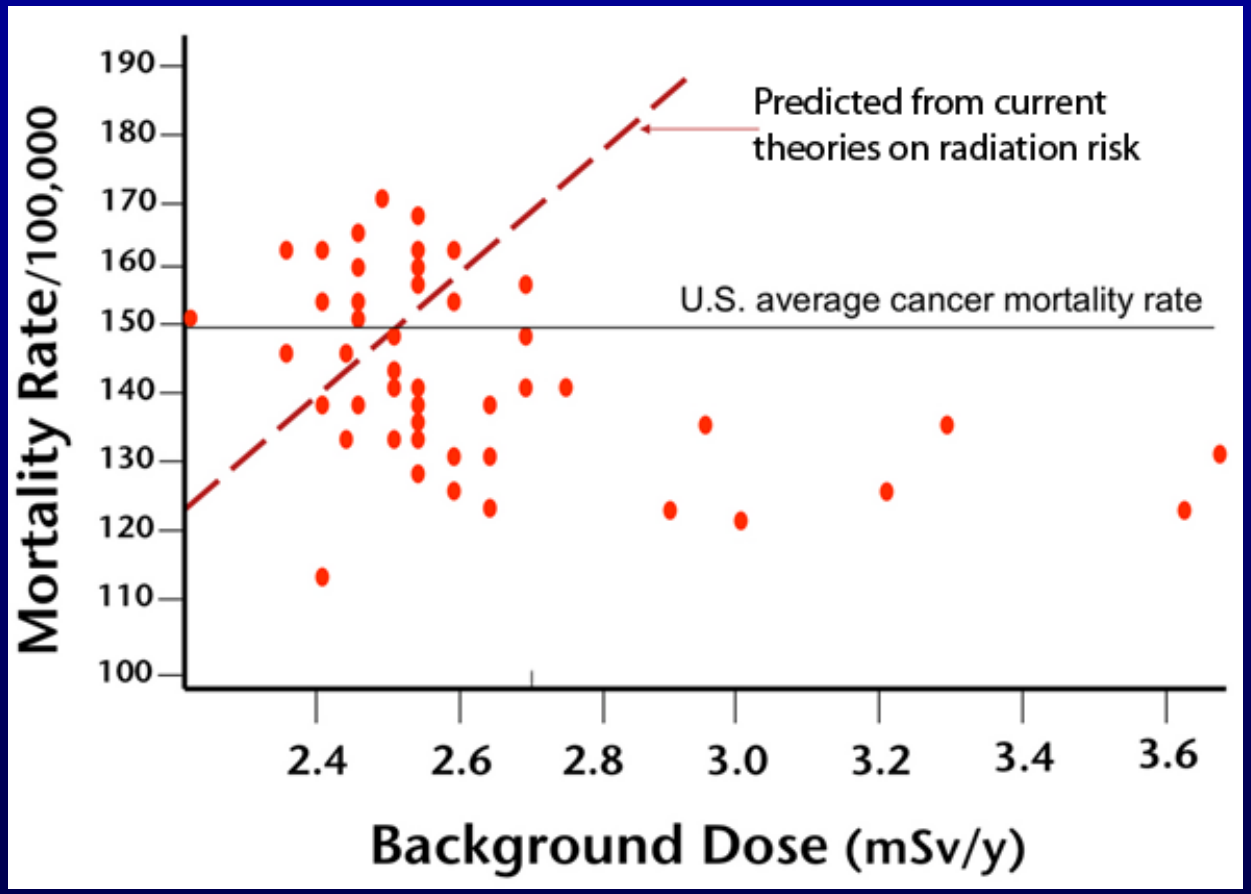
Background Radiation: Differences in Annual Cancer Mortality Rates for each U.S. State over a 17-Year Period



States with significantly higher doses (e.g. Colorado) have lower cancer rates than states with lower doses (e.g. Georgia)
(Frigerio and Stowe, 1976)

Studies of occupationally exposed workers in the nuclear power industry

- Six large combined cohort studies
  - Combined study population > 500,000 subjects
  - 30- 40 years of follow-up
  - Cumulative dose levels: 30-60 mSv

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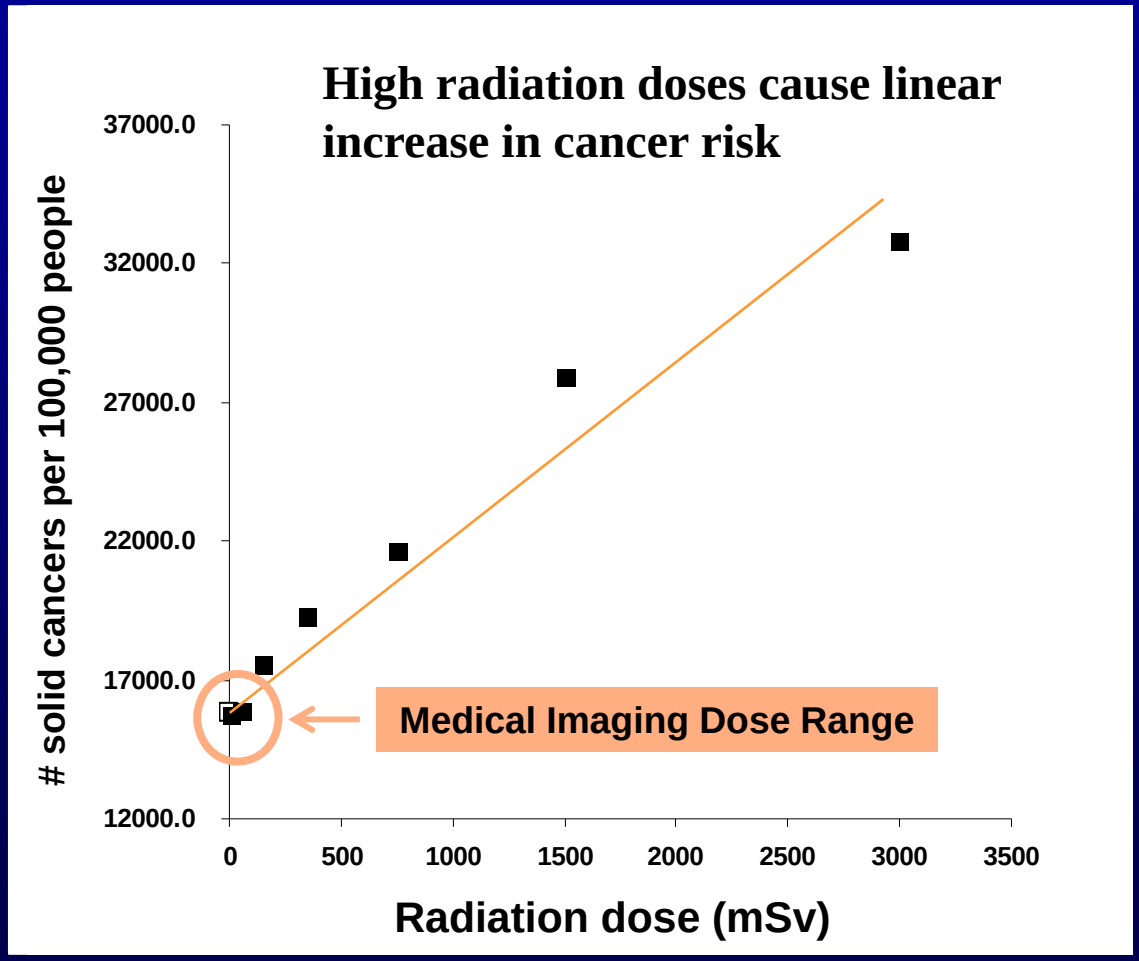
Studies of occupationally exposed workers in the nuclear power industry

- "….in most cases, rates for all causes and all cancer mortality in the workers were substantially lower than the reference populations."

  (U.S. Academy of Science, BEIR VII, 2007)

Atomic bomb survivor data



Preston et al, Radiation Research 2007;168: 1-64.
(Radiation Effects Research Foundation)

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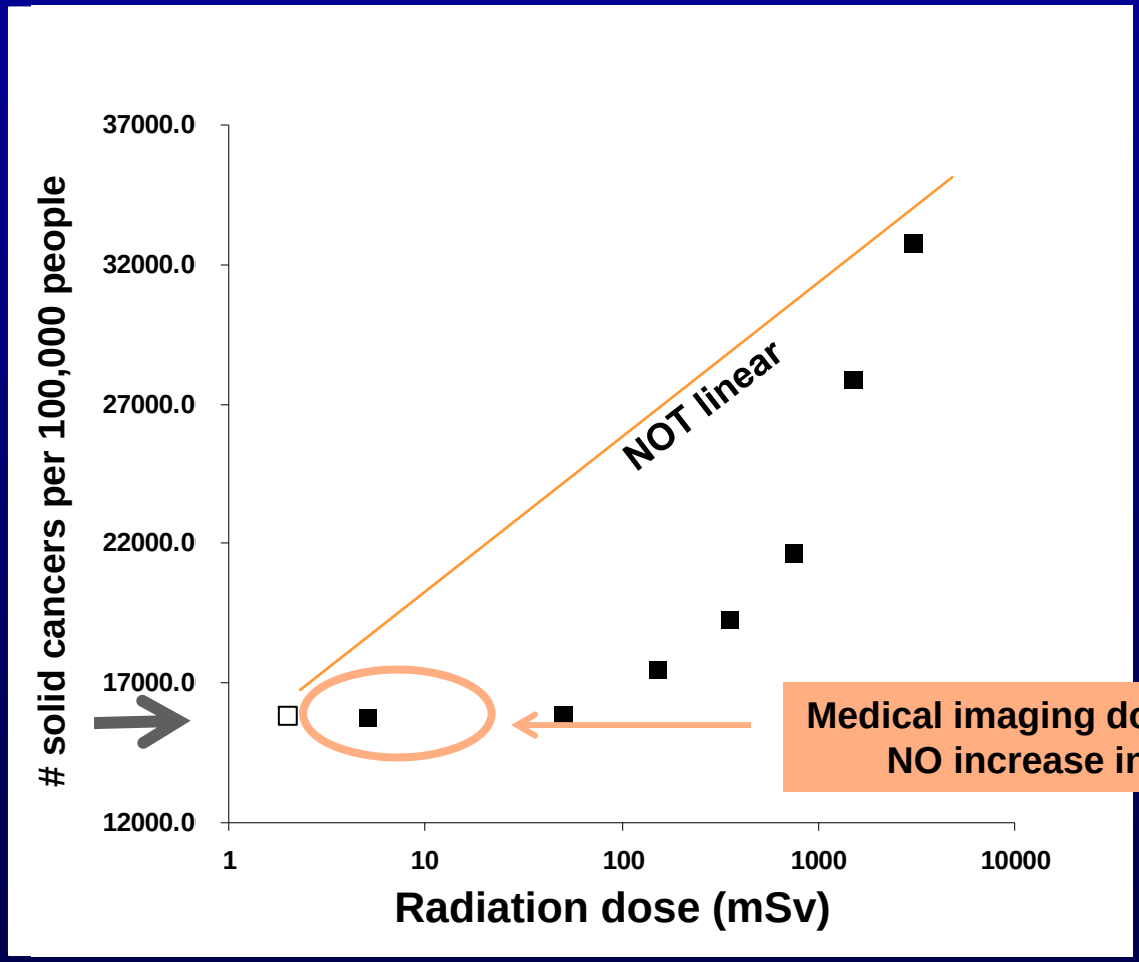
Atomic bomb survivor data
Expand scale to look at low dose data

White open square is background cancer rate



Preston et al, Radiation Research 2007;168: 1-64.
(Radiation Effects Research Foundation)

Current Perception of Radiation Risk: Incorrect

- Studies predicting risk are fundamentally flawed
  - Not proven to be any risk below 100 mSv
  - They get published anyway
  - Media reports them widely
- Conveying this information to medical personnel and patients can be difficult, in part due to
  - the general unfamiliarity with radiation dose measurement units (e.g. mrad, mGy, mSv)
  - perception that there are no safe doses of radiation

All things are poison,
and nothing is without poison;
only the dose permits something
not to be poisonous

Paracelsus (1493-1541)

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MEDICAL OBSERVER

HEALTH and MEDICAL FACTS

4 Benefits of RED WINE

Reduction in Heart Disease

Flavonoids in red wine are believed to decrease the amount of "bad" cholesterol in your bloodstream and increase "good" cholesterol. Flavonoids and resveratrol also seem to prevent platelets from sticking together, which can prevent heart attack or stroke by decreasing the risk of clot formation.

Protection Against Cancer

Resveratrol has been shown to reduce tumor incidence and inhibit growth of cancer cells in the laboratory. Studies have begun to directly link red wine consumption to reduction of cancer risk in humans.

Protection against Neurological Disorders

Researchers have found that resveratrol can help block the formation of amyloid plaques which are thought to damage brain cells and contribute to Alzheimer's Disease.

Beneficial for the Gums

Researchers have found that red wine cuts down on the inflammation and tissue damage caused by periodontal, or gum, disease. So drinking red wine actually can help your dental health, they say.

source: www.everydayhealth.com

Fatal alcohol poisoning

A person who drinks to the point of passing out can die if the concentration of alcohol in his or her bloodstream reaches a toxic level. What happens:

1 Person drinks ethanol*
80% through small intestine
20% is absorbed through stomach
Blood alcohol level rises

2 Body processes the alcohol
95% is broken down by liver
5% is exhaled or leaves body in urine, sweat, etc.

3 Intoxication depends on amount in blood

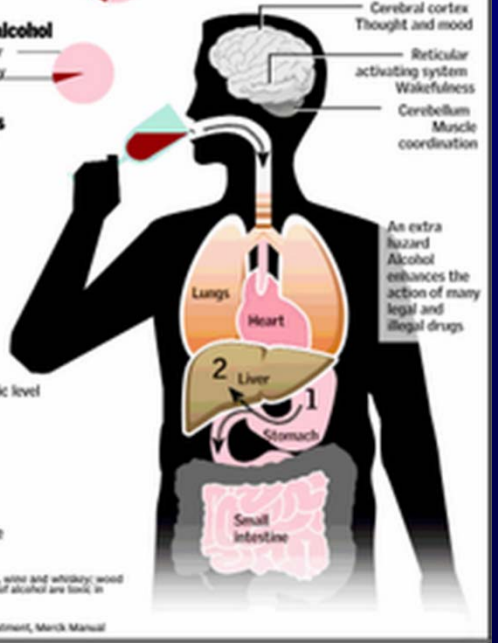
MILD
Blood alcohol level: 0-0.15
- Euphoria, slurred speech, impaired coordination
- Liver eventually clears all alcohol from blood
- Ability to drive is impaired

ACUTE
Blood alcohol level: 0.3-0.4
- Liver can't break down alcohol fast enough
- Blood alcohol level rises to toxic level
- Person loses consciousness or goes into deep coma

FATAL
Blood alcohol level: Above 0.4
- Most deaths are caused by inhaling stomach contents
- Brain function depressed; pulse slows; person stops breathing

*Or "grain alcohol," the kind used in beer, wine and whiskey; wood alcohol, rubbing alcohol and other kinds of alcohol are toxic in even small amounts

Source: Current Medical Diagnosis & Treatment, Merck Manual



Patient on Coumadin

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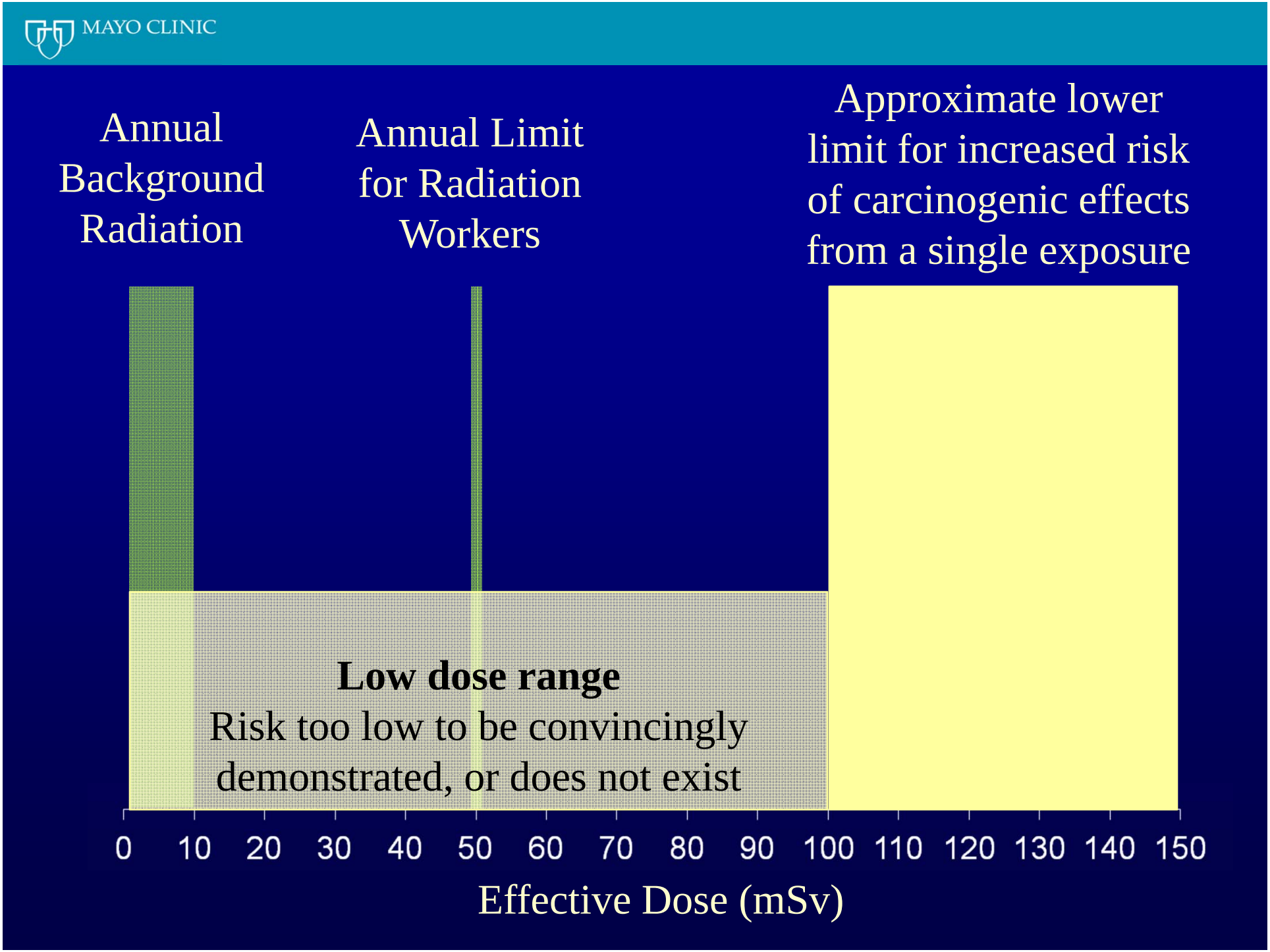
Annual Background Radiation
Annual Limit for Radiation Workers
Approximate lower limit for increased risk of carcinogenic effects from a single exposure
Low dose range
Risk too low to be convincingly demonstrated, or does not exist
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
Effective Dose (mSv)

Observational Studies

- Two recent studies of children who received CT scans suggested that these patients are at higher risk for subsequent cancer. These studies …
  - lacked a control cohort
  - did not determine patient-specific doses
  - clinical symptoms, signs, and comorbidities that led to an imaging study were not evaluated for associations with cancer
  - had results highly inconsistent with prior literature
    - Increased risk of melanoma from ionizing radiation (x- and gamma-rays)
    - Increased risk of cancers in the chest/abdomen/pelvis from head CT
    - Increased risk for older children vs. younger children
    - No increased risk of leukemia and breast cancer from radiation

Hospital blamed for death of 2-year-old

- Child fell 5 feet out a window
  - No one witnessed the fall
  - No one knew if he lost consciousness
- Brought to ER: pale, crying and vomiting
- According to the American Academy of Pediatrics, CT scans are typically only performed when a child loses consciousness after hitting their head
  - "A CT scan exposes a child to radiation equal to 300 X-rays, and can require sedation, which is risky"
- Doctor discharged child after only a physical exam; he died hours later from a subdural hematoma

Summary

- It has not been demonstrated that there is any risk from the doses of radiation used in medical imaging
  - If present, risk is too small to be convincingly demonstrated
- But the fear – warranted or not – is real, and is impacting patient care
- To address this issue, the imaging community continues to decrease radiation doses
- For any medically appropriate exam, the demonstrated clinical benefits greatly outweigh the hypothetical radiation risks

Thank you

CT Clinical Innovation Center

http://mayoresearch.mayo.edu/ctcic