Radiation Risk from Medical Imaging

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DISCLOSURES

Research Support:

<table>
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<th>NIH</th>
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<td>EB 017095</td>
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Off Label Usage
None
Growth in CT imaging

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?
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 form a three-dimensional picture of the inside of the body.

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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,”

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CT Scan Increase Could Mean More Cancer Down the Road

Date Published: Thursday, November 29th, 2007

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 Hiroshima and Nagasaki atomic bombs, they say. In response, associations, such as the American Cancer Society, are taking new steps to promote more careful technologies.

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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

CNN.com

Study: Increased Use of CT Scan Poses Cancer Risk
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
HEALTH RISKS
FROM EXPOSURE TO
LOW LEVELS OF
IONIZING RADIATION
BEIR VII PHASE 2

BEIR =
Biological Effects of Ionizing Radiation
http://www.nap.edu/openbook.php?isbn=030909156X
(406 pages)
TABLE 12D-1  Lifetime Attributable Risk of Cancer Incidence$^a$

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</table>

NOTE: Number of cases per 100,000 persons exposed to a single dose of 0.1 Gy.
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.”
# Typical Effective Doses in Medical Imaging

<table>
<thead>
<tr>
<th>Exam</th>
<th>Effective Dose</th>
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<tbody>
<tr>
<td><strong>Radiography &amp; Fluoroscopy</strong></td>
<td></td>
</tr>
<tr>
<td>Hand radiograph</td>
<td>&lt;0.1 mSv</td>
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<tr>
<td>Dental bitewing</td>
<td>&lt;0.1 mSv</td>
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<tr>
<td>Chest radiograph</td>
<td>0.1-0.2 mSv</td>
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<tr>
<td>Mammogram</td>
<td>0.3-0.6 mSv</td>
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<tr>
<td>Lumbar spine radiograph</td>
<td>0.5-1.5 mSv</td>
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<tr>
<td>Barium enema</td>
<td>3-6 mSv</td>
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<td>Diagnostic coronary angiogram</td>
<td>5-10 mSv</td>
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<td><strong>Computed Tomography</strong></td>
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<tr>
<td>Head CT</td>
<td>0.5-2 mSv</td>
</tr>
<tr>
<td>Chest CT</td>
<td>2-6 mSv</td>
</tr>
<tr>
<td>Abdomen CT</td>
<td>2-7 mSv</td>
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<tr>
<td>Pelvis CT</td>
<td>2-4 mSv</td>
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<td>Coronary artery calcification CT</td>
<td>0.1-2 mSv</td>
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<td>Coronary CT angiogram</td>
<td>1-15 mSv</td>
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<tr>
<td><strong>Radionuclide Imaging</strong></td>
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<td>Lung scan</td>
<td>2-3 mSv</td>
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<tr>
<td>Bone scan</td>
<td>3-5 mSv</td>
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<tr>
<td>Myocardial perfusion</td>
<td>12-14 mSv</td>
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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
US Cancer Rates

Cancer mortality rates by county (age-adjusted 1970 US population)
All Cancers: white males, 1970 to 1994, all ages
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
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

High radiation doses cause linear increase in cancer risk

(Radiation Effects Research Foundation)
**Atomic bomb survivor data**

*Expand scale to look at low dose data*

(Radiation Effects Research Foundation)

White open square is background cancer rate

Medical imaging dose range NO increase in risk

(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)
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.

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**Fatal alcohol poisoning**
- **Person drinks ethanol**: 20% is absorbed through stomach.
- **Blood alcohol level rises**: Lungs.
- **Body processes the alcohol**: Normal coordination.
- **Intoxication depends on amount in blood**: Over 1.00.
- **Mild**: Blood alcohol level 0.05 to 0.15.
- **Acute**: Blood alcohol level 0.3 to 0.4.
- **Fatal**: Blood alcohol level above 0.4.

**Parts of the brain affected**
- Cerebral cortex
- Thalamus
- Memory centers
- Frontallobar

**Source**: Current Medical Diagnosis & Treatment, 26th Edition
Effective Dose (mSv)

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

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