Ionizing Radiation Exposure of the Population of the United States

NCRP REPORT No. 160

IONIZING RADIATION EXPOSURE OF THE POPULATION OF THE UNITED STATES

David A. Schauer
Executive Director
Key Dates in NCRP’s History

1929: U.S. Advisory Committee on X-ray and Radium Protection

1946: U.S. National Committee on Radiation Protection

1964: National Council on Radiation Protection and Measurements (NCRP) chartered by U.S. Congress (Public Law 88-376)
Key Elements of NCRP’s Charter Under U.S. Public Law 88-376

Cornerstones of role in radiation health protection:

1) Collect and analyze information and recommendations in the public interest about:
   a) protection against radiation; and
   b) radiation measurements, quantities and units.

2) Develop basic concepts of radiation protection;

3) Facilitate effective use of combined resources of organizations concerned with radiation protection; and

4) Cooperate with national and international governmental and private organizations; and

5) Disseminate the Council’s work.
Overview of NCRP Reports on Population Dose in the United States

Medical Exposures of Patients
- Computed Tomography
- Conventional Radiography and Fluoroscopy
- Interventional Fluoroscopy
- Nuclear Medicine

Occupational Exposure from Medical Procedures

Summary
Overview

Overview

  • Main source of data on the estimates of the number of procedures:
    • commercial market benchmark reports by IMV
    • reports were supplemented by Medicare, Veterans Administration and a Large National Employer Plan.
Overview

• NCRP Report No. 160 (2009), cont.
  • Effective doses for procedures were derived by a variety of methods, each of which is described in the respective discussion for the subcategories of medical exposure.
    • CT, data on dose length product and age and body region specific conversion coefficients were utilized;
    • conventional radiography and fluoroscopy, a published survey of effective dose was applied;
    • interventional fluoroscopy, data on KAP and protocol specific dose conversion coefficients were utilized; and
    • nuclear medicine, data on dose conversion coefficients expressed as effective dose per unit administered activity were utilized.
  • Data reported as:
    • collective effective dose \((S)\) (person-Sv);
    • and effective dose per individual in the U.S. population \((E_{US})\) (mSv).
Computed Tomography

![Graph showing the total number of procedures (millions) from 1993 to 2006. The graph displays data for hospital, non-hospital, and total procedures.](image)

- Hospital
- Non-hospital
- Total

<table>
<thead>
<tr>
<th>Year</th>
<th>Hospital</th>
<th>Non-hospital</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>18.3</td>
<td>2.2</td>
<td>20.5</td>
</tr>
<tr>
<td>1994</td>
<td>19.5</td>
<td>2.3</td>
<td>21.8</td>
</tr>
<tr>
<td>1995</td>
<td>18.4</td>
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</tr>
<tr>
<td>1996</td>
<td>22.6</td>
<td>2.9</td>
<td>25.5</td>
</tr>
<tr>
<td>1997</td>
<td>25.1</td>
<td>3.5</td>
<td>28.6</td>
</tr>
<tr>
<td>1998</td>
<td>26.3</td>
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<td>30.8</td>
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<tr>
<td>1999</td>
<td>30.6</td>
<td>4.8</td>
<td>35.4</td>
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<td>2000</td>
<td>34.9</td>
<td>5.9</td>
<td>40.8</td>
</tr>
<tr>
<td>2001</td>
<td>39.6</td>
<td>6.5</td>
<td>46.1</td>
</tr>
<tr>
<td>2002</td>
<td>45.4</td>
<td>7.5</td>
<td>52.9</td>
</tr>
<tr>
<td>2003</td>
<td>50.1</td>
<td>8.7</td>
<td>58.8</td>
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<tr>
<td>2004</td>
<td>53.9</td>
<td>9.6</td>
<td>63.5</td>
</tr>
<tr>
<td>2005</td>
<td>57.6</td>
<td>10.4</td>
<td>68.0</td>
</tr>
<tr>
<td>2006</td>
<td>62.0</td>
<td>11.0</td>
<td>73.0</td>
</tr>
</tbody>
</table>
## Computed Tomography

<table>
<thead>
<tr>
<th>Category</th>
<th>Effective Dose per Scan (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>2</td>
</tr>
<tr>
<td>Chest</td>
<td>7</td>
</tr>
<tr>
<td>Abdomen &amp; pelvis</td>
<td>10</td>
</tr>
<tr>
<td>Extremity</td>
<td>0.1</td>
</tr>
<tr>
<td>Virtual colonography</td>
<td>10</td>
</tr>
<tr>
<td>Whole-body screening</td>
<td>10</td>
</tr>
<tr>
<td>Calcium scoring</td>
<td>2</td>
</tr>
<tr>
<td>Angiography – Head</td>
<td>5</td>
</tr>
<tr>
<td>Angiography – Heart</td>
<td>20</td>
</tr>
</tbody>
</table>
## Computed Tomography

<table>
<thead>
<tr>
<th>Categories</th>
<th>Scans (%)</th>
<th>S (person-Sv)</th>
<th>S (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>28.4</td>
<td>38,044</td>
<td>8.7</td>
</tr>
<tr>
<td>Chest</td>
<td>15.9</td>
<td>74,326</td>
<td>17.0</td>
</tr>
<tr>
<td>Abdomen/pelvis</td>
<td>31.7</td>
<td>212,538</td>
<td>48.6</td>
</tr>
<tr>
<td>Extremity</td>
<td>5.2</td>
<td>515</td>
<td>0.1</td>
</tr>
<tr>
<td>Angio – Heart</td>
<td>3.4</td>
<td>46,000</td>
<td>10.5</td>
</tr>
<tr>
<td>Angio – Head</td>
<td>3.0</td>
<td>10,000</td>
<td>2.3</td>
</tr>
<tr>
<td>Spine</td>
<td>6.2</td>
<td>41,369</td>
<td>9.5</td>
</tr>
<tr>
<td>Interventional</td>
<td>3.4</td>
<td>230</td>
<td>0.5</td>
</tr>
<tr>
<td>Cardiac</td>
<td>0.5</td>
<td>6,000</td>
<td>1.4</td>
</tr>
<tr>
<td>Others</td>
<td>2.5</td>
<td>8,500</td>
<td>2.0</td>
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</tbody>
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Computed Tomography

Annual Collective Effective Dose (S):

437,500 person-Sv
## Conventional Radiography and Fluoroscopy

<table>
<thead>
<tr>
<th>Examination</th>
<th>Effective Dose (mSv)</th>
<th>No. Exams (1000)</th>
<th>S (person-Sv)</th>
<th>S (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td>0.1</td>
<td>128,944</td>
<td>12,894</td>
<td>12.8</td>
</tr>
<tr>
<td>Breast</td>
<td>0.18 (0.42)</td>
<td>34,500</td>
<td>6,210 (14,490)</td>
<td>6.2</td>
</tr>
<tr>
<td>Cervical Spine</td>
<td>0.2</td>
<td>5,800</td>
<td>1,160</td>
<td>1.2</td>
</tr>
<tr>
<td>Thoracic Spine</td>
<td>1.0</td>
<td>2,590</td>
<td>2,590</td>
<td>2.6</td>
</tr>
<tr>
<td>Lumbar Spine</td>
<td>1.5</td>
<td>11,197</td>
<td>16,796</td>
<td>16.7</td>
</tr>
<tr>
<td>Upper GI</td>
<td>6.0</td>
<td>4,044</td>
<td>24,264</td>
<td>24.1</td>
</tr>
<tr>
<td>Abdomen</td>
<td>0.7</td>
<td>14,964</td>
<td>10,475</td>
<td>10.4</td>
</tr>
<tr>
<td>Barium Enema</td>
<td>8.0</td>
<td>656</td>
<td>5,248</td>
<td>5.2</td>
</tr>
<tr>
<td>IVP</td>
<td>3.0</td>
<td>1,180</td>
<td>3,540</td>
<td>3.5</td>
</tr>
<tr>
<td>Pelvis &amp; Hip</td>
<td>0.6 – 0.7</td>
<td>19,963</td>
<td>13,156</td>
<td>13.1</td>
</tr>
<tr>
<td>Other exams</td>
<td>0.005 – 1.7</td>
<td>58,131</td>
<td>1,613</td>
<td>0.7</td>
</tr>
<tr>
<td>Dental</td>
<td>0.005 (0.21)</td>
<td>500,000</td>
<td>2,528 (10,500)</td>
<td>2.8</td>
</tr>
</tbody>
</table>
Conventional Radiography and Fluoroscopy

Annual Collective Effective Dose (S):

100,500 person-Sv

(116,800 person-Sv using ICRP 2007 weighting factors for breast and dental exposures)
Interventional Fluoroscopy

Interventional Fluoroscopy Annual S (person-Sv)

- Cardiac: 68,226
- Nonvascular: 22,208
- Noncardiac diagnostic: 12,120
- Noncardiac intervention: 25,840
Interventional Fluoroscopy

- Annual Collective Effective Dose (S):

  128,400 person-Sv
Nuclear Medicine

Change in *In Vivo* Diagnostic Nuclear Medicine Procedures

- **Percent of Total**

- **Procedure**
  - Bone
  - Cardiac
  - Lung
  - Thyroid
  - Renal
  - GI
  - Brain
  - Infection
  - Tumor
  - Other

- **Year**
  - 1973
  - 1982
  - 2005
Nuclear Medicine

Nuclear Medicine S (percent), 2005

Cardiac (85 %)

Bone (9 %)
Other (1 %)
Tumor (2 %)
Gastrointestinal (2 %)
Lung (1 %)
Nuclear Medicine

Annual Collective Effective Dose (S):

220,500 person-Sv
Comparison of Medical Exposures of Patients

Medical Exposure of Patients
Collective H_{E} (percent), early 1980s

- Radiographic (68 %)
- Interventional (3 %)
- Nuclear medicine (26 %)
- Computed tomography (3 %)

Medical Exposure of Patients
S (percent), 2008

- Computed tomography (40 %)
- Radiographic (11 %)
- Interventional (14 %)
- Nuclear medicine (26 %)
Occupational Exposure

Six subcategories grouped by the nature of employment and associated type of source:

- **medical**;
- aviation;
- commercial nuclear power;
- industry and commerce;
- education and research; and
- government, DOE and military.
### Numbers of Workers and Doses

<table>
<thead>
<tr>
<th></th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitored workers</td>
<td>1,957,088</td>
<td>2,220,861</td>
<td>2,352,976</td>
<td>2,519,693</td>
</tr>
<tr>
<td>Workers with recordable dose</td>
<td>690,661</td>
<td>735,400</td>
<td>693,941</td>
<td>735,347</td>
</tr>
<tr>
<td>Collective effective dose (person-Sv)</td>
<td>508</td>
<td>559</td>
<td>546</td>
<td>549</td>
</tr>
<tr>
<td>Average effective dose (mSv)</td>
<td>0.74</td>
<td>0.76</td>
<td>0.79</td>
<td>0.75</td>
</tr>
</tbody>
</table>
Population Dose (person-Sv) from Occupational Exposure

- Medical: 39%
- Aviation: 38%
- Government, DOE & military: 3%
- Research & education: 4%
- Industry & commerce: 8%
- Commercial nuclear power: 8%

Occupational Exposure S (percent), 2006
# Radiation Exposures to U.S. Population in 2006

<table>
<thead>
<tr>
<th>Exposure Category</th>
<th>$S$ (person-Sv)</th>
<th>$E_{US}$ (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background</td>
<td>933,000</td>
<td>3.11</td>
</tr>
<tr>
<td>Medical</td>
<td>899,000</td>
<td>3.00</td>
</tr>
<tr>
<td>Consumer, etc.</td>
<td>39,000</td>
<td>0.13</td>
</tr>
<tr>
<td>Industrial, etc.</td>
<td>1,000</td>
<td>0.003</td>
</tr>
<tr>
<td>Occupational</td>
<td>1,400</td>
<td>0.005</td>
</tr>
</tbody>
</table>
Annual Collective Effective Dose (S):

1,870,000 person-Sv

Effective dose per individual in the U.S. population ($E_{US}$):

6.2 mSv
NCRP Report No. 160, Ionizing Radiation
Exposure of the Population of the United States

**Early 1980s**
- Background (83%)
- Medical (15%)
  - Occupational / industrial (0.3%)
  - Consumer (2%)

**2006**
- Background (50%)
- Medical (48%)
  - Occupational / industrial (0.1%)
- Consumer (2%)

<table>
<thead>
<tr>
<th>Category</th>
<th>Early 1980s</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collective effective dose</td>
<td>835,000</td>
<td>1,870,000</td>
</tr>
<tr>
<td>(person-Sv)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effective dose per individual in the U.S. population (mSv)</td>
<td>3.6</td>
<td>6.2</td>
</tr>
</tbody>
</table>
Informing a Wider Audience
(Scientific American – May 2011)

Exposed
Medical imaging delivers big doses of radiation

Americans are exposed to much more ionizing radiation (the most harmful type) than they were 30 years ago. Greater use of medical imaging such as CT scans accounts for almost all the increase. The tests can reveal serious health threats, of course, but they come with risks.

Radiation experts recommend that the public receive less than 1 millisievert a year beyond natural background radiation (0.3 mSv), not counting medical tests. As shown, common entire-body exposures such as airport scanners fall far below that recommendation, suggesting that anxiety about certain technologies is unwarranted.

Among medical tests, CT scans are the greatest concern. Studies indicate as many as one-third are prescribed unnecessarily. The average exposure for one scan is 71 mSv, according to David A. Schauer, executive director of the National Council on Radiation Protection and Measurements. “There is growing awareness that CT imaging must be reduced to less than 1 mSv per scan,” he says, adding that at a February meeting, companies indicated new technology could make that possible. —Mark Pesce

<table>
<thead>
<tr>
<th>Average Exposure in U.S. (mSv)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990 (6.6 total)</td>
<td></td>
</tr>
<tr>
<td>2006 (5.4 total)</td>
<td></td>
</tr>
</tbody>
</table>

Worker exposure (mSv, y-1)

- *Units are millirem (mSv) or millirem per year (mSv/yr)*

- Nuclear power plant (1.2)
- Pilot and crew (0.1)
- Astronaut on space station (0.001)
- Pelvis CT scan (0.001)
- Abdominal X-ray (0.003)
- Chest X-ray (0.1)
- Chest CT scan (0.7)
- Dental X-ray (0.005)
- Smoking (1 pack/day) (0.25)
- Airline flight (6 hours) (0.002)
- Head CT scan (2)
- Heart CT scan (0.001)
- Another CT scan (0.002)
- Arm or leg scan (0.001)

Exposure sources

- Natural Background (60%) (0.001)
- Medical exposure (30%) (0.001)
- Local background (10%) (0.001)
Recent NCRP Publications
Reports (2010 & 2011)

- **170: Second Primary Cancers and Cardiovascular Effects After Radiation Therapy**
  - L.B. Travis, Chair
  - J.D. Boice, Jr., Vice Chair

- **168: Radiation Dose Management for Fluoroscopically-Guided Interventional Medical Procedures**
  - Stephen Balter, Chair
  - Beth A. Schueler, Vice Chair
  - Donald L. Miller, Vice Chair