Radiation Workers

Martha S. Linet, M.D.
Chief, Radiation Epidemiology Branch
National Cancer Institute

November 17, 2014
Why Study Radiation Workers?

• Risk estimates for health effects primarily based on atomic bomb survivors

• For workers and the general public, most exposures are to low doses and low dose rates

• Uncertainty in extrapolating from high doses and high dose rate to low dose and low dose rate radiation exposures
Medical Radiation Worker Studies
## Medical Radiation Workers: Populations

<table>
<thead>
<tr>
<th>Population</th>
<th>Number of workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK radiologists</td>
<td>2,700</td>
</tr>
<tr>
<td>U.S. radiologists</td>
<td>6,500</td>
</tr>
<tr>
<td>U.S. Army technologists</td>
<td>6,600</td>
</tr>
<tr>
<td>U.S. radiologic technologists</td>
<td>146,000</td>
</tr>
<tr>
<td>Chinese x-ray workers</td>
<td>27,000</td>
</tr>
<tr>
<td>Japanese technologists</td>
<td>12,200</td>
</tr>
<tr>
<td>Danish radiotherapy workers</td>
<td>4,200</td>
</tr>
<tr>
<td>Canadian radiation workers</td>
<td>67,500</td>
</tr>
</tbody>
</table>

Linet et al. Radiat Res 2010
Medical Radiation Workers: Findings

• Increased leukemia risks in medical radiation workers who first worked before/during 1920s in UK and US, or before 1970 in China
• Elevated mortality from skin cancer in early UK and US radiologists
• Later Danish and Chinese medical radiation workers had elevated incident skin cancer risks
• Other solid cancer findings less consistent
• None of the results before 2002 based on dose data

Yoshinaga et al. Radiology 2004
Linet et al. Radiat Res 2010
Trends in Literature-Reported Average Annual Occupational Effective Doses to Radiologists

Source: Reports summarized in Table 5 in Linet et al. Radiat Res 2010
## Medical Radiation Worker Studies with Doses

<table>
<thead>
<tr>
<th>Population Features</th>
<th>Canadian</th>
<th>Chinese</th>
<th>U.S. Radiologic Technologists</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>67,500</td>
<td>27,000</td>
<td>146,000</td>
</tr>
<tr>
<td>Percent female</td>
<td>65%</td>
<td>20%</td>
<td>73%</td>
</tr>
<tr>
<td>1st worked</td>
<td>1951-87</td>
<td>1950-80</td>
<td>1926-80</td>
</tr>
<tr>
<td>Cum average estimated dose, exposure period</td>
<td>3.78 mSv, 1951-87</td>
<td>356 mGy, &lt;1949-94</td>
<td>76 mSv, 1916-87</td>
</tr>
<tr>
<td>Organ doses available</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Confounders</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

USRT Dose Reconstruction: 2014 Update

- 90,305 → 110,374 technologists with doses
- 350,000 → 921,134 badge doses
- Incorporated individual work history: 1 survey → 3 surveys
- Period-specific apron usage: literature and 3rd survey
- Doses to 12 organs using time period-specific conversion coefficients
Chromosome aberration dose trend (95% CI) in USRT Versus A-bomb

- Aberration trends similar to Japanese A-bomb
- Trends compatible with all other exposed groups
Risk Assessment in USRT

• 30-year cohort follow-up
  – Ongoing exposure-response 2015-16
    • Breast cancer incidence & mortality
    • Basal cell carcinoma of the skin incidence
    • Circulatory diseases mortality
  – Future exposure-response 2016-17
    • Hematopoietic malignancies
    • Other specific solid tumors
    • Cataracts
Occupational Exposures – FGIP/NM* in USRT

• **Importance**
  – Rapidly growing use internationally of
    • Fluoroscopically-guided interventional procedures
    • Radionuclides in nuclear medicine procedures
  – Limited or no previous epidemiologic investigations

*FGIP — fluoroscopically-guided interventional procedures
NM — nuclear medicine procedures
Risk Assessment for FGIP/NM in USRT

• Ever vs never FGIP and NM: 2015

• Combine work history, badge dose readings, literature,* and focus group information to refine estimated doses of technologists performing fluoroscopically-guided (FGIP) and nuclear medicine (NM) procedures: 2015-2016

• Exposure-response risk assessment: 2016-17

Nuclear Workers Studies
Large Nuclear Worker Studies

• Many individual studies, most involving low doses, low dose rates, & limited power

• National Registry of Radiation Workers (UK), 3rd follow-up, 2009

• Combined populations
  - IARC* 3-country study, 1995
  - IARC 15-country study, 2005, 2007

* International Agency for Research on Cancer
# Large Nuclear Workers Studies: Features

<table>
<thead>
<tr>
<th>Characteristics of Population</th>
<th>IARC 3-Country</th>
<th>IARC 15-Country</th>
<th>NRRW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>96,000</td>
<td>407,391</td>
<td>174,541</td>
</tr>
<tr>
<td>Percent female</td>
<td>14.6%</td>
<td>10%</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Countries</td>
<td>US/UK/Canada</td>
<td>US/UK/Japan</td>
<td>UK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Canada, etc.</td>
<td></td>
</tr>
<tr>
<td>Cum average recorded dose</td>
<td>40 mSv</td>
<td>19 mSv</td>
<td>25 mSv</td>
</tr>
<tr>
<td>No. deaths</td>
<td>15,825</td>
<td>24,158</td>
<td>26,731</td>
</tr>
<tr>
<td>No. cancers</td>
<td>3,976</td>
<td>6,715</td>
<td>8,107</td>
</tr>
</tbody>
</table>

IARC* 15-Country Study: Dosimetry

• Objective: convert recorded doses to organ doses

• Approach
  - Dosimetry subcommittee
  - Questionnaires on dosimetry practices & radiation environments
  - Special studies of representative facilities
  - Testing of representative dosimeters

* International Agency for Research on Cancer
## Large Nuclear Workers Studies: Cancer Mortality

<table>
<thead>
<tr>
<th>Study</th>
<th>All cancer excluding leukemia (linear) ERR/Gy (90% CI)</th>
<th>Leukemia excluding CLL (linear-quadratic) ERR/Gy (90% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All cancer excluding leukemia (linear) ERR/Gy (90% CI)</td>
<td>Leukemia excluding CLL (linear-quadratic) ERR/Gy (90% CI)</td>
</tr>
<tr>
<td>3-country</td>
<td>– 0.07 (–0.39, 0.30)</td>
<td>2.18 (0.13, 5.7)</td>
</tr>
<tr>
<td>15-country excl Canada</td>
<td>0.97 (0.27, 1.8)</td>
<td>1.9 (&lt;0, 7.1)</td>
</tr>
<tr>
<td>NRRW</td>
<td>0.28 (0.02, 0.6)</td>
<td>1.7 (0.1, 4.3)</td>
</tr>
<tr>
<td>Atomic bomb survivors</td>
<td>0.26 (0.14, 0.41)</td>
<td>1.4 (0.1, 3.4)</td>
</tr>
</tbody>
</table>

### IARC* 15-Country Study: Mortality for Solid Cancers Related Versus Not Related to Smoking

<table>
<thead>
<tr>
<th>Smoking-Related Vs. Not Related</th>
<th>ERR/Gy (90% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Solid Cancers</td>
<td>0.87 (0.02, 1.9)</td>
</tr>
<tr>
<td>Smoking-Related Lung cancer</td>
<td>0.91 (–0.1, 2.2)</td>
</tr>
<tr>
<td>Other smoking-related</td>
<td>1.85 (0.26, 4.0)</td>
</tr>
<tr>
<td></td>
<td>0.21 (&lt;0, 2.0)</td>
</tr>
<tr>
<td>Unrelated</td>
<td>0.62 (–0.5, 2.2)</td>
</tr>
</tbody>
</table>

Cardis et al. BMJ 2005
Large Nuclear Worker Studies: Non-Cancer Mortality

• IARC* 15-country study
  - Little evidence of dose-response relationship
  - Suggested dose-response for attained age <50

• NRRW
  - Dose-response for circulatory disease mortality
  - Possible confounding by smoking

* International Agency for Research on Cancer
Radiation Worker Studies: Assessment

• **Strengths:**
  - Provide risk estimates of cancer and other health effects associated with low dose, low dose rate radiation exposures
  - Exposure-response based on annual dose estimates derived from monitoring data (and other sources for some studies)
Radiation Worker Studies: Assessment

• Weaknesses:
  - Subject to limitations of low dose epidemiologic studies
  - Lack of badge measurement data in early periods for medical radiation workers
  - Uncertainties, errors, & missing measurements
  - Potential biases due to confounding, questionnaire-derived recall
  - Lack of data on confounding factors