Epidemiologic Studies of the Mayak Worker and Techa River Cohorts

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Mayak Nuclear Facility

- First and largest nuclear weapons facility in the former Soviet Union
- Began operations in 1948
- Large exposures to both workers and surrounding populations, mostly during the late 1940’s and 1950’s
- Protracted low dose rate exposure similar to that of interest for radiation protection
Mayak nuclear facility
Before 1990, Russian investigators established

- **Mayak worker registry**
  - Currently includes 26,000 workers hired 1948-82

- **Techa River cohort**
  - Currently includes 30,000 people who lived in river bank villages downstream of Mayak facility 1950-61

NCI, DOE, and the EC have supported research on these cohorts

- Many US and European scientists involved
Contributions of cohorts exposed from Mayak operations

• Large numbers of people exposed to a wide range of doses of low LET radiation at low dose rates
  - Both Mayak workers and Techa River cohort

• Persons exposed to internal sources
  - Plutonium (Mayak workers)
  - Strontium and cesium (Techa River cohort)

• Long term follow-up
  - Largest exposures occurred in early 1950’s
Dosimetry

• International collaborative program for improving individual dose estimates
  – Supported by DOE and EC

• Since BEIR VII, many improvements in dose estimates for both Mayak worker and Techa River cohorts
  – Large number of publications on dosimetry.
Rest of this talk

• Overview of most important findings

• Mayak worker cohort (MWC): External dose

• Mayak worker cohort (MWC): Plutonium

• Techa River cohort (TRC)
Mayak Worker Cohort: External doses

Status at time of BEIR VII

• Shilnikova et al. Radiat Res 2003

• Dose-response analyses for solid cancer and leukemia mortality for the period 1948-1997

• Based on archive film badge doses
  – no adjustment for dosimeter limitations
Mayak Worker Cohort (MWC): External Doses

Current Status

• Many dosimetry improvements

• Updated solid cancer mortality analyses based on follow-up period 1948-2008.

• Solid cancer incidence analyses 1948-2004

• Cardiovascular disease mortality and incidence analyses
Mortality from solid cancers other than lung, liver, and bone: External Dose (MWC)

<table>
<thead>
<tr>
<th>Dose (Gy)</th>
<th>Person-years</th>
<th>Observed deaths</th>
<th>Excess* deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.1</td>
<td>516,997</td>
<td>627</td>
<td>3.0</td>
</tr>
<tr>
<td>0.1-</td>
<td>248,626</td>
<td>558</td>
<td>22.9</td>
</tr>
<tr>
<td>0.5-</td>
<td>93,270</td>
<td>282</td>
<td>28.0</td>
</tr>
<tr>
<td>1-</td>
<td>72,944</td>
<td>271</td>
<td>48.9</td>
</tr>
<tr>
<td>2-</td>
<td>15,146</td>
<td>63</td>
<td>17.5</td>
</tr>
<tr>
<td>3+</td>
<td>3,913</td>
<td>24</td>
<td>7.7</td>
</tr>
<tr>
<td>Total</td>
<td>950,894</td>
<td>1825</td>
<td>127.9 (7.1%)</td>
</tr>
</tbody>
</table>

*Estimated excess due to external exposure based on the assumption of a linear dose-response.

Sokolnikov et al. 2014, in press
### ERR/Gy: Solid cancers other than lung, liver and bone: External dose (MWC)

<table>
<thead>
<tr>
<th></th>
<th>Not adjusted for Pu dose</th>
<th>Adjusted for Pu dose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mortality</strong>*</td>
<td>0.16 (0.07, 0.36)</td>
<td>0.11 (0.03, 0.21)</td>
</tr>
<tr>
<td>Colon dose</td>
<td>1825 deaths (1948-2008)</td>
<td></td>
</tr>
<tr>
<td><strong>Incidence</strong>*</td>
<td>0.07 (0.01, 0.15)</td>
<td>0.06 (−0.01, 0.14)</td>
</tr>
<tr>
<td>Hp(10)</td>
<td>1447 cases (1948-2004)</td>
<td></td>
</tr>
</tbody>
</table>

A-bomb survivors: 0.35 (0.19-0.55)

*Sokolnikov et al 2014; **Hunter et al. 2013
### ERR/Gy: Cardiovascular Disease External dose (MWC)

<table>
<thead>
<tr>
<th></th>
<th>Ischemic heart disease*</th>
<th>Cerebro-vascular disease**</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mortality</strong></td>
<td>0.03 (−0.04, 0.10)</td>
<td>0.05 (-0.03, 0.16)</td>
</tr>
<tr>
<td></td>
<td>2557 deaths</td>
<td>1578 deaths</td>
</tr>
<tr>
<td><strong>Incidence</strong></td>
<td>0.15 (0.08, 0.21)</td>
<td>0.46 (0.37, 0.57)</td>
</tr>
<tr>
<td></td>
<td>6219 cases</td>
<td>8717 cases</td>
</tr>
</tbody>
</table>

Mayak Worker Cohort: Plutonium

- Last BEIR report to address alpha emitters other than radon was BEIR IV (1988)

Currently available

- Lung, liver, and bone cancer mortality analyses
  - Clear evidence of dose-response for all three endpoints

- Lung, liver, and bone cancer incidence analyses

- Cardiovascular disease incidence and mortality analyses
Lung cancer Pu dose-response (MWC)

- Both mortality and incidence data indicate strong linear Pu dose response for lung cancer
  - Decrease in ERR/Gy with attained age

  - Interaction of Pu dose and smoking is intermediate between additive and multiplicative

  - ERR/Gy for adenocarcinomas was 11 times higher then the ERR/Gy squamous cell cancers

Gilbert et al. 2013; Labutina et al. 2013
Lung cancer Pu dose-response (MWC)
Techa River Cohort
Techa River Cohort

• 30,000 people who lived in river bank villages downstream of Mayak facility in the 1950-61

• All ages and both sexes
  – 58% female
  – 40% under age 20 in 1950
Techa River Cohort

Status at time of BEIR VII:

• No individual dose estimates (grouped by village)

• Cancer mortality analyses only
Techa River Cohort

Current Status

- Many dosimetry improvements including individual dose estimates

- Published analyses on:
  - Solid cancer mortality and incidence
  - Leukemia mortality and incidence
  - Cardiovascular disease mortality
### Solid Cancer Mortality: External Dose (TRC)

<table>
<thead>
<tr>
<th>Dose (Gy)</th>
<th>Person-years</th>
<th>Observed deaths</th>
<th>Excess* deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.01</td>
<td>519,473</td>
<td>1105</td>
<td>2.9</td>
</tr>
<tr>
<td>&gt;0,&lt;.1</td>
<td>336,733</td>
<td>969</td>
<td>17.0</td>
</tr>
<tr>
<td>0.1-</td>
<td>49,358</td>
<td>144</td>
<td>12.3</td>
</tr>
<tr>
<td>0.3-</td>
<td>21,074</td>
<td>80</td>
<td>16.1</td>
</tr>
<tr>
<td>0.5+</td>
<td>1,105</td>
<td>5</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>927,743</strong></td>
<td><strong>2303</strong></td>
<td><strong>49.7 (2.2%)</strong></td>
</tr>
</tbody>
</table>

*Estimated excess due to external exposure based on the assumption of a linear dose-response.

Schonfeld et al. 2013
## ERR/Gy: Solid cancer and leukemia
### External dose (TRC)

<table>
<thead>
<tr>
<th></th>
<th>Solid Cancer</th>
<th>Non-CLL Leukemia**</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mortality</strong></td>
<td>0.61 (0.04 to 1.3)</td>
<td>6.5 (1.8 to 24)</td>
</tr>
<tr>
<td></td>
<td>2303 deaths</td>
<td></td>
</tr>
<tr>
<td><strong>Incidence</strong></td>
<td>1.0 (0.3 to 1.9)</td>
<td>2.2 (0.8 to 5.4)</td>
</tr>
<tr>
<td></td>
<td>1836 cases</td>
<td>72 cases</td>
</tr>
</tbody>
</table>

### Cardiovascular Disease: External dose (TRC)

<table>
<thead>
<tr>
<th></th>
<th>Ischemic heart disease</th>
<th>Cerebro-vascular disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>0.56 (0.02, 0.75)</td>
<td>p &gt; 0.5</td>
</tr>
<tr>
<td></td>
<td>3194 deaths</td>
<td>1933 deaths</td>
</tr>
</tbody>
</table>

Krestinina et al. 2012
Summary

- Many publications since BEIR VII based on improved dose estimates

- New data on risks from low LET radiation from both MWC and TRC
  - Solid cancer and leukemia mortality and incidence
  - Cardiovascular disease mortality and incidence
  - Site-specific cancer risks: Not very informative

- New data on risks from plutonium from the MWC
  - Lung, liver and bone cancer mortality and incidence
  - Some data investigating risks of other cancers and cardiovascular disease
What’s coming?

- New Monte Carlo dosimetry systems for Mayak external doses, Mayak Pu doses, and Techa River doses
  - Dose-response analyses will make use of these systems to take account of dosimetry uncertainty
  - May be especially important for plutonium doses

- Updated analyses of MWC leukemia mortality data

- Pooled analyses of Pu effects in Mayak and Sellafield cohorts

- Pooled analyses of Mayak and Techa River in utero data
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