Radiation epidemiology research in Korea

: Current status and future direction

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1. Scope/Objectives
2. Environmental Radiation Exposure
3. Medical Radiation Exposure
4. Occupational Radiation Exposure
5. Research Gap: visible, invisible
6. For Future Research
Scope/Objectives

➢ The current status of radiation research in Korea and internationally
➢ Brief overview of research by exposure source category
➢ What radiation epidemiology research projects are currently performed?
➢ What research questions are being asked?
➢ Lessons from the past studies
➢ Research gaps and future directions
01

Environmental Radiation Exposure
Environmentally Exposed Population

➢ High natural background
  – external gamma
  – radon

➢ Weapons testing fallout
  – Utah, Marshall Islands, Nordic countries, USSR

➢ Contamination
  – Chernobyl, USSR, Hanford, Taiwanese steel, Fukushima
High Natural Background Radiation (HNBR) Areas

- Guarapari, Brazil;
- Kerala, India;
- Ramsar, Iran;
- Yangjiang, China

Kerala and Yangjiang have been paid particular attention.
## Natural and Unnatural Background Radiation

<table>
<thead>
<tr>
<th>Study</th>
<th>Type</th>
<th>Cancer</th>
<th>Cases</th>
<th>Cohort size/Controls</th>
<th>Mean/Median Dose (mGy)</th>
<th>ERR @ 100mGy</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>Case-Control</td>
<td>Leukemia</td>
<td>27,447</td>
<td>36,793</td>
<td>12</td>
<td></td>
<td>(3; 22)</td>
</tr>
<tr>
<td>Yiangjing, China</td>
<td>Cohort</td>
<td>Solid</td>
<td>941</td>
<td>31,604</td>
<td>85 High 22 Low</td>
<td>-0.1</td>
<td>(-0.25; 0.3)</td>
</tr>
<tr>
<td>Switerzland</td>
<td>Cohort</td>
<td>Cancer</td>
<td>1,782</td>
<td></td>
<td>9</td>
<td>3</td>
<td>(1; 5)</td>
</tr>
<tr>
<td></td>
<td>Cohort</td>
<td>Leukemia</td>
<td>530</td>
<td>2,093,660</td>
<td></td>
<td>4</td>
<td>(0; 8)</td>
</tr>
<tr>
<td></td>
<td>Cohort</td>
<td>Lymphoma</td>
<td>328</td>
<td></td>
<td></td>
<td>1</td>
<td>(-4; 5)</td>
</tr>
<tr>
<td>Finland</td>
<td>Case-Control</td>
<td>Leukemia</td>
<td>1,093</td>
<td>3,027</td>
<td>1.96 cases 1.90 controls</td>
<td>-1</td>
<td>(-1; 6)</td>
</tr>
<tr>
<td>India, Kerala</td>
<td>Cohort</td>
<td>Solid cancer</td>
<td>1,349</td>
<td>69,958</td>
<td>110</td>
<td>-0.01</td>
<td>(-0.06; 0.05)</td>
</tr>
<tr>
<td>Taiwan Buildings</td>
<td>Cohort</td>
<td>Cancer</td>
<td>117</td>
<td>6,242</td>
<td>48</td>
<td>0.19</td>
<td>(0.01; 0.31)</td>
</tr>
</tbody>
</table>
Natural Background Radiation

- small predicted effects
- influence of confounding factors.
- Large study are required
- Gamma-ray effect > radon
- The impact of residential radon on lung cancer and childhood leukaemia risk
Radon Exposure in Korea

- Natural (residential radon) and unnatural (commercial product) exposure
- Map insert
- Lung cancer map
- Radon incidents and report
The Disease Burden of Lung Cancer Attributable to Residential Radon Exposure in Korean Homes

Attributable risk of lung cancer deaths due to indoor radon exposure

Si-Heon Kim¹, Won Ju Hwang², Jeong-Sook Cho³ and [Author]

International Journal of Environmental Research and Public Health

Geographical Correlations between Indoor Radon Concentration and Risks of Lung Cancer, Non-Hodgkin’s Lymphoma, and Leukemia during 1999–2008 in Korea

Mina Ha¹, Seung-sik Hwang², Sungchan Kang², No-Wook Park³, Byung-Uck Chang⁴ and Yongjae Kim⁴

Health effects of exposure to radon bed mattress incident

Songwon Seo, Wi-Ho Ha, Jin-Kyu Kang, Dalnim Lee, Soojin Park, Tae-Eun Kwon, Young Woo Jin
## Nuclear Power Plant Accidents/Weapons Testing Fallout

<table>
<thead>
<tr>
<th>Study</th>
<th>Type</th>
<th>Cancer</th>
<th>Cases</th>
<th>Cohort size/Controls</th>
<th>Mean/Median Dose (mGy)</th>
<th>ERR @ 100mGy</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three Mile Island</td>
<td>Cohort</td>
<td>Solid Inc</td>
<td>1,643</td>
<td>21,494</td>
<td>0</td>
<td>-1</td>
<td>(-1; 30)</td>
</tr>
<tr>
<td>Chornobyl-Ukraine</td>
<td>Cohort</td>
<td>Thyroid</td>
<td>65</td>
<td>12,415</td>
<td>650/200</td>
<td>0.19</td>
<td>(0.04; 0.63)</td>
</tr>
<tr>
<td></td>
<td>Case-Control</td>
<td>Thyroid</td>
<td>66</td>
<td>835</td>
<td>cases 44 controls 16</td>
<td>4.9</td>
<td>(0.5; 12)</td>
</tr>
<tr>
<td>Chornobyl-Belarus</td>
<td>Cohort</td>
<td>Thyroid</td>
<td>23</td>
<td>12,504</td>
<td>770</td>
<td>0.21</td>
<td>(0.03; 1.0)</td>
</tr>
<tr>
<td></td>
<td>Cohort (prevalence)</td>
<td>Thyroid</td>
<td>87</td>
<td>11,970</td>
<td>560/230</td>
<td>0.21</td>
<td>(0.08; 0.54)</td>
</tr>
<tr>
<td>Chernobyl Bel, Ukr, Rus</td>
<td>Case-Control</td>
<td>Leukemia</td>
<td>421</td>
<td>824</td>
<td>11/0.9 (cases) 4/0.7 (controls)</td>
<td>3.2</td>
<td>(0.9; 8.4)</td>
</tr>
<tr>
<td>Techa River</td>
<td>Cohort</td>
<td>Solid Inc</td>
<td>1,933</td>
<td>17,435</td>
<td>52/15</td>
<td>0.08</td>
<td>(0.01; 0.15)</td>
</tr>
<tr>
<td></td>
<td>Cohort</td>
<td>Solid Mort</td>
<td>2,303</td>
<td>29,730</td>
<td>35</td>
<td>0.06</td>
<td>(0.004; 0.13)</td>
</tr>
<tr>
<td></td>
<td>Cohort</td>
<td>Leukemia</td>
<td>72</td>
<td>28,233</td>
<td>250/410</td>
<td>0.22</td>
<td>(0.08; 0.54)</td>
</tr>
<tr>
<td>Hanford I131</td>
<td>Cohort (prevalence)</td>
<td>Thyroid</td>
<td>19</td>
<td>3,191</td>
<td>174/97</td>
<td>0.07</td>
<td>(-0.03; 0.6)</td>
</tr>
<tr>
<td>Utah Fallout</td>
<td>Case-Control</td>
<td>Leukemia</td>
<td>939</td>
<td>4,302</td>
<td>2.9 cases 2.7 controls</td>
<td>4.5</td>
<td>(-0.4; 14)</td>
</tr>
</tbody>
</table>
## Living near Nuclear Power Plant

<table>
<thead>
<tr>
<th>Country</th>
<th>F/U period</th>
<th>Population</th>
<th>Comparison group</th>
<th>Study design</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>2002-2007</td>
<td>Living near NPP, Dx by Leukemia Age &lt;15</td>
<td>case 2,753 person, control 30,000 person</td>
<td>Case-Control study</td>
<td>Odds ratio 1.9 (1.0-3.3), Insufficient data, Overestimation possible, Not available to confirm living history</td>
</tr>
<tr>
<td>USA</td>
<td>1950-1984</td>
<td>Living near NPP</td>
<td>NPP area: 1,872, Comparison: 3,298</td>
<td>Ecological study</td>
<td>Before NPP operation Leukemia mortality RR=1.08, After operation RR=1.03 : no differences before/after</td>
</tr>
<tr>
<td>Germany</td>
<td>1980-2003</td>
<td>Living near NPP, Dx by Leukemia Age &lt;5</td>
<td>case 593, control 1,766</td>
<td>Case-Control study</td>
<td>Increased leukemia risk by closer distance with NPP, No confounding control</td>
</tr>
<tr>
<td>Finland</td>
<td>1975-2004, 1980-2000, 1977-2004</td>
<td>Living near NPP, Dx by Leukemia Age &lt;15</td>
<td>Adolescents &lt;15, 13,000 person/year, case 16, control 64</td>
<td>Ecological study, Retrospective cohort Case-Control study</td>
<td>SIR 1.0 (0.6-1.6), RR 1.0 (0.3-2.6), 0.9 (0.2-2.7), OR = 0.7 (0.1-10.4)</td>
</tr>
<tr>
<td>UK</td>
<td>1962-2007</td>
<td>Living near NPP, Dx by Leukemia Age &lt;5</td>
<td>case 9,821, control 9,821</td>
<td>Case-Control study</td>
<td>At Birth OR = 0.86 (0.49-1.52), At Diagnosis OR = 0.86 (0.62-1.18)</td>
</tr>
<tr>
<td>Belgium</td>
<td>2000-2008</td>
<td>Living near NPP, Thyroid cancer</td>
<td>Living NPP near 20km distance</td>
<td>Ecological study</td>
<td>Doel: RR = 0.75 (0.63-0.83), Tihange: RR = 0.85 (0.70-1.02), Mol-Dessel: RR = 1.19 (1.02-1.38), Fleurus: RR = 1.17 (1.04-1.33)</td>
</tr>
</tbody>
</table>
Cancer Risk in Adult Residents near Nuclear Power Plants in Korea - A Cohort Study of 1992-2010

Yoon-Ok Ahn, Zhong Min Li, and The KREEC Study Group

This study evaluated cancer risk for adult residents near Nuclear Power Plants (NPPs) in Korea through a valid prospective cohort composed of 11,367 adults living and 24,809 adults for the non-exposed population; 5-30 km radius and n person-years of follow-up, a total of 220,000 cancers diagnosed during 2012-2010.

Reanalysis of Epidemiological Investigation of Cancer Risk among People Residing near Nuclear Power Plants in South Korea

Jeong-Min Kim, Myoung-Hee Kim, Young-Su Ju, Seungsik Hwang, Mina Ha, Bong-Kyu Kim, Kyung Eui Zoh, and Domyung Paek

1 Department of Occupational and Environmental Medicine, Cheongju Medical Center, Cheongju 28547, Korea; juc28ten@yahoo.co.kr
2 People’s Health Institute, Seoul 07004, Korea; hongsili@gmail.com
3 Department of Occupational & Environmental Medicine, Hallym University Sacred Heart Hospital, Hallym University College of Medicine, Anyang 14068, Korea; zoro@hallym.ac.kr
4 Department of Public Health Science, School of Public Health, Seoul National University, Seoul 08826, Korea.

02 Medical Radiation Exposure
Increase in Medical Exposures: international trend

![Graph showing increase in medical exposures across different categories and periods.](image-url)
Impact of Increases in CT on Proportion of Cancers Attributable to Diagnostic Exposures

- **UK**: 0.0%
- **USA**: 0.5%
- **JAPAN**: 1.0%
- **GERMANY**: 1.5%

**Annual Diagnostic Exposures (per 1000)**

<table>
<thead>
<tr>
<th>Country</th>
<th>Use 1990s</th>
<th>Use 2000s</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Korea</td>
<td>957/1000</td>
<td>10</td>
</tr>
</tbody>
</table>

UNSCEAR 20
Pooled Analysis of Medical Cohorts and Thyroid Cancer

9 cohorts of childhood exposure
- 394 thyroid cancers
- 221 leukemias

Diagnostic/Therapeutic radiation
- Restricted to <200 or <100 mGy

Relative risk vs. Radiation dose (Gy)

Lubin, ..., Veiga (JCEM 2017); Little, ..., Berrington (Lancet Haematology, 2018)
EPI-CT: 1 Million Children from 9 Countries

Expanded UK cohort + 8 countries
- UK 320k
- Netherlands 150k
- Sweden 120k
- 150+ leukemias
- 200+ brain tumors

CT scans from RIS/PACs
- 1.4m CTs (72% head CT)
USA Kaiser Pediatric Imaging Case-Control Study

(Pis: Simth-Bindman, Migliorett, Kwan)

4 Kaiser HMOs
- 750 leukemias (estimated)
- Controls matched on age & time in health plan (exposure window)

Imaging data from PACs
- In utero & childhood exposures
Increase in Medical Exposures in Korea

- Annual average exposure in Korean: 3.08 (mSv/year),
- Medical radiation exposure: 0.74 → 1.4

Trend of annual effective dose per person by diagnostic examination
Health effects from exposure to dental diagnostic X-ray

A Survey of Pediatric CT Protocols and Radiation Doses in South Korean Hospitals to Optimize the Radiation Dose for Pediatric CT Scanning

Jae-Yeon Hwang, MD, Kyung-Hyun Do, MD, PhD, Dano Hwan Yoon, MD, PhD, Yonwoo Ah Cho, MD, PhD, Hye-Ki

Current status of medical radiation exposure in Korea - recent efforts to develop a radiation exposure control system focussed on justification and optimisation.

Do KH¹, Jung SE²

Association of Exposure to Diagnostic Low-Dose Ionizing Radiation With Risk of Cancer Among Youths in South Korea.

Hong JY¹, Han K², Jung JH², Kim JS³.
03 Occupational Radiation Exposure
<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Outcome</th>
<th>Sample size</th>
<th>Cases</th>
<th>Mean dose</th>
<th>ERR per 100mGy</th>
<th>95% CI (90% CI*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korean workers</td>
<td>2008</td>
<td>Cancer mortality</td>
<td>79,679</td>
<td>134</td>
<td>6mSv</td>
<td>0.72</td>
<td>-0.5 to 2.1</td>
</tr>
<tr>
<td>Korean nuclear workers</td>
<td>2010</td>
<td>Cancer incidence</td>
<td>16,236</td>
<td>203</td>
<td>20mSv</td>
<td>0.21</td>
<td>-0.19 to 0.9</td>
</tr>
<tr>
<td>Rocketdyne</td>
<td>2011</td>
<td>Cancer mortality</td>
<td>46,970</td>
<td>647</td>
<td>14mSv</td>
<td>0.02</td>
<td>-0.18 to 0.17</td>
</tr>
<tr>
<td>Japanese workers</td>
<td>2012</td>
<td>Cancer mortality</td>
<td>200,583</td>
<td>2,636</td>
<td>12mSv</td>
<td>0.13</td>
<td>-0.03 to 0.30</td>
</tr>
<tr>
<td>Canadian workers</td>
<td>2013</td>
<td>Cancer mortality</td>
<td>45,316</td>
<td>437</td>
<td>22mSv</td>
<td>0.18</td>
<td>-0.04 to 0.53</td>
</tr>
<tr>
<td>German nuclear workers</td>
<td>2014</td>
<td>Cancer mortality</td>
<td>8,972</td>
<td>115</td>
<td>20mSv</td>
<td>-0.1</td>
<td>-0.4 to 0.1</td>
</tr>
<tr>
<td>USRT</td>
<td>2016</td>
<td>Breast cancer</td>
<td>66,915</td>
<td>1,922</td>
<td>37mGy</td>
<td>0.07</td>
<td>-0.005 to 0.19</td>
</tr>
<tr>
<td>US nuclear workers**</td>
<td>2015</td>
<td>Cancer mortality</td>
<td>119,195</td>
<td>10,877</td>
<td>20mSv</td>
<td>0.01</td>
<td>-0.02 to 0.05</td>
</tr>
<tr>
<td>UKNRRW**</td>
<td>2009</td>
<td>Cancer incidence</td>
<td>174,451</td>
<td>11,133</td>
<td>25mSv</td>
<td>0.03</td>
<td>0.004 to 0.05</td>
</tr>
<tr>
<td>French nuclear workers**</td>
<td>2017</td>
<td>Cancer mortality</td>
<td>59,004</td>
<td>2,536</td>
<td>26mSv</td>
<td>0.04</td>
<td>-0.04 to 0.13†</td>
</tr>
<tr>
<td>INWORKS</td>
<td>2015</td>
<td>Cancer mortality</td>
<td>308,297</td>
<td>17,957</td>
<td>21mGy</td>
<td>0.05</td>
<td>0.018 to 0.079†</td>
</tr>
</tbody>
</table>
Path to recognition of occupational carcinogens

Analytical studies

Comparative mortality

Case reports

Deaths from major causes and leukemia in RSNA, 1958-1988, with expected deaths based on the age- and time-specific mortality rates of the AAMO

<table>
<thead>
<tr>
<th>Cause of death</th>
<th>Age group (years)</th>
<th>Observed deaths in RSNA</th>
<th>Expected deaths in AAMO</th>
<th>Expected observed ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>All causes</td>
<td>35-49</td>
<td>79</td>
<td>61.5</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>50-64</td>
<td>339</td>
<td>271.3</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>65-79</td>
<td>438</td>
<td>293.0</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>75-79</td>
<td>556</td>
<td>628.0</td>
<td>1.4</td>
</tr>
<tr>
<td>Leukemia</td>
<td>35-49</td>
<td>2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>50-64</td>
<td>8</td>
<td>1.1</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>65-79</td>
<td>9</td>
<td>4.7</td>
<td>2.3</td>
</tr>
</tbody>
</table>
|               | 75-79            | 19                      | 7.7                     | 11.3                   | 2.5

Red bone marrow dose (mGy)
Korean Study


Lee WJ1, Cha ES, Ha M, Jin YW, Hwang SS, Kong KA, Lee SW, Lee HK, Lee KY, Kim HJ.


Jeong M1, Jin YW, Yang KH, Ahn YO, Cha CY.


A national survey of occupational radiation exposure among diagnostic radiologic technologists in South Korea.
Lee J1, Cha ES2, Jeong M3, Lee WJ4.
Korean Study

**Occupational radiation exposure and its health effects on interventional medical workers: study protocol for a prospective cohort study.**

Ko S^1,2, Chung HH^3, Cho SB^4, Jin YW^5, Kim KP^6, Ha M^7, Bang YJ^1,2, Ha YW^1, Lee WJ^1,2.

**Projected lifetime cancer risks from occupational radiation exposure among diagnostic medical radiation workers in South Korea.**

Lee WJ^1, Choi Y^2, Ko S^3, Cha ES^3, Kim J^4, Kim YM^5, Kong KA^6, Seo S^7, Bang YJ^3, Ha YW^3.

**Assessing the health effects associated with occupational radiation exposure in Korean radiation workers: protocol for a prospective cohort study.**

Seo S^1, Lim WY^1, Lee DN^1, Kim JU^1, Cha ES^2, Bang YU^2, Lee WJ^2, Park S^1, Jin YW^1.

**Thyroid cancer risks among medical radiation workers in South Korea, 1996-2015.**

Lee WJ^1, Preston DL^2, Cha ES^3, Ko S^3, Lim H^4.
Research Gap: visible, invisible
05 For Future Research
Summary of Epidemiologic Considerations

1) Environmental exposure

- Design Issues
- Confounding
- Dose Uncertainty
Summary of Epidemiologic Considerations

2) Medical Exposure

- Contemporary RT regimens, IMRT, proton: lower doses to larger volumes
- RT dose/volume effects (combination)
- Interaction between RT and Chemotherapy
- Study highly radiosensitive population and outcomes to maximize power
- Retrospective record linkage design for efficiency, to avoid recall bias
- Long follow-up periods
- Bias, Confounding by indication & reverse causation
3) Occupational Exposure

- New pooling efforts and updating of existing cohorts
- Evolution of study cohorts
- Analytical methods to handle uncertainties in dose estimates
- Attention to temporal factors: older age distributions at end of follow-up
- Counterfactual frameworks for analysis
- Nested studies to improve exposure/outcome information
- Research programs
Thank You