Cancer mortality among German aircrew: second follow-up

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Introduction

• Regulative Aspects
  – ICRP recommends to consider flying personnel as occupationally exposed (1991)
  – Implementation in National Radiation Protection Regulations (Germany: 2000)

• Scientific interest
  – Effects of neutron radiation
  – Low dose effects

• Concerns of employees: Health Risk?
Cosmic radiation exposure

- Primary cosmic radiation generates complex field of secondary particles
- Neutrons dominate effective dose
  - 10% dose, ~ 50% dose equivalent
- Dose rates depend on altitude, latitude, solar cycle
- Range from 1-10 microSv/h
  - 600 – 1000 hours per year typical
- Personal dosimetry
  - not useful / recommended for routine use
  - dose calculation software (CARI, EPCARD, others)
• Tissue equivalent proportional counters

• Bubble detectors

Courtesy of M. Meier, DLR
Other “exposures” with potential relevance for cancer risk

**Occupational exposures of aircrew**
- Electromagnetic fields
- Turbine exhausts, Passive smoking (in the past)
- Circadian rhythm disruptions, shift work
  - IARC 2008: 2A carcinogen
- Pesticides

**Other risk factors**
- Life-style factors (UV, Alcohol)
- Reproductive factors
ESCAPE
European Studies of Cancer Among flying PErsonnel

- Low doses: small potential risk increases
- Maximise power by large study size
- European cooperation, 9 countries
  - (Denmark, Finland, Germany, Greece, Iceland, Italy, Norway, Sweden, United Kingdom)
- Coordination: German group
- Cohort studies with very similar design
- F/U 1960 – 1997 (some variations)
## ESCAPE: SMR Cancer

<table>
<thead>
<tr>
<th>Cause of death</th>
<th>Cockpit, Men</th>
<th>Cabin, Men</th>
<th>Cabin, Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>O</td>
<td>SMR</td>
<td>95% CI</td>
</tr>
<tr>
<td>All cancer</td>
<td>677</td>
<td>0.68</td>
<td>0.63 - 0.74</td>
</tr>
<tr>
<td>Buc.cavity/pharynx</td>
<td>13</td>
<td>0.54</td>
<td>0.29 - 0.95</td>
</tr>
<tr>
<td>Large intestine</td>
<td>64</td>
<td>1.07</td>
<td>0.81 - 1.38</td>
</tr>
<tr>
<td>Rectum</td>
<td>30</td>
<td>0.80</td>
<td>0.54 - 1.16</td>
</tr>
<tr>
<td>Lung</td>
<td>153</td>
<td>0.53</td>
<td>0.44 - 0.62</td>
</tr>
<tr>
<td>Malig.melanoma</td>
<td>25</td>
<td>1.78</td>
<td>1.15 - 2.67</td>
</tr>
<tr>
<td>Breast</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prostate</td>
<td>54</td>
<td>0.94</td>
<td>0.71 - 1.26</td>
</tr>
<tr>
<td>CNS</td>
<td>41</td>
<td>1.20</td>
<td>0.87 - 1.67</td>
</tr>
<tr>
<td>All lymphoma</td>
<td>25</td>
<td>0.75</td>
<td>0.48 - 1.13</td>
</tr>
<tr>
<td>Non-CLL leukemia</td>
<td>21</td>
<td>1.12</td>
<td>0.67 - 1.70</td>
</tr>
</tbody>
</table>
Methods

• Cohort definition
  – All crew identified from personnel records of Lufthansa and LTU International Airways
  – Inclusion 1960 - 1997
  – Cabin crew: minimum ½ year cumulative
  – Cockpit: no limit
  – Limited information of pre-entry flight activity
  – No information on post-exit flight activity
Follow-up and analysis

• All non-deceased cohort members (as of end 1997) followed up via
  – Personnel files (still employed ?)
  – Population registries
  – Public health offices (to obtain death certificates)
  – Intense cohort search to reduce losses
Analysis

- SMR and 95% CI (Ref: German pop.)
- Correction for missing causes of death using a proportional imputation method
  - stratum-specific in stratified analyses
- Poisson regression analysis to estimate effects of duration of employment
  - 0-<10y, 10-<20y, 20-<30y, 30+y
- High correlation *duration-dose* shown previously *

* Hammer et al, Rad Env Biophys 2000
Exposure information

• Duration of employment as aircrew
  – No information on part time employment

• for cockpit: information on licence, type of aircraft, annual individual block hours

• flight schedules of aircraft
  – µSv/Block hour, per year and aircraft type

• leads to job exposure matrix for an estimate of annual effective dose
## Dosimetry: Job-Exposure-Matrix

### Job history \times \text{Job-Exposure-Matrix} = \text{estimated radiation dose}

<table>
<thead>
<tr>
<th>PK</th>
<th>Name</th>
<th>Flugstunden</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Muster</th>
<th>Flugstunden</th>
<th>Flugstunden</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>F1 Lockheed</td>
<td>F1 B707</td>
</tr>
<tr>
<td>Vorjahre</td>
<td>1978</td>
<td>290</td>
</tr>
<tr>
<td></td>
<td>1979</td>
<td>377</td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td>446</td>
</tr>
<tr>
<td></td>
<td>1981</td>
<td>510</td>
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<td>1982</td>
<td>445</td>
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<td>1985</td>
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<td>1986</td>
<td>212</td>
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<td></td>
<td>1987</td>
<td>377</td>
</tr>
<tr>
<td></td>
<td>1988</td>
<td>354</td>
</tr>
<tr>
<td></td>
<td>1989</td>
<td>312</td>
</tr>
<tr>
<td></td>
<td>1990</td>
<td>269</td>
</tr>
<tr>
<td></td>
<td>1991</td>
<td>333</td>
</tr>
</tbody>
</table>

| Total | 916   | 3647       | 5876       | 1268       |
Job-Expositions-Matrix (JEM)

Job Exposure Matrix for Lufthansa cohort
computed from flight schedules with CARI-5E

Date

Effective Radiation Dose Rate (µSv/h)

B 707
B 727
B 737
B 747
B 757
A 300
A 310
A 320
A 340
DC 10
Convair 440
Super-G
Viking
F-27

Data up to 1997

- Median cumulative dose of German pilots
  - retired pilots (as of 1997): 42 mSv
  - active pilots: 20 mSv
  - Max. lifetime: ~ 80 mSv

- Same approach used in extended f/u
  - Data protection issues an obstacle
  - Data collection ongoing
### Results German cohort: follow-up to end 2003

<table>
<thead>
<tr>
<th></th>
<th>Cockpit</th>
<th></th>
<th>Cabin</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td>Persons</td>
<td>6017</td>
<td>90</td>
<td>3735</td>
<td>17022</td>
<td>26864</td>
</tr>
<tr>
<td>deaths 1997</td>
<td>255</td>
<td>0</td>
<td>170</td>
<td>141</td>
<td>566</td>
</tr>
<tr>
<td>deaths 2003</td>
<td>385</td>
<td>0</td>
<td>232</td>
<td>266</td>
<td>883</td>
</tr>
<tr>
<td>cancer deaths</td>
<td>127</td>
<td>0</td>
<td>45</td>
<td>103</td>
<td>275</td>
</tr>
<tr>
<td>lost to follow-up</td>
<td>67</td>
<td>2</td>
<td>96</td>
<td>453</td>
<td>618</td>
</tr>
<tr>
<td>emigrated</td>
<td>345</td>
<td>7</td>
<td>302</td>
<td>1339</td>
<td>1993</td>
</tr>
<tr>
<td>Person-years</td>
<td>136413</td>
<td>1125</td>
<td>71374</td>
<td>296563</td>
<td>505475</td>
</tr>
<tr>
<td>Mean follow-up (yrs)</td>
<td>22.7</td>
<td>12.5</td>
<td>19.1</td>
<td>17.4</td>
<td>18.8</td>
</tr>
</tbody>
</table>

*Missing CoD: Cockpit 6.3%; Cabin 13.6%*
Duration of employment

<table>
<thead>
<tr>
<th>Arithm. mean</th>
<th>Cockpit, Males</th>
<th>Cabin, Males</th>
<th>Cabin, Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>not employed</td>
<td>20.18</td>
<td>13.79</td>
<td>8.73</td>
</tr>
<tr>
<td>still employed</td>
<td>18.31</td>
<td>14.39</td>
<td>14.58</td>
</tr>
</tbody>
</table>
Standardized Mortality Ratios - Cockpit

• Will be presented in conference-related publication

• Overall:
  – SMR for all cancer reduced,
  – Maked reduction of lung cancer SMR
  – Few individual cancers with elevated SMR
Standardized Mortality Ratios – Cabin Crew

- Will be presented in conference-related publication

- Most cancers with non-significant SMRs
  - Includes breast cancer
Discussion

- Large cohort of aircrew
- About 60% increase in cohort deaths from 1997-2003
  - Low overall mortality cockpit (SMR ~ 0.5)
- Follow-up of a mobile group poses difficulties
- Loss to follow-up moderate
  - Missing death certificates continue to be a problem
Exposure

• Outstanding: computation of radiation dose estimates
  – CARI
  – EPCARD software
  – Consider computing ERR per dose
Outlook: non-cancer endpoints

- Melanoma (Iceland, Sweden)
- Cataract (Iceland)
- Reproductive health (USA)
- Mental health, stress (Italy, USA)
- Cardiovascular health (Sweden)
- Chromosomal aberrations (latest: NIOSH-NCI study, OEM 2009)
  - finds association of translocation frequency (in lymphocytes) with flight years
Outlook

• COSMIC (or ESCAPE II)
  – Extended health follow-up of existing cohorts until 31.12.2004 or longer
  – Extended dosimetry data
  – Inclusion of further cohorts (US PAN AM cohort)
  – Relevant increases in case number

• Next update of pooled analyses
  – Additional measure: time zones crossed?
  – Germany
    • Additional use of EPCARD 3.3.4
    • National Dose Registry (since 08/2003)
Acknowledgments

• EU (BIOMED) for ESCAPE I
• BfS for COSMIC
• Germany
  – Deutsche Lufthansa, LTU
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  – BG für Fahrzeughaltungen
Thank you

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