Increased Cancer Mortality Risk for NASA’s ISS Astronauts: the Contribution of Diagnostic Radiological Examinations

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NASA Policy & Practices

- NASA Standard 3001 – NASA SPACE FLIGHT HUMAN SYSTEM STANDARD VOLUME 1: CREW HEALTH
  - Career exposure to radiation is limited to not exceed 3 percent Risk of Exposure Induce Death for fatal cancer.
  - Short-term dose limits are imposed to prevent clinically significant non-cancer health effects including performance degradation, sickness, or death in-flight
    - Limited by specific organ, i.e. Blood forming organs, lens of the eye, skin, etc

- For limitation of astronaut risks, NASA monitor all exposures to radiation from spaceflight, occupationally related aviation, and medical exposures required for flight certification
  - The monitoring of aviation and medical exposures is a departure from accepted practices within the ground based radiological protection community

Note: this presentation focuses on radiation exposure risks incurred by the Astronaut Corp
Motivation

• The NASA Radiation Health Officer found a need to educate physicians and astronauts on the radiation exposures and relative risks from various procedures

  – Particularly at a time when new monitoring requirements were being considered

  – This information can also be useful for counseling astronauts reluctant of x-ray exams for fear it may limit their flight career
Required X-rays

Diagnostic X-ray images are required for:

• Acceptance into the Astronaut Corps.
• Screening for mission impacting health issues
• Monitoring of physiological changes due to long-term spaceflight
• Verification of recovery to pre-flight health following long-term spaceflight
## Currently Required X-rays

<table>
<thead>
<tr>
<th>Monitored X-ray Exams</th>
<th>Frequency</th>
</tr>
</thead>
</table>
| Bone Density (DEXA)              | Upon selection into Corps  
Tri-annual  
6 months post flight until density recovery |
| Chest x-ray                      | Annual                                                                    |
| Coronary Calcification (EBCT)    | Upon selection  
Males 40+ every 5 years  
Females 50+ every 5 years      |
| Dental                           |                                                                          |
| Bitewing                         | Once per year  
Every 5 years                                                                 |
| Panoramic                        |                                                                          |
| Mammogram                        | Upon selection  
40-50 years old every two years  
50+ years annual exams          |
Dose Computation

Doses were computed on the average male and female astronaut using commercially available software*:

<table>
<thead>
<tr>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height 177 cm</td>
<td>Height 169 cm</td>
</tr>
<tr>
<td>Weight 82.7 Kg</td>
<td>Weight 63.1 Kg</td>
</tr>
</tbody>
</table>

Average age at entry into the Corps 36
Average age at first mission 42
Average age at second mission 52

* PCXMC and ImPACT
## Dose Results

### Males

<table>
<thead>
<tr>
<th>Exam Type</th>
<th>Effective dose per series (mSv)</th>
<th>Percent of average U.S. annual dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td>0.1</td>
<td>3.0 %</td>
</tr>
<tr>
<td>EBCT</td>
<td>0.3</td>
<td>8.3 %</td>
</tr>
<tr>
<td>Dental Bitewing (4) or Panoramic</td>
<td>0.028</td>
<td>0.78 %</td>
</tr>
<tr>
<td>DEXA series (7)</td>
<td>0.013</td>
<td>0.4 %</td>
</tr>
</tbody>
</table>

### Females

<table>
<thead>
<tr>
<th>Exam Type</th>
<th>Effective dose per series (mSv)</th>
<th>Percent of average U.S. annual dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td>0.1</td>
<td>3.0 %</td>
</tr>
<tr>
<td>EBCT</td>
<td>0.3</td>
<td>8.3 %</td>
</tr>
<tr>
<td>Dental Bitewing (4) or Panoramic</td>
<td>0.028</td>
<td>0.78 %</td>
</tr>
<tr>
<td>DEXA series (7)</td>
<td>0.025</td>
<td>0.7 %</td>
</tr>
<tr>
<td>Mammogram</td>
<td>0.52</td>
<td>14.4 %</td>
</tr>
</tbody>
</table>

U.S National Average Background Dose $≈ 360$ mrem / year
Dose Results

Annual Dose from Required Medical Exams

U.S. Average Annual Background Dose

- Males
- Females

Dose Equivalent (mSv)

Age at Exposure
Dose Results

Annual Dose from Required Medical Exams

<table>
<thead>
<tr>
<th>Age at Exposure</th>
<th>Dose Equivalent (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>40</td>
<td>0.5</td>
</tr>
<tr>
<td>45</td>
<td>1</td>
</tr>
<tr>
<td>50</td>
<td>1.5</td>
</tr>
<tr>
<td>55</td>
<td>2</td>
</tr>
<tr>
<td>60</td>
<td>2.5</td>
</tr>
</tbody>
</table>

- **Males**: All Breast exams from X-rays
- **Females**: Breast exams Alternating between X-rays and MRIs
NASA’s Risk Model

- **REID** – Risk of Exposure Induced Death
  - Cancer induction is believed to be the most significant health impact from radiation exposure
  - In current model risk varies with the age and sex of the astronaut
  - Non-cancer mortality not currently included

- NASA is required to manage to below a 3% excess risk of death
  - Uncertainties in the risk projection are large enough that NASA manages to the 95% Confidence Interval

- Data on non-cancer mortality are being accumulated and should be reflected in NASA’s next risk model
Risks in Perspective

• To compare doses from medical exposures the risks were compared to a long astronaut career
  – Continuing availability for spaceflight is the main concern for most astronauts
    – Medical doses were compared to a male and female astronaut with a total of 2 typical shuttle missions and 2 typical space station missions.

Currently

  Typical Shuttle mission – 300-400 km – 2 weeks – 8 mSv (800 mrem)
  Typical Station mission – 300-400 km – 6 months – 80 mSv (8000 mrem)
Cumulative Excess Mortality Risk

Male

<table>
<thead>
<tr>
<th>Age</th>
<th>Medical Procedures</th>
<th>Aviation</th>
<th>Shuttle Mission #2</th>
<th>Station Mission #2</th>
<th>Shuttle Mission #1</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>45</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>50</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>55</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>60</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>
Cumulative Excess Mortality Risk

Female

Percent Excess Cancer Mortality Risk

- Medical Procedures
- Aviation
- Shuttle Mission #2
- Station Mission #2
- Station Mission #1
- Shuttle Mission #1

Age

40 45 50 55 60
Conclusions

• Medical has a very low overall contribution
  – 1 day in space ≈ 2.5 chest x-rays (0.10 mSv)
  – 1 day in space ≈ 43 days on earth (3.6 mSv / yr)

• Career cumulative mortality risk from diagnostic x-rays
  • Males 0.014 % or 1.4 in 10,000
  • Females 0.046 % or 4.6 in 10,000

• Medical x-rays will not prohibit an astronaut (male or female) with an long career from additional missions
Questions ?