Nuclear Powered Intensive Care
Radiation Exposure of Intensive Care Trauma Patients

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1985– Rainbow Warrior

- Greenpeace ship en route to Mururoa atoll to protest against French nuclear testing and the radiation damage in the Pacific.
- Sunk in Auckland Harbour – in the an act of State-sponsored terrorism by French agents.
# COMPARISON OF RADIATION DOSES

(mSv per year)

**Global natural background doses**

- **Typical range**: 1-10
- **Maximum**: \(\sim 100\)
- **Average**: 2.4

**Mururoa and Fangataufa natural background dose**: 1.4 - 3

**Current additional doses from remaining residual radioactive material at Mururoa and Fangataufa**

- **Maximum at Tureia**: < 0.0001
- **Average at Mururoa and Fangataufa**: < 0.01
- **Maximum at Kilo-Empereur region in Fangataufa**: \(\sim 0.25\)

**Maximum additional dose at Tureia following a rock slide at Mururoa**: 0.007 (initial year)

**IAEA recommended guidelines for remediation**: 10
Risks of Radiation Damage in NZ

- People who received 100mSv or greater are at an increased risk of developing cancer
- 1 in 100 people exposed to 100mSv would develop solid organ cancer or leukaemia
- Current models suggest a linear relationship between dose and biological effect, with no ‘safe’ threshold

Board on Radiation Effects Research (BEIR VII) report, 2005

65% of Nagasaki & Hiroshima survivors exposed to < 100mSv

This chart shows that natural sources of radiation account for about 82% of all public exposure while man-made sources account for the remaining 18%.
<table>
<thead>
<tr>
<th>Method</th>
<th>Conventional unit</th>
<th>SI unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation exposure</td>
<td>Roentgen (R)</td>
<td>Coulombs per kilogram (C/kg)</td>
</tr>
<tr>
<td>Radiation dose</td>
<td>Rad</td>
<td>Gray (Gy)</td>
</tr>
<tr>
<td>Equivalent dose</td>
<td>REM</td>
<td>Sievert (Sv)</td>
</tr>
<tr>
<td>Effective dose</td>
<td>Effective dose equivalent (Sv)</td>
<td>Sievert (Sv)</td>
</tr>
<tr>
<td>Computed tomography dose index</td>
<td>—</td>
<td>Milligray (mGy)</td>
</tr>
<tr>
<td>Dose length product</td>
<td>—</td>
<td>Milligray centimetre (mGy.cm)</td>
</tr>
</tbody>
</table>

1 Gy = 1 J/kg.
1 rad = 100 Gy.
10 mSv = 1 REM (1 mSv = 100 mREM).
Terminology

Cumulative Effective Dose (CED)
\[ = \sum \text{(Dose Length Product} \times \text{Tissue weighting factor)} \]

- Takes into account the different biological effects of absorbed radiation on different body organs
- Expressed as milli-Sieverts (mSv)
## Tissue weighting factors

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Tissue weighting factor, $w_T$</th>
<th>Sum of $w_T$ values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone-marrow (red), colon, lung, stomach, breast, remainder tissues$^a$</td>
<td>0.12</td>
<td>0.72</td>
</tr>
<tr>
<td>Gonads</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Bladder, oesophagus, liver, thyroid</td>
<td>0.04</td>
<td>0.16</td>
</tr>
<tr>
<td>Bone surface, brain, salivary glands, skin</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.00</td>
</tr>
</tbody>
</table>

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$^a$ Remainder tissues: Adrenals, extrathoracic (ET) region, gall bladder, heart, kidneys, lymphatic nodes, muscle, oral mucosa, pancreas, prostate ($\sigma^3$), small intestine, spleen, thymus, uterus/cervix ($\varphi$).

Routine CXR in ICU

- Of 645 CXRs performed in medical patients,
  - 127 (19.7%) led to one or more management changes.
- In the 66 surgical patients with ICU stay <48 hrs,
  - 15.4% of routine CXRs changed management.
- 35 surgical patients with an ICU stay > 48 hours,
  - 26% of 100 routine films changed management.
- Of 74 mechanically ventilated ICU patients,
  - 13 (17.6%) new major findings discovered only by CXR.
Routine CXR

• Several studies have done a very limited cost accounting of the potential savings
  - The overall impact on patient outcome has not been investigated.
  - A true assessment of cost-effectiveness has yet to be determined.

• However
  - Radiation exposure (0.02 mSv) is low.

• What about other radiological investigations?
## Radiation Doses Equivalent

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Effective dose, mSv*</th>
<th>Chest radiograph equivalents, no.</th>
<th>Equivalent background radiation time</th>
<th>Increased risk of fatal cancer†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest radiograph (posteroanterior)</td>
<td>0.02</td>
<td>1</td>
<td>2.4 d</td>
<td>—</td>
</tr>
<tr>
<td>Chest/abdomen CT scan</td>
<td>10.00</td>
<td>500</td>
<td>3.3 yr</td>
<td>—</td>
</tr>
<tr>
<td>4-slice†</td>
<td>4.55</td>
<td>228</td>
<td>1.5 yr</td>
<td>1/2197</td>
</tr>
<tr>
<td>40-slice†</td>
<td>1.60</td>
<td>80</td>
<td>6 mo</td>
<td>1/6250</td>
</tr>
<tr>
<td>64-slice†</td>
<td>1.52</td>
<td>76</td>
<td>6 mo</td>
<td>1/6579</td>
</tr>
</tbody>
</table>

CT = computed tomography.

*Based on the assumption of an average effective dose from natural background radiation of 3 mSv/yr (US).

†Increased risk of fatal cancer = effective dose (Sv) × risk coefficient of fatal cancer in adults.

‡Newer CT technologies with automatic exposure control and multislice scanning.

CT Scans: How bad?

- CT accounts for the single largest radiation exposure in trauma patients.
- 1 CT Body = 500 CXR
- Exposure to 100 mSv could result in a solid organ cancer or leukemia in 1 of 100 people.

Trauma Resuscitation

- A = airway
- B = breathing
- C = circulation
The New Resuscitation

• A = airway
• B = breathing
• C = CT scan
## Trauma guidelines: Abdo

<table>
<thead>
<tr>
<th>HAEMODYNAMICALLY STABLE</th>
<th>HAEMODYNAMICALLY UNSTABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear signs of abdominal injury.</td>
<td>Laparotomy</td>
</tr>
<tr>
<td>CT</td>
<td></td>
</tr>
<tr>
<td>No abdominal signs <strong>or</strong> signs unreliable due to:</td>
<td>CT</td>
</tr>
<tr>
<td>- altered conscious level [GCS ( \leq 13 )]</td>
<td>DPL or USS [FAST]</td>
</tr>
<tr>
<td>- paralysis</td>
<td>or</td>
</tr>
<tr>
<td>- significant pelvic or chest injury</td>
<td>Laparotomy</td>
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</tbody>
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No abdominal signs or signs unreliable due to:
- altered conscious level (GCS < 13)
- paralysis
- significant pelvic or chest injury

<table>
<thead>
<tr>
<th></th>
<th>DPL or USS [FAST] or Laparotomy</th>
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Traumatic Resuscitation

• A = accuse
• B = blame
• C = criticize
The problem

- Multiple injured trauma patients receive a substantial dose of radiation.
- Radiation exposure is cumulative.
- The low individual risk of cancer becomes a greater public health issue when multiplied by a large number of examinations.
  - 29,000 cancers and 14,500 deaths annually in the USA.
- Though CT scans are an invaluable resource and are becoming more easily accessible, they should not replace careful clinical examination and should be used only in appropriate patients.

Berrington et al. Arch Intern Med/Vol 169 (No. 22), Dec 14/28,
Has CT usage increased in trauma?

- Calculate the cumulative effective radiation dose received by ventilated trauma patients from admission to discharge from ICU.

- Compare 2 time periods
  - compare the number of CT’s performed
  - cumulative effective dose

Methods

- A retrospective analysis of patient clinical and radiological data
- 2 cohorts of 40 consecutive adult trauma admissions ventilated during ICU admission to Hawkes Bay ICU
- starting 1/1/04 and 1/1/09

## Results: the 2 cohorts compared

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2009</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median age</td>
<td>29.5</td>
<td>37</td>
<td>0.34</td>
</tr>
<tr>
<td>Sex (% M)</td>
<td>67.5</td>
<td>90.0</td>
<td></td>
</tr>
<tr>
<td>APACHE II</td>
<td>19.5</td>
<td>17</td>
<td>0.56</td>
</tr>
<tr>
<td>SAPS2</td>
<td>43</td>
<td>34</td>
<td>0.37</td>
</tr>
<tr>
<td>Risk of Death</td>
<td>0.175</td>
<td>0.155</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Total CT scans during ICU stay

p = 0.81

Total Radiation in ICU (mSv)
Median and Quartiles

p = 0.02

Daily Radiation in ICU (mSv) Median and Quartiles

$p = 0.02$

So what does this mean?

- There has been an increase in the radiation dose exposure of ICU trauma patients in recent years, largely due to complexity of the CT scans.
- Increased radiation exposure is consistent with other studies.
- What evidence is there of benefit?
Similar studies

- CT accounts for the single largest radiation exposure in trauma patients
  

- Increase in the mean number of CT exams per patient in 2007 compared with 2003 (4.41 v 3.44)

  Salottolo, K et al. Crit Care Med 2009; 37: 1336-1340
Alternatives

- **MRI:**
  - Access (timeliness)
  - Access (monitoring & resuscitation)

- **FAST/ US scan:**
  - Reliability & reproducibility
  - Only detects presence of fluid.
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- **MRI:**
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  - Reliability & reproducibility
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- **Sequential Clinical Examination**
Avoid routine repeat scans

Of 692 patients
  • In no patient without clinical deterioration did a change in management arise from a repeat routine Head CT
  • A Glasgow Coma Scale score less than 15 (13 or 14),
  • age higher than 65 years,
  • multiple traumatic lesions found on first head CT,
  • interval <90 minutes from arrival to first head CT
  – predicted independently a worse RRHCT.

Routine repeat Head CT is unnecessary in MHI.

Velmahos, G et al Routine repeat head CT for minimal head injury is unnecessary. J Trauma (2006) 60:3, 494–9;
But – repeat routine CT scans are being advocated

- **Routine follow-up CT scans**
  - beneficial in those patients with MBI
  - worsening CT findings may lead to
    - higher levels of medical management
    - neurosurgical intervention.

- **Some patients may be asymptomatic**

- **a prospectively randomized multi-centered trial would be beneficial.**
Monitoring Use

- Prospectively monitor CT requests:
  - What is expected to be found
  - What intervention / management change will result from scan
  - Audit the scan indications, scan results, and interventions that arise.
Marie Curie

- 1903, awarded Nobel prize in Physics
  - with Pierre Curie, and Henri Becquerel
- 1911 awarded Nobel prize in Chemistry

- 1934 died from aplastic anaemia almost certainly contracted from exposure to radiation.

- Much of her work had been carried out in a shed, without taking any safety measures.
- She had carried test tubes containing radioactive isotopes in her pocket remarking on the pretty blue-green light that the substances gave off in the dark.
The radiation dose to trauma patients is increasing. Related to increased number and complexity of CT scans, the risk from radiation exposure has been studied. The benefits to our patients are yet to be determined.

Be aware of radiation exposure when ordering examinations and prospectively monitor practice. CT should not replace careful clinical examination.
Thanks to Michaela, Rochelle, Tom, Catherine and Umesh