Radiation Incidents: The Rad Aspects of Patient Assessment

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There's Gonna Be a Test
REAC/TS

- Dept. of Energy asset with expertise in the medical management of radiation incident victims
- Operated for DOE by Oak Ridge Associated Universities (ORAU) – ops began 1975
- Avg’d one Call for Assistance per week since inception
- Only CLIA* certified cytogenetic biodosimetry lab in US
- WHO and IAEA affiliated (WHO – REMPAN, IAEA – RANET)
- 24/7 deployable at direction of DOE
- Accident and medical countermeasure registries
- Provision of multiple educational programs, both domestically and internationally

*clinical laboratory improvement amendments
REAC/TS Missions – 24/7

conus – 4 hrs  oconus – 6 hrs

- Radiation Medicine advice and consultation
- Health Physics radiation dose assessments
- Deployable Emergency Response Teams (ERT 1 & 2) for on-scene assistance

Physician
Health Physicist
Nurse/Paramedic
Education Related to the Medical Management of Radiological Incidents (Typical Year)

- 8 REM 3.5 day courses
- 2 ARM 4.5 day courses
- 3 HP 4.5 day courses
- 2 Pre-hospital 1.5 day courses
- 3 specially designed courses provided locally (3.5–4.5 days)
- 3 offsite courses for DOE facilities (1-2 days)
- 10 offsite courses for private entities
- Multiple invited presentations/lectures
- Multiple international courses
Prussian Blue and DTPA
The most effective means for removing radioactive cesium is the administration of Prussian Blue.  
Goiania data: 69% reduction in T½-eff (adults)
Effect of PB on Excretion (Goiania)

IAEA: The Radiological Accident in Goiania
Diethylenetriaminepentaacetate (DTPA)

- Preferred chelator for initial patient management (Pu, Am, others)
- Should be given as soon as possible after accident.
- Calcium or Zinc (Ca/Zn-DTPA)
- Ca-DTPA is approximately 10 times more effective than Zn-DTPA for initial chelation of transuranics (w/in 24 hours).
- After 24 hours, Ca-DTPA and Zn-DTPA are essentially equally effective.
- Repeated dosing of Ca-DTPA can deplete the body of zinc and manganese, so Zn-DTPA preferred for long term treatment.
- Can reduce the radiation dose by up to 80% (early treatment)

Fun Fact: The word chelation is derived from Greek, chēlē, meaning "claw.”
Medical vs. Regulatory... A Real Difference
Be Prepared to Be Uncomfortable

Criticality Accident in Japan, 1999

Thermal burns that occurred in a contaminated area

Industrial Radiography Accident, Peru

Criticality Accident in Japan, 1999
Care of the Patient

• **Medical needs have priority over contamination control concerns**
  – Goal is delivery of prompt and appropriate medical care to the victim(s) of a radiological accident while minimizing the potential for the contamination of the healthcare team, their equipment, and the facility.
Dose Estimation Tools
Rapid Dose Estimation to Help Guide Medical Management

Assessment of potential dose magnitude to help guide medical management:

- Quick
- Easy
- Representative of potential

The creator of the universe works in mysterious ways. But he uses a base ten counting system and likes round numbers.

- Scott Adams
Common Sense

According to Merriam-Webster, common sense is a sound and prudent judgment based on a simple evaluation of the situation or facts.

Science is a first-rate piece of furniture for a man's upper chamber, if he has common sense on the ground floor.

- Oliver Wendell Holmes Sr.
External Dose Estimation Tools
# Useful Dose Constants

<table>
<thead>
<tr>
<th>Radionuclide/ Half-Life</th>
<th>Distance (R-cm²/hr- mCi)</th>
<th>Surface* (R/min-Ci)</th>
<th>Dose Rate at 1 cm Tissue Depth** (R/min-Ci)</th>
<th>Dose Rate at 3 cm Tissue Depth** (R/min-Ci)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-60/5.26y</td>
<td>13.0</td>
<td>609</td>
<td>114</td>
<td>16.0</td>
</tr>
<tr>
<td>Cs-137/30.17y</td>
<td>3.26</td>
<td>113</td>
<td>28</td>
<td>3.7</td>
</tr>
<tr>
<td>Ir-192/74d</td>
<td>4.80</td>
<td>180</td>
<td>43</td>
<td>5.5</td>
</tr>
<tr>
<td>Ra-226/1620y</td>
<td>8.25</td>
<td>473</td>
<td>72</td>
<td>9.7</td>
</tr>
</tbody>
</table>

*Primarily due to electron buildup in the capsule wall. From Waller, et.al, IRPA 13 poster (abstract 2350443)

**From NCRP Report No. 40, Appendix B, Table 6

Notes:
Assumes point source geometry.
Sources are cylinders approximately 3mm (diameter) x 3 mm.
Metal (usually stainless steel) source capsules are approximately 6 mm (diameter).

1 Ci = 37 GBq
## Local Injury Thresholds

<table>
<thead>
<tr>
<th>Dose</th>
<th>Effect</th>
<th>Timing* (time post exposure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 rads, 3 Gy</td>
<td>Epilation</td>
<td>14-21 days</td>
</tr>
<tr>
<td>600 rads, 6 Gy</td>
<td>Erythema</td>
<td>Early, then 14-21 days later</td>
</tr>
<tr>
<td>1000-1500 rads, 10-15 Gy</td>
<td>Dry Desquamation</td>
<td>2-3 Weeks</td>
</tr>
<tr>
<td>1500-2500 rads, 15-25 Gy</td>
<td>Wet Desquamation</td>
<td>2-3 Weeks</td>
</tr>
<tr>
<td>&gt; 2500 (&gt; 25 Gy)</td>
<td>Deep Ulceration/Necrosis</td>
<td>Dependent upon dose</td>
</tr>
</tbody>
</table>
# ARS Thresholds

<table>
<thead>
<tr>
<th>Dose</th>
<th>Syndrome</th>
<th>Signs/Symptoms*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-100 rads, 0-1 Gy</td>
<td>NA</td>
<td>Generally asymptomatic, potential slight drop in lymphocytes later (near 1 Gy)</td>
</tr>
<tr>
<td>&gt; 100 rads, &gt; 1 Gy</td>
<td>Hematopoietic</td>
<td>Anorexia, nausea, vomiting, initial granulocytosis and lymphocytopenia</td>
</tr>
<tr>
<td>&gt; 6-800 rads, &gt; 6-8 Gy</td>
<td>Gastrointestinal</td>
<td>Early severe nausea, vomiting, watery diarrhea, pancytopenia</td>
</tr>
<tr>
<td>&gt; 2000 rads, &gt; 20 Gy</td>
<td>Cardiovascular/ CNS</td>
<td>Nausea/vomiting within first hour, prostration, ataxia, confusion</td>
</tr>
</tbody>
</table>
Time to Emesis as a Function of Dose

Credit: Dr. Ron Goans, MD, PhD
Lymphocyte Counts with Values Predicted by Andrew’s Model

Normal and Dicentric Chromosomes
Dicentric Assay Summary

• Circulating lymphocytes easily collected and cultured
• Low dicentric background rate (~1 per 1,000 cells)
• Independent of age and gender
• Ease of detection
• Useful range is around 0.25 to 5.0 Gy
• Reproducible dose response
• Proven in accidents over four decades
• Considered the gold standard
Many things can affect biological responses – For Instance:

Factors that Influence Dose Estimation
Radiation Quality and Dose-rate Effect

Neutron mean energies
0.7  MeV
7.6  MeV
14.7 MeV

250 kVp x rays @ 1.0 Gy/min
\(^{60}\text{Co} \gamma \text{ rays} @ 0.5 \text{ Gy/min}
250 kVp x rays @ 0.2 \text{ Gy/h}
\(^{60}\text{Co} \gamma \text{ rays} @ 0.18 \text{ Gy/h}

Source: NRPB, UK.
Time for the Test
Common Sense

- Are time estimates accurate?
- Are distance estimates accurate?
- Movement counts!
- Signs/symptoms vs. calculated dose
- Not everybody acts as the textbook predicts
- Err on side of conservatism?

Never assume the obvious is true.
- William Safire
Internal Dose Estimation Tools
The Basic Definitions

Intake → Into → Body

Uptake → By → Extracellular Fluid

Deposition → In → Organ, Tissue
Inhalation

• About 10% of the intake (1-5 μm particles) can be estimated to be found in the anterior nares provided the samples are taken within the first 45 minutes, or so, of intake

• Comparison to ALI

• Potential use of CDG
  – Clinical Decision Guide
  – NCRP-161
Derived Reference Level (DRL)

- The DRL is that amount of contamination in a wound that would result in a CDE to an organ of 50 rem or a CEDE of 5 rem (US definitions)
- Not regulatory in nature, but similar to an ALI for wounds
- The DRL is a REAC/TS tool
- Based on NCRP Report No. 156 modeling
- Dose coefficients were calculated using AIDE
- Mixes ICRP 26 and 60 definitions/weighting factors
## Wound DRLs of Interest in dpm

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Based on*</th>
<th>Weak</th>
<th>Moderate</th>
<th>Strong</th>
<th>Avid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-60</td>
<td>ED</td>
<td>1.54E+08</td>
<td>1.54E+08</td>
<td>1.65E+08</td>
<td>2.01E+08</td>
</tr>
<tr>
<td>Sr-90</td>
<td>BS</td>
<td>2.20E+07</td>
<td>2.20E+07</td>
<td>2.25E+07</td>
<td>2.38E+07</td>
</tr>
<tr>
<td>Tc-99m</td>
<td>ED</td>
<td>2.00E+11</td>
<td>2.56E+11</td>
<td>9.33E+11</td>
<td>8.78E+11</td>
</tr>
<tr>
<td>I-131</td>
<td>Thy</td>
<td>7.06E+07</td>
<td>8.01E+07</td>
<td>1.26E+08</td>
<td>3.46E+08</td>
</tr>
<tr>
<td>Cs-137</td>
<td>ED</td>
<td>2.20E+08</td>
<td>2.20E+08</td>
<td>2.23E+08</td>
<td>2.34E+08</td>
</tr>
<tr>
<td>Ir-192</td>
<td>ED</td>
<td>4.49E+08</td>
<td>4.66E+08</td>
<td>6.21E+08</td>
<td>1.69E+09</td>
</tr>
<tr>
<td>U-235</td>
<td>BS</td>
<td>8.23E+05</td>
<td>8.23E+05</td>
<td>8.29E+05</td>
<td>8.46E+05</td>
</tr>
<tr>
<td>U-238</td>
<td>BS</td>
<td>8.55E+05</td>
<td>8.55E+05</td>
<td>8.63E+05</td>
<td>8.78E+05</td>
</tr>
<tr>
<td>Pu-239</td>
<td>BS</td>
<td>1.81E+03</td>
<td>1.81E+03</td>
<td>1.85E+03</td>
<td>1.92E+03</td>
</tr>
<tr>
<td>Am-241</td>
<td>BS</td>
<td>1.65E+03</td>
<td>1.65E+03</td>
<td>1.68E+03</td>
<td>1.74E+03</td>
</tr>
<tr>
<td>Cf-252</td>
<td>BS</td>
<td>5.14E+03</td>
<td>5.15E+03</td>
<td>5.75E+03</td>
<td>7.96E+03</td>
</tr>
</tbody>
</table>

* ED – Effective Dose, Thy – Thyroid, BS – Bone Surface
Common Sense

- Facial contamination
- Contamination within the breathing zone
- Mouth breathing
  - Mouth swabs?
- Shielding from body fluids
- Time from intake
- Other issues

Common sense is calculation applied to life.
- Henri Frederic Amiel
Ohio – October, 2011

Source: REAC/TS Registry
**Industrial Radiography**

- A nondestructive technique using ionizing radiation to view objects

Accident Concerns: high dose rates, source location relative to irradiated tissue, duration of exposure, movement, shielding, others
Initial Information

• REAC/TS notified on 10-24-2011
  – 30YO worker who had an exposure to 130 kVp x-rays on 10/05.
  – The time and distance from the x-ray generator were not clearly known and the worker did not even think he had his hand in the x-ray beam.
  – They did several incident reconstructions and thought he might have had a dose of 70 rad to the thumb. But, on 18 October, the workers thumb pad began to become red.
  – The wound is progressing somewhat but is not a blister yet according to the RSO.
Quick Calculations (based on mock-up)

- Dosimeter placed 12” from window for 6 seconds
- Window: 1.75” from target
- Dosimeter 13.75” from target

Dosimetry results - 20 rads @ 12” from window
Window is 1.75” from the target

\[
\frac{(20 \text{ rads})(13.75'' \text{ from target})^2}{(1.75'' \text{ from target})^2} = (x \text{ rads})(1.75'')^2
\]

\[
(20)(189.0625) = 3.0625 \times 3.0625
\]

\[
1234.7 = x
\]

1234.7 rads @ 1.75” from target or at the window.
5-week Timeframe
Date irradiated: 5 October 2011
Recent Rapid Evolution of Injury
**Fingernails for EPR**

- Electron Paramagnetic Resonance (EPR) is based on the spin, and resulting magnetic moment, of the unpaired electron of a free radical
  - NOTE: All questions about EPR will be met with a blank stare.

- EPR provided the dose to the fingernails...other tissues?
  - IRSN EPR results: 19+/−6 Gy
  - US Naval Dosimetry Center EPR results: 13+/−3 Gy
Thermographic Image

Images captured 07-17-13
South Carolina – 2010

Source – REAC/TS Registry
Details

• On 14 June 2010 an individual punctured his right index finger while “flagging” vented cans of legacy waste from another facility (primary contaminant: Pu-238)
• Initial wound site contamination levels were 300 dpm alpha (ZnS scintillation probe used)
• Decision was made to chelate with Ca-DTPA (known contaminant, done within the first hour, or so)
• 43.5 keV line observed (0.04% abundance) w/ HPGe
• 3mm punch biopsy performed – 14k dpm
• Later excision removed an additional 3k dpm
• 3rd excision (day 9) – 3.8k dpm
Flag and Puncture Site
Wound Site After Punch Excision
Third Excision (day 9)
Bioassay and Chelation

- Urine collection was begun on the first day and continued daily until day 16
- Chelation performed on day 1 and 3-16 (Ca-DTPA on day one, Zn-DTPA on remaining days)
- First urine sample ~ 24.2k dpm/day
- Patient returned home days 17-22. No chelation performed or samples collected
- Day 23, no chelation. Sample collected (79 dpm per day – previous numbers ~ 450 – 650 dpm/day)
- Day 24 – switched to 2x per week chelation
- 20th chelation performed on 14 July 2010
- Skull, knee, liver counts negative (to continue 1/month)
How well we communicate is determined not by how well we say things but how well we are understood.

- Andrew Grove
Risk Perception

Real Risk does not equate to Perceived Risk does not equate to Acceptable Risk
Public “Education”
I would not know how I am supposed to feel about many stories if not for the fact that the TV news personalities make sad faces for sad stories and happy faces for happy stories.

- Dave Barry
Dr. Steven Garner (Chairman of Radiology, NY Methodist Hospital) demonstrates new device.

50 sec mark: The reporter is wearing an electronic dosimeter in the studio. It’s reading 8+/- μR/hr. The reporter asks, “When would you be worried?” Response: “If this were more than 30.” (which is 2.63 mSv or 263 mrem/yr.)

Note: Per NCRP 160 (2009), page 77 - Approximately 2.5 million Americans receive annual doses from ubiquitous background in excess of 20 mSv (2000 mrem). The lowest annual doses are just over 0.5 mSv (50 mrem). The arithmetic mean is 3.11 mSv (311 mrem). 68%, or about 2.1 mSv (210 mrem), is from radon.

3 min, 20 sec mark: It’s (Fukushima) a time bomb right now. If it melts down right now, all the people that are within a 10 mile radius, including our servicemen, will be in big trouble.
You need a little bit of iodine so the thyroid gland in your neck can make hormones to regulate your metabolism. But your body can't tell the difference between the normal iodine found in salt or seafood and the radioactive variety from a wayward nuclear power station.

The supplemental iodine isn't a complete guarantee of protection. A lag in taking the pills after exposure can reduce the supplement's effectiveness, for instance. Also, the iodine pills only offer work against radioactive iodine — not other radioactive elements…
KNOXVILLE, Tenn. (AP) _ In a case that at first glance could pass for a science fiction movie plot, radioactive frogs are loose at a government lab.

About 100 so-called "hot frogs" have been caught hopping away from a contaminated pond where they hatched this spring, officials at the Department of Energy's Oak Ridge National Laboratory said. "They don't have six legs and four eyes," said Frank Kornegay, the lab's environmental coordinator. He said they look like ordinary leopard frogs common in Tennessee.

The radioactive frogs are safe unless you eat them - and leopard frogs aren't exactly a delicacy.
In Closing...
Importance of HP Integration... Get to Know the People

An understanding of the basic health physics concepts is important because it helps build the foundation for understanding the mechanisms of radiation injury.

Equally as important, it is essential that good communications occur between the medical/field-responder and health physics staffs.
Challenges for Responders

- Establishing radiological controls
- Interaction with responders and medical personnel
- Dose estimation
  - Remember: garbage in = garbage out
- Interaction with management and investigators
- Public information
- Patient interaction

The single biggest problem in communication is the illusion that it has taken place.
- George Bernard Shaw
A Few Dosimetry Rules

• Dose estimates should inform, but not determine medical decisions
• Be a realistic pessimist
• Consider the maximum CREDIBLE accident
• Develop contingency plans...things change
• Medical management assuming an over-estimate of dose is usually less consequential than medical management assuming an under-estimate
• Eventually the patient will tell you what the dose was (N. Wald, M.D.)
When Communicating...

- Tell the truth
- Keep it simple, but accurate
- Avoid acronyms
- Not everybody has the same perceptions, be flexible
- If speaking in public, be ready for comments (personal experience)

*The two words 'information' and 'communication' are often used interchangeably, but they signify quite different things. Information is giving out; communication is getting through.*

- Sydney J. Harris
Good Help

• REAC/TS Pocket Guide

Topics covered include:
• Basic health physics
• Basic external/internal dose calculation
• Acute local and whole body injuries/illnesses
• Treatment for internal contamination
• Patient decontamination
• Delayed effects
• Psychological aspects

Free: Available in PDF or iBook

Also of Potential Use

• Proceedings of the 5th International REAC/TS Symposium on the Medical Basis for Radiation-Accident Preparedness and the Biodosimetry Workshop

• 25+ internationally recognized experts
  – Local injury
  – WB irradiation/ARS
  – Internal Contamination
  – Case Reviews
  – Biodosimetry
  – Other areas of interest

Available via Amazon.com
**More Good Help**

- Rapid Internal and External Dose Estimation

- Radiation Emergency Medical Management

- Generic Procedures for Medical Response During a Radiological Emergency

- NCRP 161 – Mgt of Persons Contam. with Radionuclides
- NCRP 128 – Radionuclide Exposure of the Embryo/Fetus
- NCRP 174 – Preconception and Prenatal Exposure
Incident Response and Communication Help

- NCRP 138 – Mgt of Terrorist Events Involving Rad Material
  - NCRP Commentary 19 – Key Elements of Preparing Emergency Responders for Nuke/Rad Terrorism
- NCRP 165 – Responding to a Rad/Nuke Terrorism Incident: A Guide for Decision Makers
- NCRP 166 – Monitoring and Decorp. after a Rad Event
- NCRP 115 – Risk Estimates for Radiation Protection
- NCRP 160 – Radiation Exposure of the Population of the US
- Communications with the Public in a Nuke or Rad Emergency
(http://www-pub.iaea.org/MTCD/publications/PDF/EPR-Communcation_web.pdf)
Info Re: Medical Procedures

• Dose Estimates and Other Compendia (REAC/TS):

• Dose calculators and other information (RADAR):
  – http://www.doseinfo-radar.com/

• HPS Ask the Expert (Medical Issues):
  – http://hps.org/publicinformation/ate/cat5.html
Let’s End with the Conclusions

- Health physics management of a severe radiation accident is not for the faint of heart
- Get used to medical terminology and hospital setting/procedures
- Stick to your area of expertise
- Understand and recognize fears/perceptions
- Call REAC/TS at 865-576-3131 (normal hours) or 865-576-1005 (24-hr)
Thank You!