Health Effects of Radiation

Rebecca Bittner, M.D.
Assistant Professor, Department of Radiology
The George Washington University
What determines radiation’s effects?

- Type of radiation
- Total dose
- Number of dose fractions (exposures)
- Dose rate
- Biologic system
- Method of exposure
Types of Radiation: Electromagnetic

**X-rays**
- High voltage anode
- Glass wall
- Cathode
- Tungsten filament
- Tungsten target
- Be window
- Focusing tube
- Wire lead
- Takeoff angle
- Center of generated X-ray
- Takeoff angle
- Filament

**Gamma rays**
- Energy
- Radiation
- Radiative Atom
- Particle

- 60-Co
- 137-Cs
- 99m-Tc
Types of Radiation: Particulate

- **Beta (electron)**
  - $^{131}$-I
  - $^{137}$-Cs
  - $^{90}$-Sr
- **Alpha (2 protons, 2 neutrons)**
  - $^{222}$-Rn
  - $^{236}$-Pu
  - $^{238}$-U
- **Neutron**
  - Atomic bomb, chain reaction
Measuring Radiation

- Amount of radioactive material
  - Becquerel (Bq) = 1 decay per second
  - Curie (Ci) = $3.7 \times 10^{10}$ Bq = 37 GBq
    - Activity equivalent to 1 gram of 226-Ra
    - Example: bone scan uses 20 mCi (0.020 Ci) of 99m-Tc
      - =0.74 GBq
    - Chernobyl released $10^{19}$ Bq = 1,000,000,000 GBq (270 x $10^6$ Ci) of radionuclides!

- Radiation dose: energy deposition
  - Gray (Gy) = 1 Joule/kg
  - Rad = 0.01 Joule/kg

- Equivalent dose: different LET (energy transfer rate)
  - Sievert (Sv) = 1 Gy of X-rays/gamma rays
  - Rem = 0.01 Sv = 10 mSv
Examples of Radiation Doses

- Natural background radiation: 0.01 mSv/day
- Chest X-ray, 2 views: 0.06 mSv
- In US: background + medical: 2 mSv/yr
- Within Fukushima reactor: 1000 mSv/hr
- EPA limit for emergency responder: 750 mSv
- Acute radiation syndrome: 2000 mSv
Radiation Effects

- **Method of exposure**
  - Atomic bomb explosion, criticality accident
  - Active nuclear reactor
    - Gamma, neutrons, [heat, blast]
  - External contamination (whole body)
    - Fallout
    - 131-I, 137-Cs
  - Internal contamination (target organs)
    - Inhaled
    - Food, water (131-I, 137-Cs)
Whole-body exposure

- Chernobyl – emergency workers
- Acute Radiation Syndrome
- Prodrome:
  - GI: nausea, vomiting, diarrhea
  - Neuromuscular: fatigue, apathy, fever, headache, hypotension
Acute Radiation Syndrome

- 3 types
- 1. Highest dose (>50 Gy ≈ 50,000 mSv):
  - Cerebrovascular syndrome
  - Die in 24 – 48 hr
- 2. Intermediate dose (5 – 12 Gy ≈ 5,000-12,000 mSv)
  - Gastrointestinal syndrome
  - Die in days (without medical support)
- 3. Lower dose (2.5 – 5 Gy ≈ 2,500-5,000 mSv)
  - Hematopoietic syndrome
  - Die after several weeks (without medical support)
Acute Radiation Syndrome

- Fortunately, affects very few

- So – what are the more general concerns/effects?
  - External contamination
  - Internal contamination
External contamination

- Depends on what is released
  - $^{131}$I, $^{137}$Cs
- Detection:
  - Personal dosimeter
  - Geiger-Müller counter
  - Whole-body counting
  - Biological dosimetry
    - Blood cells, excreted radionuclides
- What to do:
  - Clothes, soap and water!
Internal contamination

- How long does the radionuclide last?
- What kind of radiation does it produce?
- Where does it go?

Example: 131-I
- $t_{1/2} = 8$ days
- beta and gamma
- Thyroid
  - Thyroid cancer: RR 6.2/Gy
  - Also hypothyroidism, benign thyroid nodules

Example: 137-Cs
- $t_{1/2} = 30$ years
- gamma
- Muscle, bone; hematologic changes
Internal contamination

- Food, water, air
- EPA: RadNet
  - Air: air filter, charcoal cartridges
  - Precipitation: gamma
  - Milk: gamma spectrometry (131-I, 137-Cs, 140-Ba)
  - Drinking water: 131-I, 137-Cs, 134-Cs, etc.
- Food: radiation meters
- Specific measures to ameliorate radiation damage:
  - Potassium iodide if exposed to 131-I
  - Other meds in testing: block cell self-destruction
Fukushima

- April 20, 2011
- 131-I in 8 prefectures
  - 2.4 – 80 Bq/m²
  - (80 Bq = 2 x 10⁻⁶ mCi = .000002 mCi; < one ten-millionth of the dose used to treat hyperthyroidism)
- 137-Cs in 7 prefectures
  - 2.5 – 87 Bq/m²
- Gamma ray dose rates: 1.9 μSv/h = .0019 mSv/hr = 0.0456 mSv/d
  - Remember: background = 0.01 mSv/d
Summary

- Severe effects: at the reactor, nuclear bomb
- External decontamination
- Internal: Air, food, water
  - $^{131}$I – thyroid disease (hypothyroidism, benign and cancerous nodules)
  - ?Longer-term, mildly elevated risk of other cancers
    - Hiroshima, Nagasaki