Low Dose Radiation Risk

Antone Brooks
Washington State University
TriCities

5 May 2004
My Background

• Early interest in radiation
  (Watching atomic weapons in southern Utah)

• MS in radiation ecology  
  (Chasing fallout)

• PhD in radiation biology in genetics
  (Trying to discover what radiation is actually doing inside people)

• Investment of my life in research on health effects of low doses of radiation
Risk Models

Is risk always proportional to dose?
Can any amount dose increase risk?
Can a single radioactive ionization can cause cancer?
Background Radiation and Background Cancer
Background Radiation
Radiation is everywhere

We live in a sea of radiation...
The average background radiation per person is 370 millirems (mrem) per year. This varies widely depending on where someone lives, and their occupation, health and lifestyle.
Most background radiation is natural.

It is part of nature.

It has always been here.

People have always lived with it.
Radiation comes from space—sun and cosmic rays.

Because this type of radiation is somewhat shielded by the atmosphere, the dose is higher at higher altitudes.

Space and airline travel has higher radiation doses.
Every 200 feet increase in altitude increases dose 1 mrem/year
Radiation comes from the earth

Some rocks, like Uranium are radioactive. So are coal and some building materials such as granite.

The natural radiation from the granite in Grand Central Station is higher than is allowed to certify a nuclear power plant.
Radon is a radioactive gas that comes from inside the earth. Usually radon escapes into the air in very small amounts and does not hurt us. However, sometimes radon can get trapped in buildings. Then there is more radiation than is healthy.
Cells in our body contain radioactive elements, such as Potassium, which come from the food we eat.
• Are low levels of radiation an essential part of life?
• The body does not distinguish between natural and man-made.
• Neither natural nor man-made background radiation have been shown to be harmful.
• The body has developed repair mechanisms to deal with negative effects of high levels of radiation.
Normal annual exposure from natural radiation

About 300 mrem/yr

- Radon gas: 200 mrem
- Human body: 40 mrem
- Rocks, soil: 28 mrem
- Cosmic rays: 27 mrem

Normal annual exposure from man-made radiation

About 70 mrem/yr

- Medical procedures: 53 mrem
- Consumer products: 10 mrem
- One coast to coast airplane flight: 2 mrem
- Watching color TV: 1 mrem
- Sleeping with another person: 1 mrem
- Weapons test fallout: less than 1 mrem
- Nuclear industry: less than 1 mrem
Dose Ranges

(mSievert)

- **Total Body Therapy**
  - 0 - 10,000 mSv

- **Total Tumor Dose**
  - 0 - 10,000 mSv

- **A-bomb survivors**
  - Human LD50

- **Significant cancer risk at > 200 mSv (UNSCEAR)**

- **Typical mission dose on Int. Space Station**
  - 1 - 2 mSv

- **Typical annual dose for commercial airline flight crews**
  - 0 - 1 mSv

- **Bone (Tc-99m)**
  - Thyroid (I-123)

- **Medical Diagnostics**
  - Dental X-ray
  - Chest X-ray

- **ICRP Negligible Dose**
  - 0 - 0.1 mSv

- **NRC Clean-up Standards**
  - 0.2 - 0.4 mSv

- **EPA Clean-up Standards**
  - 0.1 - 0.3 mSv

- **3-Mile Island Ave Ind**
  - 0 - 0.01 mSv

- **Occupational Limit NRC, EPA**
  - 50 - 100 mSv

- **Natural background**
  - 0.1 - 1 mSv

- **Site Decommissioning/License Termination**

- **Cancer Radiotherapy**
  - 0 - 10,000 mSv

- **Experimental Radiobiology**
  - 0 - 10,000 mSv

- **Cancer Epidemiology**
  - 0 - 10,000 mSv

- **DOE Low Dose Program**
  - 0 - 10,000 mSv

- **Regulatory Standards**
  - 0 - 10,000 mSv
Background Cancer
Stomach Cancer Risk

Multiple factors impact cancer

Smoked Foods
Smoked Speck
Smoked Smoking
Aging
Shipyard

Type A Blood
Type A Blood
Effects of Atomic Bomb

- Killed outright by the bomb or acute radiation effects: 100,000 people
- Survived for lifespan study: 86,572 people
Atomic Bomb Survivor
Excess Cancer

Population of Survivors Studied 86,572

Total Cancers observed after the Bomb 8,180
Total Cancers Expected without Bomb 7,743

Total Cancer Excess 437

Excess Tumor 334 + Excess Leukemia 104 = 437
Why now?

• Standards have been set from high dose effects, but low dose effects have not been measurable until now

• New technological developments and biological discoveries have made it possible to study low dose effects
Key Research Areas

• Technological Advances

• Biological Advances
Alpha-Particle Radiation System

- Video Camera
- Microscope Objective Lens
- Mylar Bottom Petri Dish
- Piezoelectric Shutter
- Beam Control Slits
- Beam from Accelerator
- Scintillation Detector
- Newport Positioning Stage
- Scintillation Plastic
- Manually Adjustable Collimeter
- Faraday Cup
- Vertical Bending Magnet

Texas A&M
GenePix: scanner by Axon

2 color laser
Confocal imaging

LLNL
Relationship between biological responses to radiation
Radiation-induced changes in gene expression

Dose (cGy)

Low Dose Genes

High Dose Genes

Wyrobek
Adaptive Response

When a small dose of radiation is given before a larger one, it would be expected there would be more chromosome aberrations than when just the large dose was given. But that is not what happens. With a small “tickle” dose before the larger dose, there were only about half as many aberrations than with just a large dose!

Observed

Expected

Intervention

Shadley and Wolff 1987
Bystander Effects
Bystander Effect

All-or-none dose response

- Numbers of particles per targeted cell
- Fraction of cells damaged

Intervention

- One cell targeted per dish
- Four cells targeted per dish

Belyakov et al. 2001
After a cell is damaged by radiation, all of its progeny are damaged.
Genomic Instability

- Gene mutation
- Chromosome aberration
- Mitotic failure-aneuploidy
- Cell death
- Micronuclei

Intervention
Gene Mutation and Expression in Cancer

Single Cell Response

- Normal
- Initiation
- Promotion
- Progression

Gene Mutation- a rare event

Whole Body Response

- Normal
- Gene Activation
- Down Regulation
- Progression

Gene Expression- a common event
There is a need for a change in interpreting radiation biology

- Adaptive response and protective effects vs detrimental effects
- Hit theory vs. bystander effects
- Mutation vs. gene induction
- Single cell vs tissue responses
What have we learned?

- High doses of radiation can produce cancer
- Radiation is a good cell killer
- Radiation is a poor mutagen/carcinogen
- Low doses of radiation produce different cell and molecular responses than high doses (Protective vs harmful?)
- Linear extrapolation of risk is conservative