Limits for Exposure

MRS. HEATHER HERB, B.S., R.T.(R)(M)
MI PROGRAM

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Alphabet Soup

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Organizations in Radiation Protection

- International Commission on Radiological Protection
- National Council on Radiation Protection and Measurements
- United Nations Scientific Committee on the Effects of Atomic Radiation
- Biological Effects of Ionizing Radiation Committee

Evaluates relationship of dose and biological effects

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International Commission on Radiological Protection (ICRP)

- International authority on the safe uses of ionizing radiation for occupational and public
- Established in 1928
- Provides clear and consistent guidance for occupational and public dose limits
- Makes recommendations but does not enforce them
- Committee examples:
  - Radiation effects
  - Radiation exposure
  - Protection in medicine
  - Applications of recommendations

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National Council on Radiation Protection and Measurements (NCRP)

- Nongovernmental , nonprofit, private corporation chartered by Congress in 1964
- Reviews recommendations from ICRP to be incorporated into US protection criteria
- Not an enforcement agency
  - Recommendations must be enforced by the state and federal agencies

NCRP
National Council on Radiation Protection & Measurements

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United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

- Established in 1955
- Evaluates human and environmental exposures from a variety of sources
  - Radioactive material
  - Radiation accidents
  - Radiation producing machines
- Assesses risk of radiation induced cancers and genetic effects
  - Uses information from studies of the Japanese atomic bomb survivors

UNSCEAR

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Biological Effects of Ionizing Radiation Committee (BEIR)

- Formed by the National Research Council and organized by the US National Academy of Sciences
- Advisory group that reviews studies of biologic effects of radiation and risk assessment
  - Early radiation workers
  - Atomic bomb victims of Hiroshima and Nagasaki (1945)
  - Victims from the Chernobyl nuclear power station disaster (1986)
    - *trivia fact- Chernobyl had 400X more exposure than Hiroshima atomic bomb*
  - Fukushima (2011)

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What happens next?

- Based on the recommendations from these four organizations, limits to radiation exposures are established by congressional act or mandated by the state
- National and state agencies are responsible for enforcing the standards after they are established

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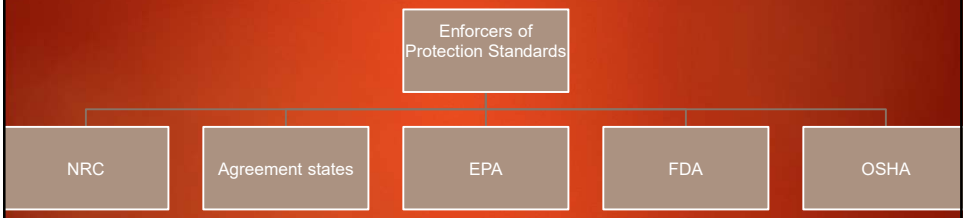
US Regulatory Agencies



Enforces protection of general public, patients, and personnel

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Nuclear Regulatory Commission (NRC)

- Formerly known as the Atomic Energy Commission
- Federal agency that controls the possession, use and production of atomic energy in the interest of national security
- Can enforce radiation protection standards
- Does not regulate or inspect x-ray facilities
- Controls manufacturing of prostate cancer radioactive seed implants and thyroid cancer radioactive material
- Has authority to have written contract with state governments
  - Gives states freedom to govern items covered under the NRC jurisdiction
- Mainly oversees nuclear energy industry
  - Design
  - Working mechanisms
  - Production and handling of nuclear fuel
  - Supervises hazardous waste material

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Prostate Cancer Seed Implants

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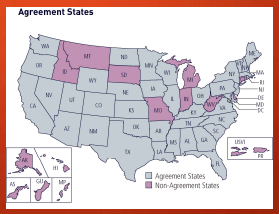
Agreement States

- US states that agree with NRC to enforce regulations through health departments
- Non-agreement states have the state and NRC enforce regulations by sending agents to the facility
- States may have their own regulations
- PA is an agreement state since March 31, 2008
- Note: nuclear reactors fall solely under the NRC jurisdiction



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Environmental Protection Agency (EPA)

- Established in December 1970
- Responsible for protecting the health of humans and safeguarding the natural environment
- Oversees development and enforcement of regulations for radiation in the environment
- Determines levels of radon

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Food & Drug Administration

- Regulates design and manufacturing of electronic products, including diagnostic equipment
- Does onsite inspections of equipment, especially mammography to determine level of compliance
  - Mammography Quality Standards Act- 1992
- Compliance ensures protection to the user and the patient from faulty manufacturing
- Radiopharmaceuticals fall under FDA regulations
- CDRH- Center for Devices and Radiological Health
  - Protecting and promoting public health

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Code of Federal Regulations

- 21 CFR
  - Standards for protection against radiation for occupationally exposed
  - https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=1020.32&SearchTerm=fluoroscopy

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Occupational Safety & Health Administration

- Monitoring agency in places of employment (industry)
- Regulates occupational exposures
- Regulates "right to know" of employees, must provide training and written information
  - Hazardous substances
  - Infectious agents
  - Ionizing radiation
  - Non-ionizing radiation

OSHA
Occupational Safety and Health Administration

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State Agencies

- Department of Environmental Protection (DEP)
  - Bureau of Radiation Protection
    - Commonwealth of PA Title 25, Article V, Chapters 216-240
    - Performs surprise hospital visits
- Department of Health
  - Radiation & Nuclear Med departments
  - Does onsite inspections
- PA Patient Safety Authority
  - Adverse patient events are reported

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Department of Transportation

- Responsibility to control the transportation of radioactive materials
  - Mode
  - Package
  - Labeling

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Radiation Safety Programs

- Requirements
  - Image facilities must have an effective and detailed safety program to safeguard everyone
  - Beginning with administration
    - Delegate funds in the budget
    - Oversee development of policies and procedures
    - Provide equipment necessary for starting and maintaining the program

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Radiation Safety Committee (RSC)

- Helps develop safety programs that are NRC mandated
- Provides guidance and facilitates its ongoing operation
- PA state law requires a facility with 2 or more modalities to have a RSC

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RSC at Reading Health

Committee Members

Michael L. Gent, MD, Chairman
Chandrasekhar Kota, PhD, Radiation Safety Officer
Carl J. Seidl, Vice-President, TRHMC
Beverly Stoudt- Radiology Adminstration
Keystone Physics, Ltd.
Michael Haas, MD, Radiation Oncology
Robert Pattillo, MD, Cardiology
Adam Sigal, MD, ED
Jenny Follweiler, Nuclear Medicine
Kelly Dunkelberger, Radiology
Kristie Pietruszynski, Interventional Radiology
John Noll, RN, Perioperative Services
Judith Koch, RN, Nursing
Connie Nabozny, Cardiology
Jacqueline Talarico, Spring Ridge Center
Chris Zatwarnicki- Radiation Oncology
Michael Romeo, MD, Radiology

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Radiation Safety Officer (RSO) Responsibilities

- Develops and oversees radiation safety program
- Ensures everyone is adequately protected
- Maintains monitoring records and counsels individuals with high readings
- Day to day supervision of safety program
- Identifies safety problems, provides corrective actions, & verifies these actions were followed through
- Provides information for a formal review annually

Dr. Chandrasekhar Kota

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Qualifications for RSO

- Usually a medical or health physicist, radiologist, or individual deemed qualified by training and experience
- Needs to be approved by the NRC and the state

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Authority for the RSO

- Able to stop operations that they consider unsafe
- Insures corrective action is taken
- Identify radiation safety problems
- Given sufficient time and resources to ensure the program is running properly

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Acts/ bills/ reports

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Radiation Control for Health & Safety Act of 1968

- Public Law 90-602
- Protects the public from unnecessary hazardous exposure from products such as microwaves, tv's, and x-ray equipment
- Restricts the equipment performance, not the user

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Consumer-Patient Radiation Health & Safety Act of 1981

- Public Law 97-35
- Sets guidelines requiring minimum standards for radiology programs and persons administering procedures and the certification of these persons
- Under the discretion of the Secretary of Health and Human Services
- Ensures medical and dental procedures follow safety standards
- No legal penalty exists for noncompliance

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CARE Bill

- Ensures accreditation of education programs and the licensure or certification of persons performing x-rays or radiation therapy
  - Demonstrates competence by education, experience & examination
- 2007 they redefined to represent the focus of the bill:
  - Consistency, Accuracy, Responsibility & Excellence

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ALARA

- Developed in 1954
- Adopted by NCRP
- Accepted by all regulatory agencies
- This is a joint effort of the technologist and physician to achieve
- Also referred to as optimization (ORP) by ICRP
- Extremely conservative level- linear, non threshold
  - effects and dose are directly proportional, without a threshold
- Achieved by proper safety procedures and qualified workers

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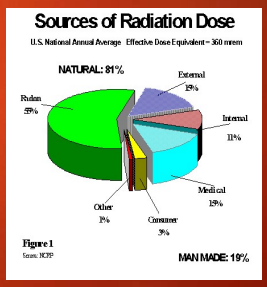
Effective Dose Limiting System (EfD)

- Assesses exposure and risk of biologic damage to workers and the public
- Upper boundaries that can result in bodily injury or genetic damage
- Can be expressed in
  - Whole body
  - Partial body
  - Individual organ



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NCRP

REPORTS

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NCRP Report #102

- Came out in 1989
- Recommendations on equipment design, performance and use
- Guidelines for:
  - Minimum lead (Pb) equivalent for shielding
  - Minimum aluminum (Al) filtration required
  - Guidelines for mobile and fluoro exposure rates

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NCRP Report #116

- Came out in 1993
- Limitation of Exposure to Ionizing Radiation
  - Effective Dose Limits
    - Occupational
    - Non occupational
    - Cumulative effective dose
    - Pregnant worker

- Somatic & genetic effects kept to a minimum
- Goal of radiation protection
- Makes recommendations for risk-benefit analysis of radiation exposures

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NCRP Report #160

- Came out in 2009
- Due to the increased amount of ionizing radiation seen in 2006
  - 7X more since 1980's according to the NCRP
  - Mainly CT and NM
- Provides a review of "Ionizing Radiation Exposure to the Population of the United States"

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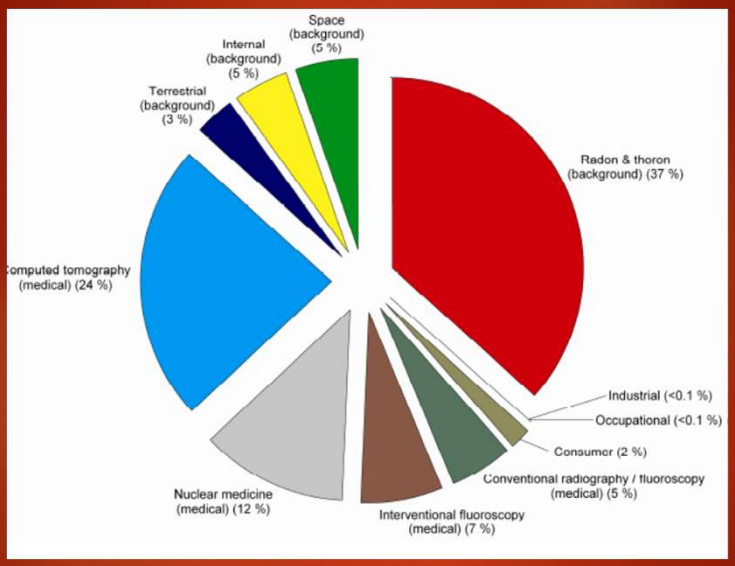

Radiation Protection in Medical Radiography, 7th Ed. Statkiewicz Sherer

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NCRP Report #180

- Came out in 2018
- Covers management of exposure to ionization radiation in the United States
  - Purpose is to prevent deterministic effects (acute and chronic tissue reactions) and reduce the probability of stochastic effects (primarily cancer)**

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Radiation Induced Responses

- Non-stochastic- directly related to the dose received
- Stochastic- randomly occurring

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Non-stochastic (Deterministic)

*may hear it called tissue response

- Cell killing effects
- Does not normally occur below the threshold
- Above threshold severity increases as the dose increases
- These doses are usually higher than diagnostic x-ray

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Examples of Non-Stochastic Effects

- Early (occurs within few hours or days)
  - Erythema
  - Decreased WBC
  - Epilation
  - Gastrointestinal syndrome
  - Cerebrovascular syndrome
- Late
  - Cataracts
  - Fibrosis
  - Organ atrophy
  - Reduction of fertility
  - Sterility

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Stochastic (Probabilistic)

- Mutational
- No threshold
- Chance of occurrence increases with each exposure, probability increases also
- Random effects, cannot determine who will be effected
- Assumption that no minimal safe dose exists

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Examples of Stochastic

- Cancer
- Genetic alterations
  - Teratogenesis- radiation of the fetus in utero
  - Mutagenesis- radiation of reproductive cells before conception

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Occurrence of radiation induced malignancy

- Chance increases with an increased dose to the somatic cells
- Severity is not dose related, but the chance increases as the dose increases

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Objectives of Radiation Protection

- Prevent non-stochastic (deterministic) effects from happening by keeping dose limits below thresholds
- Limit risk of stochastic (probabilistic) effects to a conservative level as compared to the benefit of the exposure

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Radiation Protection

- linear, non threshold
  - Chance of occurrence increases with each exposure, probability increases also
  - ALARA follows the same guidelines

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Philosophy of Radiation Protection

- Chance of biologic damage and amount of damage are directly proportional
- Smallest dose has potential to cause harm
- Radiation has benefits but has potential for destruction
- Must weigh the benefit of the exposure against the risk

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Organ Sensitivity

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Critical Organs Examples

- Gonads
- Blood forming organs such as red bone marrow
- Lung tissue
- Thyroid

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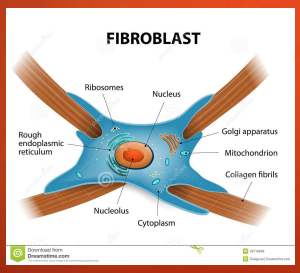
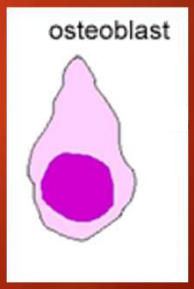
Medium Sensitivity Examples

- Osteoblast
  - Bone forming
- Fibroblast
  - Connective tissue





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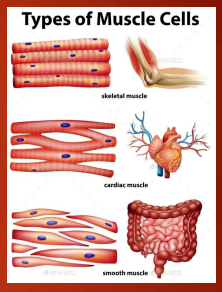
Low Sensitivity Examples

- Muscle cells
- Nerve cells



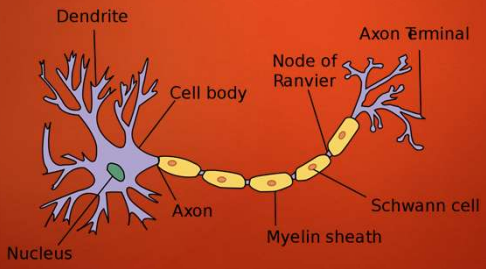


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TABLE 4-3 Organ or Tissue Weighting Factors

Organ or Tissue	Weighting Factor (W_T)
Gonads	0.20
Red bone marrow	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Esophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surface	0.01
Remainder*†	0.05

Radiation Protection in Medical Radiography, 7th Ed. Statkiewicz Sherer

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Dose Per Technique

Representative Entrance Skin Exposures, Bone Marrow Dose and Gonadal Dose from Various Diagnostic X-Ray Procedures

Exposure Factors (kVp/mAs)	Entrance Skin Dose (mGy_t)*	Bone Marrow Dose (mGy_t)	Gonad Dose (mGy_t)
76/50	2.0	0.10	<1
110/3	0.1	0.02	<1
70/40	1.5	0.10	<1
72/60	3.0	0.60	2.25
74/60	4.0	0.30	1.25
70/50	1.5	0.20	1.50
60/5	0.5	0.02	<1
125/300	40.0	0.20	0.50
125/400	20.0	0.50	20

Radiation Protection in Medical Radiography, 7th Ed. Statkiewicz Sherer

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Dose Per Procedure

TABLE 2-6 Representative Entrance Exposure and Fetal Doses for Radiographic Examinations Frequently Performed With a 400-Speed Image Receptor

Examination	Entrance Skin Exposure (mR)	Fetal Dose (mrad)
Skull (lateral)	70	0
Cervical spine (AP)	110	0
Shoulder	90	0
Chest (PA)	10	0
Thoracic spine (AP)	180	1
Lumbosacral spine (AP)	250	80
Abdomen (AP)	220	70
Intravenous urogram (IVP)	210	60
Hip*	220	50
Extremity	5	0

Radiation Protection in Medical Radiography, 7th Ed. Statkiewicz Sherer

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Law of Bergonie and Tribondeau

- Cells are more sensitive when they are immature and rapidly dividing

Jean Alban BERGONIE (1857-1925)

Louis TRIBONDEAU (1872-1918)

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NCRP Recommendations

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Occupational Annual Limits

- Effective dose limit- 50mSv (5 rem)
- Lens of eye-150mSv (15 rem)
- Localized skin area- 500mSv (50 rem)

- ICRP has lowered effective dose limit to 20 mSv, but the US has not yet adopted this rate

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Cumulative Effective Dose (CumEfD)

- Person's age in years X 10mSv
  - Or person's age in years x 1 rem
- Pertains to the whole body
- Also known as the cumulative dose formula

Person is 56 years old= 560 mSv

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Non-occupational dose limits

- Public exposed:
  - 1mSv (0.1 rem)- continuous exposure
  - 5mSv (0.5 rem)- infrequent exposed
  - These limits are set for people who accompany a patient to radiology
    - Spouse
    - Parent
    - Guardian
- Hospital employees who are not radiology employees:
  - 1mSv (0.1 rem)
- There is not a specific dose limit for patients that are being imaged

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Embryo-Fetus Limits (conceptus)

- 5 mSv (0.5 rem) entire gestational period
- Not exceeding 0.5 mSv (0.05 rem) in any one month

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Students under the age of 18

- 1mSv (0.1 rem)

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Additional Terms

- **NIRL**
  - negligible individual risk level
  - NCRP, exposure that is below risk of fatality compared to other risks of daily life
- **NID**
  - negligible individual dose
  - Provides a low level cut off for regulatory agencies
  - reduction in level is unnecessary; dismissed because the level is very low; 0.01 mSv per Report 116

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REVIEW

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Radiation Protection Organizations

PROVIDE GUIDELINES, NOT ENFORCEMENT

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BEIR

- Biological Effects of Ionizing Radiation Committee
- Studies the effects of groups of people that were exposed such as Atomic bomb victims (Hiroshima and Nagasaki), early radiation workers, and victims from Chernobyl
- Future studies from Fukushima

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US Regulatory Agencies

ENFORCERS OF THE PROTECTION STANDARDS

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NRC

- Nuclear Regulatory Commission
- Former Atomic Energy Commission
- Controls atomic energy for national security
- Mainly oversees nuclear energy industries (mechanics of power stations, NM procedures, seed implants for prostate cancer and thyroid cancer)
- Approves RSO

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Agreement States

- Agree to follow the guidelines set by the NRC and enforce it through the state health department
- Non-agreement states are enforced by the NRC agents

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EPA

- Environmental Protection Agency
- Protects humans and the natural environment
- Enforces regulations for the control of radiation in the environment
- Set level for radon in homes

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FDA

- Food and Drug Administration
- Regulates production of electronics, including diagnostic equipment
- Performs on-site inspections, especially mammography

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OSHA

- Occupational Safety and Health Administration
- Regulates occupational exposures and "right to know" for employees
  - Hazardous substances
  - Infectious agent
  - Radiation

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State Department

DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF RADIATION PROTECTION

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RSO

- Radiation Safety Officer
- Dr. Chandra Kota

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RSC

- Radiation Safety Committee
- Dr. Michael Gent is the chairman

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Acts & Bills

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  - TVs
  - Microwaves
  - X-ray equipment
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CARE bill

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NCRP Reports

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    - Pregnant worker
- Somatic & genetic effects kept to a minimum
- Goal of radiation protection
- Makes recommendations for risk-benefit analysis of radiation exposures

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NCRP Report #160

- Reviews the increased exposures of the population of United States from 2006
- Mostly due to medical imaging

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- Covers management of exposure to ionization radiation in the United States
  - Purpose is to prevent deterministic effects (acute and chronic tissue reactions) and reduce the probability of stochastic effects (primarily cancer)

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You have BRAINS in your HEAD.
You have FEET in your SHOES.
You can STEER yourself any
DIRECTION you CHOOSE.
~ Dr. Seuss

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