Radiation Quantities & Units

Mrs. Heather Herb, B.S., R.T.(R)(M)

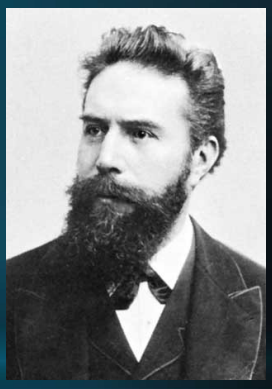
MI Program

1

Historical Timeline in Radiation Protection

2

November 8, 1895



Wilhelm Conrad Roentgen
"On a New Kind of Ray a Preliminary Communication"

3

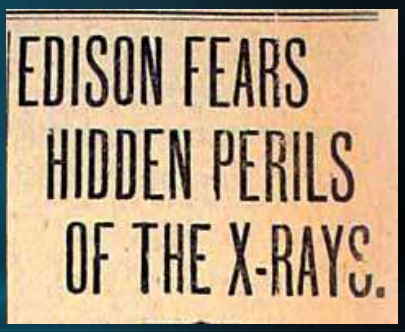
*First Clinical Radiograph in US

* February 1896- Hanover physician Dr. Gilman Frost and Dartmouth College physics professor Edwin Frost took the first known clinical radiograph
* It was a boy's broken wrist and the exposure took 20 minutes

4

* 1904- First Radiation Induced Death in US

Clarence Madison Dally


EDISON FEARS
HIDDEN PERILS
OF THE X-RAYS.

What piece of radiology equipment did Thomas Edison invent?

5

* 1910
1st cancer related death to a physician from occupational exposure

6

Early 1900's

- Radiodermatitis
  - Radiologists and dentists
  - Resulted in cancer
- Aplastic anemia
  - Bone marrow failure
- Leukemia
  - Abnormal overproduction of WBC

7

1921

- British X-ray and Radium Protection Committee was founded
  - Set up guidelines to reduce occupational injury
  - Did not succeed because they did not have enough background knowledge or a measurement techniques

8

*1900- 1930

- *Skin erythema dose- inaccurate because it varied from person to person
- *First International Congress of Radiology met
- *ICRU (International Commission on Radiation Units and Measurements) was established
- *Roentgen accepted but not clearly defined
- *A “tolerance dose” of 0.2 Roentgen per day established

9

*1935-1950

- *“Tolerance dose” lowered to 0.1 Roentgen per day
- *Roentgen internationally accepted as a unit of measurement for exposure
- *NCRP established
- *International System of Units was established (SI)
- *Maximum Permissible Dose (MPD) replaced the “tolerance dose”
  - *Expressed in rem (radiation equivalent man)

10

1970-1990's

- Dosimetry and risk analysis established
- Effective Dose Equivalent (H_E)
  - Measured in sievert
- SI units were adopted

11

Effects of Radiation

- Somatic
- Genetic

12

Somatic effects

- Effects that are seen in the individual who received the exposure
  - Short term (acute or early)
    - Erythema
    - Decrease in blood cells
    - Disruption of GI structures and function
    - CNS failure
  - Late effects
    - Cancer
    - Cataracts
    - Embryologic effects during 1st trimester
    - Shortening of life span

13

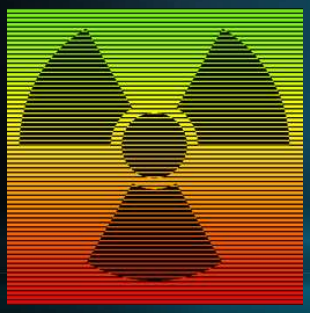
Genetic effects

- Damage to the cell's genetic code/ DNA molecule
- Seen in offspring of the individual who received the exposure
- Exposure is received pre-conception
  - Excessive mutations

14

Basic Radiation Quantities

- Exposure
- Absorbed Dose
- Dose Equivalent
- Radioactivity



15

Exposure (X)

- Amount of radiation that may strike an object when in the vicinity of a radiation source (ionization in air)
- Used to measure radiation exposure or intensity
- Measures tube output of imaging systems and radiation monitors used to calibrate machines
- Applies only to x-ray and gamma
- Measured in
  - SI: Coulomb/kilogram (C/kg)
  - Traditional: Roentgen (R)
- Conversion

  $1R = 2.58 \times 10^{-4}$ C/kg

16

Air Kerma

- SI unit that can express how energy transfers from the beam to a material (example: the skin surface of a patient or technologist)
- Sometime used to describe
  - Tube input
  - Tube output
  - Exposure to skin surface
- Kinetic energy release in matter, material or unit mass
- Measured in gray (Gy)
  - Usually expressed in mGy or mGy/min
- ESAK- entrance skin air kerma- dose index that is obtained from the center of the x-ray beam using a calibrated electronic dose meter

17

Absorbed Dose (D)

- Amount of energy (radiation) absorbed per unit mass (patient tissue)
- Measures the absorbed patient dose
- The higher the atomic number the higher the absorbed dose
- Responsible for biologic damage to the tissue that is exposed
- Measured in
  - SI: Gray (Gy) (less commonly used is the J/kg)- named after English physicist (Louis Harold Gray- the father of radiobiology)
    - Can be expressed in mGy
  - Traditional: rad (radiation absorbed dose)
- Conversion

  1 Gy= 100 rad

18

*Conversion

If 1 Gy= 100 rads then:

10 Gy= ?? rads

10 * 100 = 1000 rads

Or

545 rads= ?? Gy

545/ 100= 5.45 Gy

19

Equivalent Dose (EqD) or Dose Equivalent (H)

- *Average dose in human tissue or organs by different types of radiation that measures biologic harm
- *Measures the quantity of radiation received by radiation workers (occupational exposure seen on badge reports)
- *Utilizes radiation weighting factor to determine amount of damage per type of radiation
- *Measured in
  - *SI: Sievert (Sv) – named after a Swedish medical physicist (Rolf Maximilian Sievert)
    - *Sometimes expressed as mSv
  - *Traditional: rem (radiation equivalent man)
- *Conversion

  1 Sv = 100 rems

*textbook

20

*Conversion

If 1 Sv= 100 rems then:

2 Sv = ?? rems

2 x 100 = 200 rems

Or

450 rems = ?? Sv

450/ 100= 4.5 Sv

21

*1 Sv = 1000 mSv

*Example:

*5 Sv= 5000 mSV

BOX 4.6 **Subunits of the Sievert**

Smaller fractions of measured quantities such as the sievert (Sv) will have a prefix. Examples follow.

Prefix	Subunit	Symbol	Fraction	Factor
centi-	centisievert (cSv)	c	1/100	10^{-2}
milli-	millisievert (mSv)	m	1/1000	10^{-3}
micro-	microsievert (μSv)	μ	1/1,000,000	10^{-6}

Radiation Protection in Medical Radiography, 8th Ed. Statkiewicz Sherer

*Sievert conversion

22

W_R = harmfulness of type of radiation

TABLE 3-2 Radiation Weighting Factors for Different Types and Energies of Ionizing Radiation

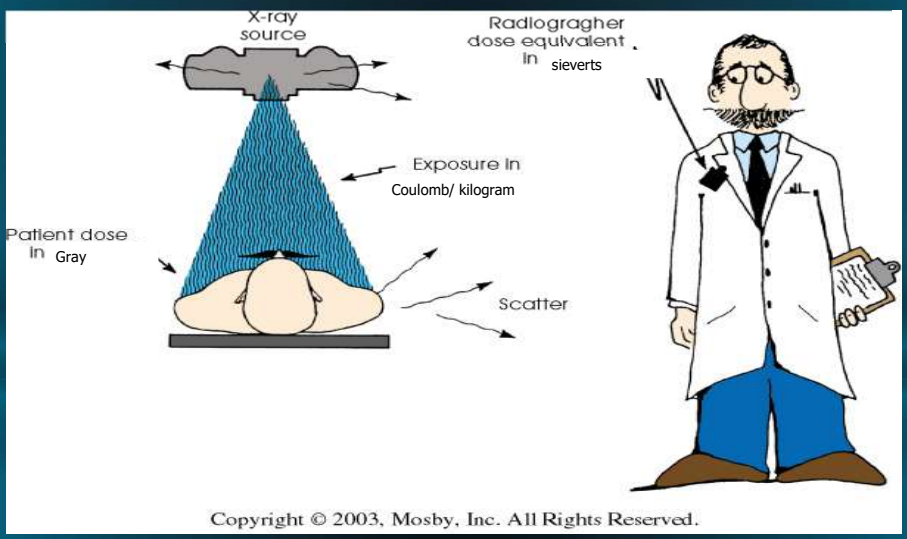
Radiation Type and Energy Range	Radiation Weighting Factor (W_R)
X-ray and gamma ray photons and electrons (every energy)	1
Neutrons, energy <10 keV	5
10 keV-100 keV	10
>100 keV-2 MeV	20
>2 MeV-20 MeV	10
>20 MeV	5
Protons	2
Alpha particles	20

Data adapted from International Commission on Radiological Protection (ICRP): *Recommendations*, ICRP Publication No. 60, New York, 1991, Pergamon Press.

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

23

*Patient vs. Technologist Doses



24

*Mrs. Herb's mnemonic

Ex CAGES

EXPOSURE
COULOMB/ KILOGRAM
ABSORBED DOSE
GRAY
EQUIVALENT DOSE
SIEVERT

25

*Radioactivity (A)

*Measures the quantity of radioactive material
*Not used in diagnostic x-ray
*Measured in
  *SI: Becquerel (Bq)- named after a French engineer and scientist (Antione Henri Becquerel)
  *Traditional: Curie (Ci)- named after Pierre and Marie Curie
  *In 1903 the Curies and Mr. Becquerel won the Nobel Prize for work with radioactivity
*Conversion
  1 Ci= 3.7 X 10^{10} Bq

Trivia fact- Marie Curie died from aplastic anemia most likely caused by radiation exposure

26

*Effective Dose (E)

*Measures an overall risk of radiation exposure and biological damage from ionizing radiation

- *Measured in sievert (Sv) or rem
  - *Sometime expressed in mSv
- *Takes into consideration the type of radiation and the radiosensitivity to determine harm (radiation induced cancer or genetic effects, stochastic effects)
- *Uses Tissue Weighting Factors

W_T = sensitivity of type of tissue to radiation

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

27

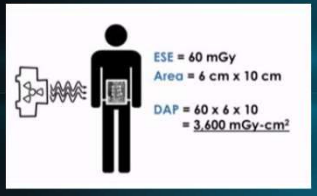
*Dose Area Product (DAP)

*A way to calculate patient dose taking into consideration the technique that is used and the size of the field (ESE x area)

*Takes into consideration the dose and the volume of tissue exposed

- *Same technique with smaller field size= less harm

*Gives a better indication of overall harm



28

Collective Effective Dose (ColEfD)

- Exposure of a population or group from low doses of different types of ionizing radiation
  - Measured in person-sievert or man-rem

Example:

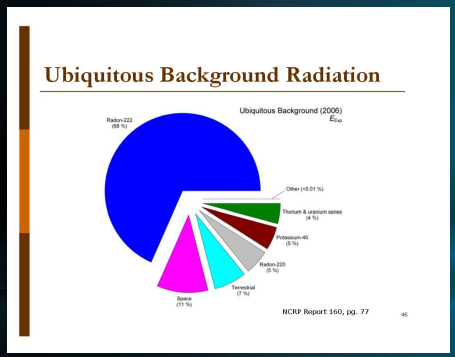
200 people receive 0.25 Sv

200 X 0.25= 50 person sievert or man- rem

29

Average Effective Dose (Eexp)

- Dose to an individual in a group exposed to a specific source

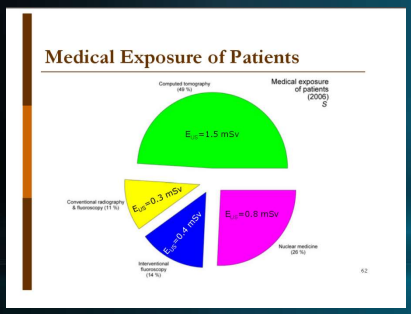


http://pbadupws.nrc.gov/docs/ML1122/ML11229A695.pdf

30

Effective Dose Per Individual in US (EUS)

- Dose per individual in the US population whether exposed to the source or not



http://pbadupws.nrc.gov/docs/ML1122/ML11229A695.pdf

31