This information is to augment your readings in the Syllabus. No questions in this area will be on the test. This is simply to help you in your understanding of the material in the chapters.

Introduction to Radiation Injury and Protection.

1. Elizabeth Fleischmann-Aschheim was a pioneer as an x-ray photographer. Tragically, she was also among the very first to die from the then-unknown effects of radiation poisoning. She had been written about in the San Francisco Chronicle in June 1900 as having accomplished amazing pictures of solders returning from the Philippines during the Spanish American War. At the age of 30 she became interested in the "magical rays capable of penetrating all woven fabrics as if they were mere vapor, piercing the flesh ... and passing through cords and muscles and bones with varying facility." After a year of study she opened an X-ray clinic on Sutter Street. Five years later the same paper reported her death. Her arm was amputated and she never recovered. She was only 38.

2. The first person to die from overexposure from radiation was Clarence Dally, assistant to Thomas Edison. They were working on a fluoroscope unit. As a result of Dally's death, Edison stopped all experiments with radiation.

3. By 1896, just a year after Roentgen's discovery of the properties of x-rays, more than 20 cases of severe x-ray burns had been noted.

4. There are two sources of ionizing radiation: Natural (background) and human made.

- Background from the sun & radioactive elements (like radium).
- Human made:
    - fallout from nuclear weapons and incidents from power plants
    - radioactive material used in industry
    - medical and dental exposures.

5. When it was established that radiation was harmful it became necessary to establish ways to measure its use.

- Initially used a dose which was the amount to turn the skin red. Erythema,
- Ionization chambers were invented and are, of course, more accurate. This unit measure the amount of ionizing radiation that produces one cubic centimeter of air, ions carrying one electrostatic unit of quantity of electric of either sign. This was in 1938 and the unit is called the "R" short for Roentgen.
- In 1956 the RAD measurement was coined and it stands for the amount of radiation absorbed in a medium. The new SI equivalent unit is called the Gray and one Gray equals 100 RADs. At the same time the unit of biological effect, the rem, was labeled. The SI equivalent is called the Sievert. One Sievert is equal to 100 REMs.

- d. 1 R =1 RAD = 1 rem
- e. RAD is an acronym for Radiation Absorbed Dose
- f. Rem is an acronym for Radiation Equivalent Man

7. In 1964 the National Council on Radiation Protection and Measurement (NCRP) was chartered. It continues to provide information and recommendations in the public interest concerning radiation measurement and protection.

Fundamental principles of radiobiology

A. FROM MOLECULES TO HUMANS

1. It is known x-rays are harmful

2. If they are intense enough, they can cause cancers, leukemia and genetic damage

3. The major problem is that we just don't know for sure the amount of radiation which can cause damage caused by diagnostic x-rays (benefit vs risk)

4. Regardless it is important to produce high quality radiographs with the least amount of radiation exposure

5. Effects of x-rays on humans are the results of interactions at atomic levels.

- Scatter which is created in the diagnostic range, interacts either with the whole atom (excitation of the atom) or with the outer shell electrons (Compton which ionizes the atom)
- photoelectric effect which is an ionizing reaction with the inner shell electron THIS is what gives contrast.
    - You can have density without contrast....but you CAN NOT have contrast without density.
    - Photoelectric Effect gives contrast
    - Compton gives additional density on the image..it degrades contrast.That is why we use measures to remove it.
    - BUT remember if you do remove it, you MUST increase your technique.

6. In either case, energy is deposited in the tissue and this can cause a molecular change.

- chemical binding properties can change.
- molecule may break or could relocate positions
- the molecule may then function improperly or cease to function
- this could cause damage or kill the cell

7. At each stage recovery is possible

- ionized atoms can become neutral
- molecules can be mended
- cells and tissues can recover

B. HUMAN BIOLOGY

1. Body is made of atoms, the level at which radiation interaction occurs.

2. It is the atomic composition that determine the character and degree of the radiation interaction.

3. It is the molecular and tissue composition that defines the nature of the radiation injury.

4. 85% of the body is hydrogen and oxygen

5. Radiation interaction can change the growth and metabolism of the cell

6. Metabolism is the collective process of catabolism (breaking down) and anabolism (building up). Each cell has its own programing and x-rays can alter the process.

I'm not going to go into the Molecular the cellular composition at this point to much degree. If you are interested in more information refer to a biology text.

Just need to understand that the HUMAN CELL

1. has to major segments

a. nucleus, Has DNA, RNA, protein and water

b. cytoplasm==larger part of the cell has the same except DNA

1. endoplasmic reticulum allows nucleus to communicate with the nucleus
2. mitochondria==where energy is produced
3. ribosomes==protein synthesis
4. lysosomes==enzymes digest cellular fragments

2. it takes a dose of about 1 Mrad to produce a measurable change in any physical characteristic of any of these parts

3. But it takes only a few rads to affect a living cell to produce a measurable biologic response

4. Less than 100 rad can kill the cell actually less to affect the nucleus

5. These cells form tissues which form organs.

6. The sensitivity of these cells depends

a. on the stage of the cell from immature cells to mature== the undifferentiated are the most sensitive

b. also the type of cell (page 64 in your Syllabus).

Note not all of us are using the same printed syllabus. In some cases the page numbers may vary by one or two numbers.

LAW OF BERGONIE' AND TRIBONDEAU

Two French scientists theorized and observed that radio-sensitivity was a function of the metabolic state of the tissue being irradiated.

1. Stem cells are radiosensitive. The more mature a cell is, the more resistant it is to radiation.

2. The younger the tissues and organs, the more radiosensitive they are

3. When the level of metabolic activity is high, radiosensitivity is also high.

4. As the proliferation rate for cells and the growth rate for tissues increases, the radiosensitivity increases also

C. BIOLOGIC FACTORS AFFECTING RADIOSENSITIVITY

1. Age =more radiosensitive before birth and less so as get older and then increases again with old age (not clear at what age this is.).

2. Gender== females less radiosensitive than males but some question about the validity of this statement.

3. Recovery==in vitro experiments = if cell not killed before the next division, it will recover, but can be mutated slightly

D. RADIATION DOSE-RESPONSE

1. two characteristics --linear or non-linear and threshold or non-threshold

a. linear=directly proportional to the dose when dose is doubled the response is doubled

b. nonthreshold= any dose regardless of size is expected to produce response

c. non-linear==means different doses give different response

d. threshold= just means that it takes a specific amount to get a response.

2. When we study the effects of radiation exposure on humans we accept the model of Linear/Non-threshold

E. MOLECULAR AND CELLULAR RADIOBIOLOGY

1. Radiation can effect DNA=genetic material for each cell

2. Direct hit if on any of the critical components of the cell such as the DNA

3. Indirect hit if on less critical parts of the cell ==this is what causes free radicals=this transfers the energy to the more critical parts

4. 80 % of body is water so most of the interactions are indirect at least 95%

5. Target theory===the cell may die if the radiation hits specific parts of a cell if the molecule and if the part hit is a one and only cell or part of a cell or is critical in cell survival

6. Multi-target, single hit model

a. threshold phenomenon==human cells are complex and are thought to have more that a single critical target==so if there are very low doses of radiation all should be well but if more likely hood of being hit

EARLY EFFECTS OF RADIATION

1. Effect in a few days or weeks is early effect

2. Death=never reported short term for diagnostic ranges. even in the older cases of long term doses were much higher them

3. Larger accidental exposure from nuclear weapons or energy field have resulted in death. Chernobyl in 1986 30 died. At Three Mile Island there were no deaths

4. If death occurs within days or weeks it is called acute radiation syndrome

5. The sequence of events following high-level radiation exposure are

a. **PRODROMAL SYNDROME**==matter of minutes to hours=immediate response and can last form a few hours to a coupe of days

b. **LATENT PERIOD**== no sign often it is assumed there will be no long range problem or that the person is healed

c. **HEMATOLOGIC SYNDROME**==latent period up to 4 weeks general feeling of well-being==yet what is happening is there is a reduction in numbers of white cells, red cells and platelets in the circulating blood.

1. the manifest period is characterized by mild diarrhea, lethargy and fever maybe vomiting.

2. not lethal dose recovery begins in 2-4 weeks but up to 6 weeks for full recovery

3. if fatal usually infection is the cause of death

d. **GI SYNDROME**==as above but then

1. loss of appetite

2. again lethargic.

3. diarrhea will increase in severity to watery and bloody stools 4. death within 4-10 days of exposure

4. the cell renewal in the lining of the intestines is usually 3-5 days remember that radiation kills the stem cell so there is no tissue so the passage of fluids across the intestinal membrane stops and electrolyte imbalance occurs also bleeding

e. **CENTRAL NERVOUS SYSTEM SYNDROME**==death matter of hours to 3 days

1. first severe nausea and vomiting within minutes=

2. get confused feeling burning sensation in skin

3. diminished vision

4 loose consciousness within first hour

5. possible latent period up 6-12 hours

6. again prodromal symptoms but worse than disorientation, breathing problems, loss of muscle coordination, convulsive seizures, loss of equilibrium, lapses into a coma, then dies.

7. Cause of death is the elevated fluid content of the brain resulting in increased intracranial pressure, inflammation in blood vessels

8. also at the doses high enough to effect the CNS would also effect all other organ systems

5. The LD 50/30 is the dose of radiation to the whole body that will result in death within 30 days to 50% of the subjects so irradiated.

Humans 300 ray but it has been proven humans can tolerate much higher doses up to 550 rads

6. **Mean Survival Time**==the higher the dose the shorter the time to death. from 200 rad 60 days to 1000 rad 4 days

7. **LOCAL TISSUE DAMAGE**

a. local not whole body

b. cell death is shrinkage (atrophy) of the tissue or organ it may recover or lead to total non function

1. skin

a. Erythema(sunburn)

b. desquamation (ulceration)

c. epilation (loss of hair)

2. Gonads

a. doses a low as 10 rads can cause an effect

b. major difference is female stem cells multiply in number during fetal life 7 million during mid pregnancy them begin to decline because of spontaneous degeneration== them suspended until puberty (now down to several hundred thousand) the 4-500 are available for fertilization (ovum) during life span.

c. male-testes are continuous being produced form stem cells 3- 5 weeks process

d. OVARIES=early radiation will cause reduction in size

doses of 10 rads in mature female delay menstruation

200 rads temporally sterility

500 rads permanent sterility

25-50 rads can cause genetic damage

e. TESTES=will also atrophy after high doses of radiation doses as low a 10 rads reduction in number of sperm 200 rad temporary sterility start 2 months and last up to 12 months 500 will cause permanent sterility

1. early tech in the 20-30's went for weekly blood tests because there was no personnel monitor devices. so blood tested total cell counts and white cell differential count. If over 25% greater than normal time off until corrected. problem was that it takes 25 rads whole body to affect these changes and that is very high,

2. principal response to radiation exposure is a decrease in all types of blood cells in the circulating peripheral blood.

3. following initial exposure the first cells to become affected are the lymphocytes (immune response), platelets develop more slowly

9. **CYTOGENETIC EFFECTS==**

1. effect on genetic aspects of the cells, particularly chromosomes.

2. in test studies they know radiation causes problems but in live cells in humans no real testing but still know there are problems.

3. If the cell survives the damage will be manifested during next mitosis following exposure.

4. hit can break a rung , two hits can cause it to break apart

LATE EFFECTS OF RADIATION

1. Late effects can follow low doses delivered over a long time period

2. Usually as a result of diagnostic but could be caused by one large but not large enough to kill

3. Radiation induced malignancy and genetic effects

4. Life span shortening (this is possibly but hard to know for sure)

5. very difficult to get any true scientific studies because dose in not normally known, but assumed low and the frequency of response is very low.

LOCAL TISSUE EFFECTS

1. Skin==chronic irradiation can result in carcinoma and severe nonmalignant changes=old radiologist before gloves got calloused, discolored and weathered appearance to hands and forearms. get dry brittle and crack

2. chromosomes==cause late response to leukemia

3. Cataracts==in 1932 E.O.Lawrence of University of California built the first cyclotron, a machine capable of accelerating charged particles to very high energies. Ability to study the nuclear structure of atoms. Looked at the results through a device similar to the old fluoroscope screens. Got high radiation exposure to the lens of the eyes because the looked directly into the beam.

In 1949 a paper was written which reported cataract in these physicists. by 1960 several hundred cases were reported.

4. radiosensitivity of the lens of the eye is age dependent, older greater effect and shorter the latent period. average is 15 years.

5. occupational exposures to lens of the eye are considered low enough not to wear protective glasses

6. CT patient head can get up to 5 rads per slice so patient should wear if it won't effect diagnostic info

LIFE SPAN SHORTENING=

1. it is concluded that at the worst, humans can expect a reduced life span of 10 days for every rad.==for radiation workers only 12 days==simply accelerates premature aging and death

2. yet observations on human populations exposed haven't really proved this ==atomic bomb survivors, watch-dial painters, etc.

3. radiologist in early 1930's did die 5 years younger than general population, but by 1965 same

4. also a study was done on Rad Techs from world war II using poorly designed machines and results show no difference from general population

RADIATION-INDUCED MALIGNANCY

Most conclusions are from experiments on animals

1. Leukemia=increases with increase dose (animals)

    a. A-bomb survivors= 300, 000 in those cities, 100,000 killed 100,000 received much radiation studied nearly this number expected 52 cases of leukemia but got 144.

    b. Radiologist=by 1940's pernicious anemia and leukemia were reported to be very high

As many as 8 out of 175 death result of leukemia. Now results equal to general poulation

2. Cancer==many cancers have been listed as being implicated as radiation induced.

    a. Thyroid=radiation to shrink thymus -20 years later nodules developed and some cases of thyroid cancer==24 out of 3000 and none out of their non irradiated siblings (5000)

    b. Bone cancer== radium watch-dial painters 72 out of 800 over 50 years have been reported Radium half life is 1620 years

    c. Breast cancer= increase in patients with TB. apparently they had artificial pneumothorax included in their affected lung done under fluoroscopy. Those patients who faced the tube had a greater incidence second group was women who had acute postpartum misstates were treated with x-rays 75-1000 rads

    d. Lung cancer=miners who worked in uranium mine and those where radon 9 decay products of uranium) have higher incidence of CA

TOTAL RISK OF MALIGNANCY==approximately.. 50-150 death from radiation induced malignancy following an exposure of 1 rad to 1,000,000 persons with in 25 years.

RADIATION AND PREGNANCY

1. Effects on fertility-discussed earlier=but additionally study done in 1927 and 1955 on American radiologist found depressed fertility and increased congenital abnormalities in offspring

2. Irradiation in Utero=embryo is rapidly developing cells it is highly sensitive

    a. within 2 weeks of fertilization possible prenatal death with results in spontaneous abortion.=been observed in high dose radiotherapy

    b. but it appears that if there is no abortion then there are no effects.

    c. 2nd week to 10th two effects may occur skeletal and organ abnormalities can be induced

    d. diagnostic low- increase abnormalities 1% above normal dose of 10 rad

e. a British study has taken all childhood malignancies by comparing similar children who were not x-rayed and have found that the rate of leukemia is 50% higher than the other group

f. high radiation has affected the sizes of the offspring Japan 1 inch shorter and heads smaller

3. Genetic effects=no true data on humans but on mice it has been proven that doubling the dose of radiation will produce twice the frequency of genetic mutation.

HEALTH PHYSICS= is concerned with providing radiation protection for persons employed in radiation industry and the population at large==term was coined during the early days of the "Manhattan Project" (secret wartime effort to develop the atomic bomb.) to describe the group of physicists and physicians who were in charge of ensuring radiation safety of those working on the project.

A. CARDINAL PRINCIPLES OF RADIATION PROTECTION=time, distance and shielding

1. time=keep it short

    a. directly proportional Exposure=rate X time====225 mR/hr X 36 mins = 135 mR

    b. on-off 5 min timer shouldn't need to go past it

2. distance = maintain a large distance between source and exposed person

- inverse square law= the formula is clearly stated in the syllabus

3. shielding=insert shielding between source and exposed person

    a. usually lead

    b. HVL

B. MAXIMUM PERMISSIBLE DOSE=that which will produce no significant radiation effect(given today's info)

- no radiation worker should receive above this exposure
- has changed over time

C. X-RAYS AND PREGNANCY=particular care and action

- time dependence-often pregnancy is not known
- spontaneous abortion can occur but generally with excessively high amounts of radiation (no known reason for a women to have a TAB based upon Dx dose)
- congenital abnormalities skeletal deformities
- pregnant tech= must inform of problems fill out forms, give additional badge, can't do fluoroscope and portables
- pregnant patient=be careful 10 day rule 10 days following onset of menstruation (obsolete now) Now just be careful
- if find out after wards figure out fetal dosage use 10-25 rule ==If lower than 10 rad a TAB is not indicated unless other circumstances==over 25 rad a TAB may be justified ==between careful consideration must be taken
- fetal dose in the 1 to 5 rad range is usually for most series of examinations SO no problem

RADIATION PROTECTION PROCEDURES

A. OCCUPATIONAL EXPOSURE

1. rad (gray)= dose = radiation energy absorbed

2. Roentgen (coulomb /kg)= exposure radiation intensity in air

3. rem (seivert)= dose equivalent= biologic effectiveness of radiation energy absorbed.

4. max perm dose rad personnel is 5 rem year (50 mSv/yr)

5. highest occupational exposure is during fluoroscope especially during special procedures

B. PATIENT DOSE

1. frequency is increasing between 6-10 % a year in US

2. Exposure is generally reported in Skin Dose (easy to measure) and gonadal dose (important as discussed), and bone marrow, (because responsible for radiation induced leukemia)

a. skin dose also referred to as (ESE) entrance skin exposure=usually tested with the TLD thermoluminescence dosimeter

b. For every milliamperes of fluoroscopic technique, it is assumed a table top intensity of 2 rad/min

3. Genetically significant dose (GSD) defined as the gonad dose that, if received by every member of the population, would be expected to produce the total genetic effect on the population as the sum of the individual doses actually received.

C. REDUCTION OF OCCUPATIONAL DOSE

1. 95% of exposure comes form fluoroscope. specials, and portable

fluoroscope minimum beam-on -time step back

2. Monitoring required when there is any likelihood that an individual will receive more than one fourth the max permissible dose.

3. Personnel monitoring report as stated in the syllabus

4. Protective apparel worn when necessary

5. radiology personnel should never be used to hold patients (except in an emergency)

D. REDUCTION OF UNNECESSARY PATIENT DOSE

1. Unnecessary examinations

a. mass screening for TB

b. hospital admissions

c. pre-employment physicals

d. periodic health exams

2. repeats

3. technique

4. positioning

5. shielding

DESIGN OF X-RAY APPARATUS

1. there are more than 100 radiation protection devices-some for radiographic or fluoroscope assemblies, some for both.

2. Protective tube housing leakage reduces leakage to less than 100 mR/hr at

distance of 1 meter

DESIGN OF PROTECTIVE BARRIERS

1. two types of secondary radiation = scatter and leakage

2. the intensity of scatter radiation 1 meter (m) from patient is .1% of the intensity of the useful beam at the patient.

3. factors affecting barrier thickness

a. distance from source-it is to the next room not the inside of the room with source and that is usually center of room

b. and time of use

RADIATION DETECTION AND MEASUREMENT clearly written in the syllabus so information is not repeated here.