Classroom notes for: Radiation and Life Lecture 15

98.101.201

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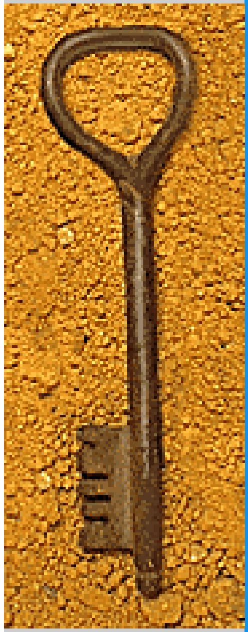
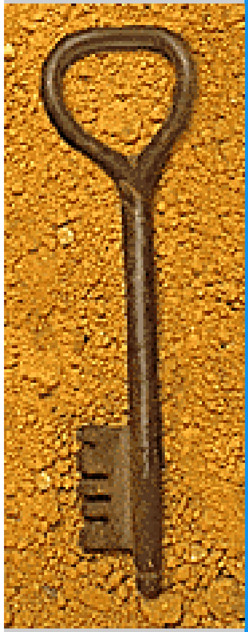


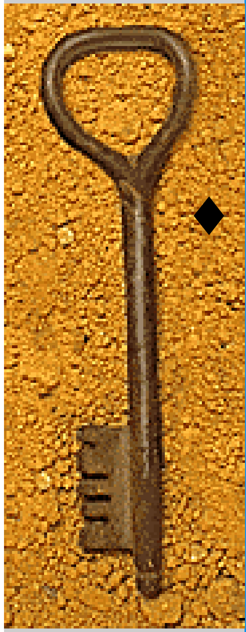
What is radiation therapy?

Radiation therapy (also called radiotherapy, x-ray therapy, or irradiation) is the use of a certain type of energy (called ionizing radiation) to kill cancer cells and shrink tumors. Radiation therapy injures or destroys cells in the area being treated (the “target tissue”) by damaging their genetic material, making it impossible for these cells to continue to grow and divide. Although radiation damages both cancer cells and normal cells, most normal cells can recover from the effects of radiation and function properly. The goal of radiation therapy is to damage as many cancer cells as possible, while limiting harm to nearby healthy tissue.



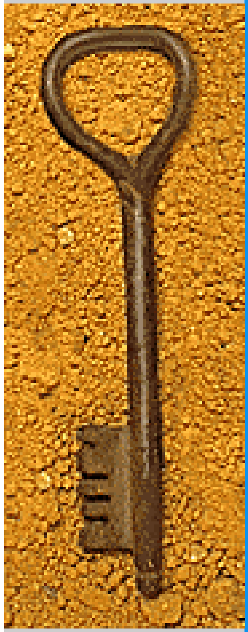
<u>Medical X-Rays (39 mrem/yr- 11% of total)</u> (NCRP 93)

- Medical x-rays are an external diagnostic tool; they're used to find "hidden" causes to problems inside the body, such as a cavity in a tooth, or a hairline fracture in a bone.
- Recall that Wilhelm Roentgen discovered x-rays in 1895.
  - The medical implications were immediately obvious – within a year practicing physicians were using them.
- In 1898, the British Army used a mobile x-ray unit at the battle of Omdurman in the Sudan. The first military use of x-rays coincided with the last cavalry charge of the British Army, in which, incidentally, Sir Winston Churchill participated. *(Radiation and Life,* Hall, p. 85)

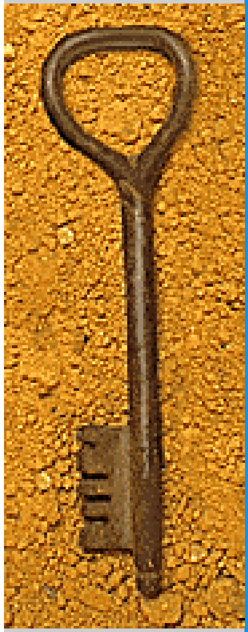


7 out of 10 Americans get a dental or medical x-ray each year http://www.fda.gov/cdrh/consumer/xraybrochure.html)

- Medical x-ray machines operate on two main principles. Quite simply, using high voltage, electrons are beamed at a tungsten target.
- As the electrons accelerate in it, they give of bremsstrahlung x-rays.
  - An accelerating charge, when not bound in a shell, radiates energy (remember Maxwell?).
  - The x-ray photons emitted have a range of energies. Bremsstrahlung energy losses typically represent only a very small fraction of the overall energy lost while the charged particle is traveling through matter.
- For example, a .25 MeV electron that is completely stopped in tungsten (Z=74) will lose about 1.1% of its energy via Bremsstrahlung emission. (*Radiation Safety and Control, Volume 2*, French and Skrable, p. 16)

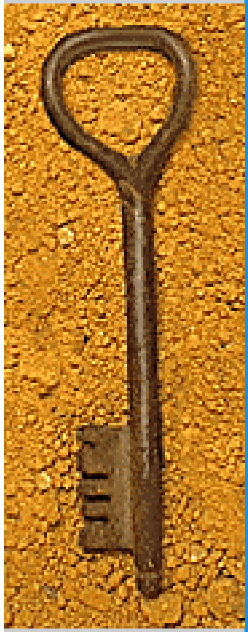


- Also, some K shell electrons are knocked from the tungsten atoms. When higher energy electrons "fall" into the vacancies, characteristic x-rays are generated.
- A filter near the x-ray source blocks the low energy rays so only the high energy rays pass through a patient toward a sheet of film. (http://www.cord.edu/faculty/manning/physics215/studentpages)
- The use of filters produce a cleaner image by absorbing the lower energy x-ray photons that tend to scatter more.(http://www.ndt-ed.org/EducationResources/CommunityCollege/Radiography)



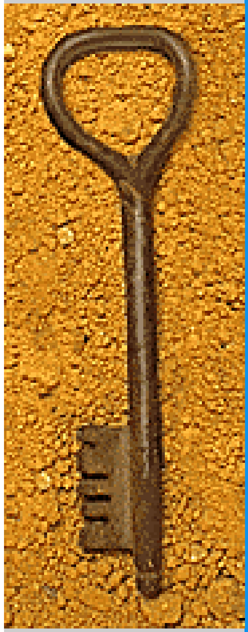
In general, more x-rays will penetrate soft tissue than bone, and hence bone will show on photographic film (or in digital images).

- X-ray films for general radiography consist of an emulsion-gelatin containing a radiation sensitive silver halide and a flexible, transparent, blue-tinted base. The emulsion is different from those used in other types of photography films to account for the distinct characteristics of gamma rays and x-rays, but X-ray films are sensitive to light. Usually, the emulsion is coated on both sides of the base in layers about 0.0005 inch thick. Putting emulsion on both sides of the base doubles the amount of radiation-sensitive silver halide, and thus increases the film speed.

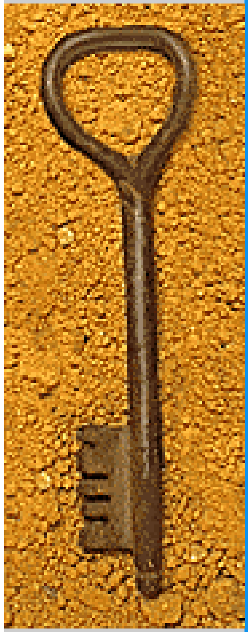


The emulsion layers are thin enough so developing, fixing, and drying can be accomplished in a reasonable time. A few of the films used for radiography only have emulsion on one side which produces the greatest detail in the image.

When x-rays, gamma rays, or light strike the grains of the sensitive silver halide in the emulsion, a change takes place in the physical structure of the grains. This change is of such a nature that it cannot be detected by ordinary physical methods. However, when the exposed film is treated with a chemical solution (developer), a reaction takes place, causing formation of black, metallic silver. It is this silver, suspended in the gelatin on both sides of the base, that creates an image.



- It is often called back scatter when it comes from objects behind the film. Industry codes and standards often require that a lead letter "B" be placed on the back of the cassette to verify the control of back scatter. If the letter "B" shows as a "ghost" image on the film the letter has absorbed the back scatter radiation indicating a significant amount of radiation reaching the film. Control of back scatter radiation is achieved by backing the film in the cassette with sheets of lead typically 0.010 inch thick. It is a common practice in industry to place 0.005 lead screen in front and 0.010 backing the film.(http://www.nd-ted.org/EducationResources/CommunityCollege/Radiography)
  - The film, placed behind the body, is blackened to an extent dependent on the amount of x-rays it receives. It will be blackest where the body is thin and composed of soft tissues. Bones show up as light shadows because they absorb some of the x-rays and prevent them from reaching the film. (*Radiation and Life*, Hall, pp. 87-88)



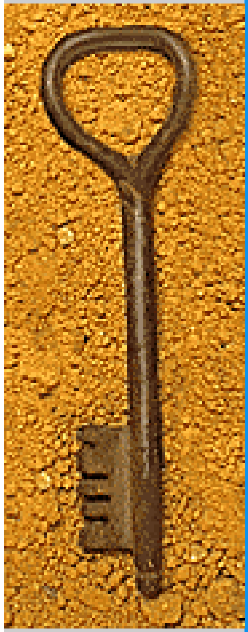
- There are really only three tissues that are sufficiently different from each other in terms of x-ray absorption to show up on an x-ray film: bone, air and soft tissue.

(http://www.thenakedscientists.com)

- Soft tissue can also be investigated using x-rays; for instance barium in the digestive system will block x-rays, allowing a clear view of the gastro-intestinal tract.

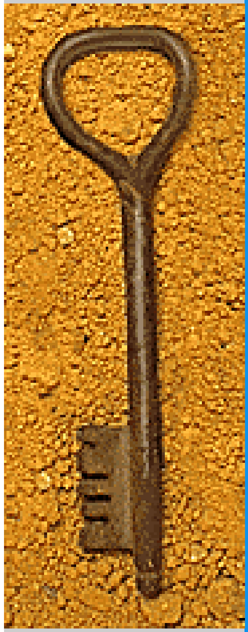
- A major advantage of using x-rays as a diagnostic tool is that they are non-invasive; the doctor does not have to open the patient.

- Some specialized procedures exist, that, although they are diagnostic x-ray procedures, we'll consider separately because of details that make them somewhat different from standard x-rays.

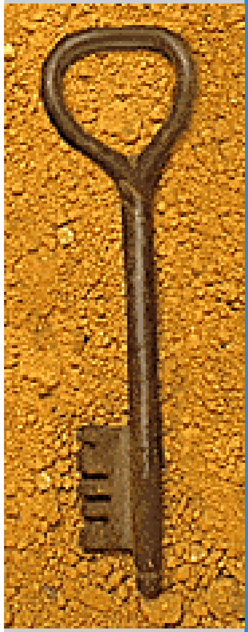


Mammography

- Mammography is a technique whereby x-ray pictures of the breast are taken in order to detect the possible presence of cancer.(*Radiation and Life*, Hall, p. 93)
- It remains one of the most successful (if not *the most* successful) forms of screening for breast cancer.
- It can be used to detect tumors as small as 5 mm in diameter (as of 1984- the size tumor currently detectable today is undoubtedly much smaller) (*Radiation and Life*, Hall, pp. 93-94)
- Since only soft tissue is being viewed, the x-rays used are very low energy doctors to distinguish between fat, muscle, and cysts or tumors.



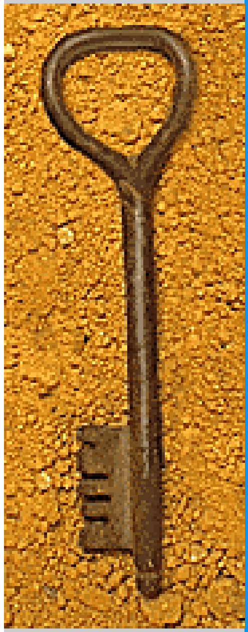
- This procedure has been somewhat controversial over the years, so it is instructive to consider a risk vs. benefit analysis.
- In 1984, the dose received would amount to about 2 rad total (for both breasts) for each mammography procedure. *(Radiation and Life,* Hall, p. 240) Again, the dose received today is probably a smaller number, but we'll use this as a benchmark.
- This is roughly equivalent to getting a dose over the entire body of about 300 mrem; so in 1984, each patient received roughly 300 mrem per mammogram.
- If millions of healthy young women receive annual mammograms at these doses, there is a small chance that a few may develop cancer as a result (although according to Stephen Feig, director of the Breast Imaging Center at Thomas Jefferson University in Philadelphia, "No woman has ever been shown to develop breast cancer as a result of mammography"; *Boston Globe*, 12/2/97- although some studies refute his comments.



- On the “flip-side”, the benefits of receiving annual mammographies have been clearly documented.
- <u>Age Group</u> <u>Reduction in Death Rate from Breast Cancer</u>
- 40-49 35%
- 50-59 45%

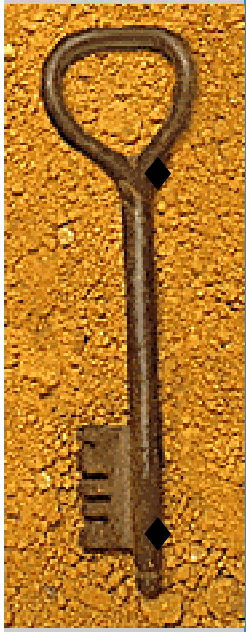
Boston Globe, 12/2/97

- The compromise is that only older women (over 40) are recommended to receive annual mammograms.
- Younger women have much lower incidences of breast cancer.
- Younger women have denser breast tissue, so it is much harder to see tumors in them, anyway.
- The collective dose received by the female population is significantly reduced when the cut-off age is 40.



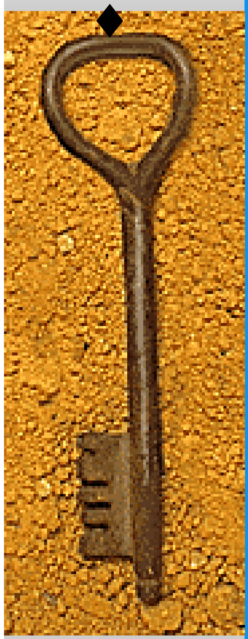
Computer- Assisted Tomography (CAT or CT)

- This procedure was originally designed to allow a better visualization of the brain. *(Radiation and Life,* Hall, p. 240)
- The x-ray machine uses narrow x-ray beams that produce an axial view of the region of interest. CT scans typically produce better detail than traditional x-ray procedures.
- Typical exposures from CT procedures are in a range from 3,000 to 5,000 mR to the part of the body exposed to the x-ray beam. (*The Health Physics Society's Newsletter*, April 2002, p. 8)
- Here I used the term "exposure" correctly because the radiation level is quoted in Roentgens (R), rather than in rems.
- CT scanning now make up an appreciable percentage of all diagnostic procedures performed, estimated at 10% of all radiology procedures and 67% of the total effective dose by Mettler, et al. (2000) (*The Health Physics Society's Newsletter*, April 2002, p. 8)
- It is currently thought that the increased use of CT scanning will result in a higher annual dose in the category "Medical X-Rays", though this remains to be seen.

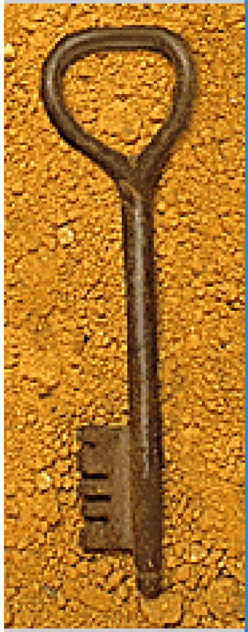


CT Safety Concerns

- Unfortunately, CT scanning has also taken on a controversial aspect. As of Spring 2002, a large number of “whole-body” CT screening facilities had opened across the country. Many terms are used to describe the process: spiral CT scan, helical CT scan, low-dose CT scan, and whole-body CT scan.
- The procedure is similar to what we’ve already discussed, but what is of concern is that these scans are done for self-referred patients in the absence of any symptoms.
  - “Whole-body screening is the performance of whole-body CT examinations on otherwise healthy individuals who have no clinical symptoms indicating the need for or justification for the procedure,” according to Ken Miller, Professor of Radiology and Director of the Division of Health Physics at Penn State Hershey Medical Center in Pennsylvania.
  - “There simply is no evidence right now that whole-body CT screening lowers morbidity or mortality,” according to Kelly Classic, a health physicist at the Mayo Clinic in Rochester, Minnesota.

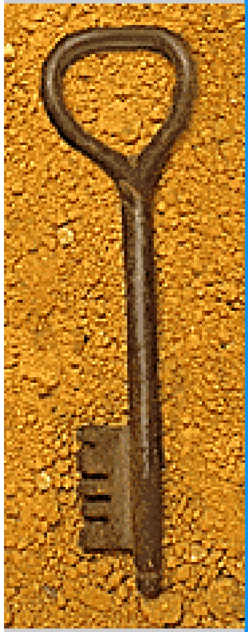


- Most of the risks are hard to quantify. Whole-body CT screening protocols aren't standardized, we don't know the competence or credentials of persons performing or reading the scans, and we don't know what technology is being used for the scans (although we do know that some are using a technology called electron-beam CT). Another risk is the high prevalence of false positive findings that can lead to unnecessary additional studies, patient anxiety, and increased health-care costs," according to Kelly Classic.
  - "Whole-body CT-screening facilities typically do not use intravenous contrast media in their protocols and for that reason do not match the clinical accuracy of visualization that is characteristic of diagnostic CT," according to health physicist Stanley Stern.
- There is also concern that people are being misled into believing a negative scan means they're healthy.
- Typical exposures from CT procedures are in a range from 3,000 to 5,000 mR to the part of the body exposed to the x-ray beam, so this procedure has been misleadingly labeled as "low-dose" by those marketing it.



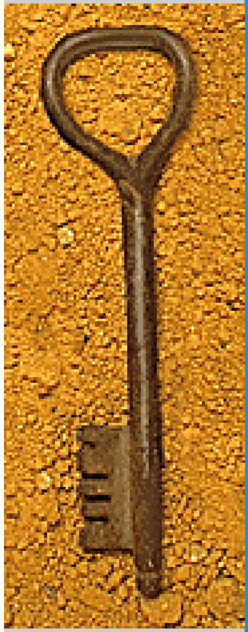
Average Doses

diagnostic procedure	dose in mrem (per procedure)
extremity x-ray	1
dental x-ray	1
chest x-ray	6
pelvis/hip x-ray	65
skull/neck x-ray	20
CT scan (head?)	110

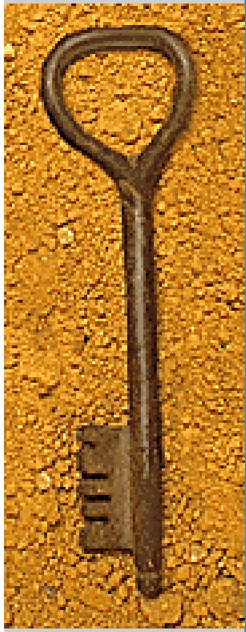


Nuclear Magnetic Resonance Imaging (NMR or MRI)

- MRI is a procedure that doesn't use ionizing radiation. However, we'll consider it in the diagnostic x-ray section because it is a widely used medical diagnostic tool that deserves to be explored in some detail.
- The procedure works as follows:
- The patient is placed in a magnetic field. You've probably all seen pictures of the doughnut-shaped magnets of the MRI device.
  - The nuclei of atoms in the patient line up with this field. Many atomic nuclei can be pictured as tiny magnets; however, they are not normally aligned in the same the same direction because thermal agitation jiggles them continuously and ensures the poles always point in random directions. A magnetic field must be very strong to overcome the agitation; the earth's magnetic field is far too weak to do this. When they are aligned, imagine them as tops that are all perfectly spinning in unison.



- A radio wave field is then applied; this causes the atoms to precess around the magnetic field that is still being applied because they are now in a higher energy state.
- Imagine a top that is spinning but also making a slow circular motion; that’s precession.
- When radio wave field is removed, the atoms stop precessing and realign with the magnetic field, returning to their original lower energy state.
- The drop to the lower energy state results in the emission of electromagnetic energy, in this case, radio waves.
- The radio wave energy emitted depends upon exact tissue composition; thus, NMR imaging provides a “picture” and composition.



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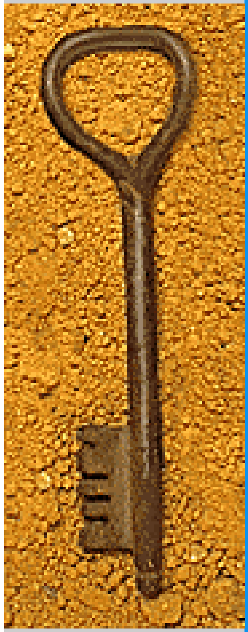
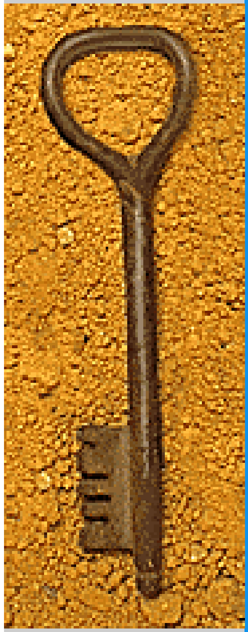
- The radio wave energy emitted depends upon exact tissue composition; thus, NMR imaging provides a "picture" and composition.
  - There is still some debate as to the health effects of subjecting patients to such high magnetic fields; we won't discuss this because neither magnetic fields nor radio waves are ionizing radiation.



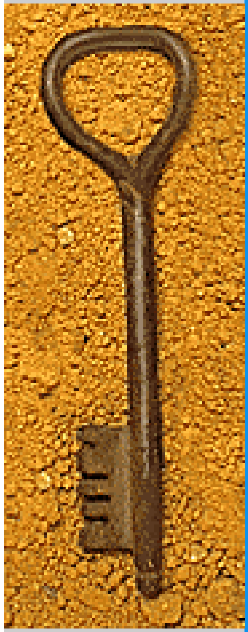
Nuclear Medicine (14 mrem/yr- 4% of total) (NCRP 93)

- Nuclear medicine can be broadly categorized in two different ways.
- diagnostic vs. treatment
- external vs. internal
- Thus you can have, for instance, an internal diagnostic procedure, or any combination of the above two categories.



Nuclear Medicine as a Diagnostic Tool

- Nuclear medicine can be used as a diagnostic tool; consider internally administered nuclear medicine used for imaging.
- Two atoms with same Z (# of protons) are the same element. Thus, they have identical (or nearly identical) chemical properties. If they have identical numbers of protons, they have identical numbers of electrons.
- They may have differing numbers of neutrons. In other words, the two atoms are isotopes of the same element. As a result, one of the atoms may be a radioactive isotope, or radioisotope.
- Particular chemicals are preferentially absorbed by certain body tissue and/or organs.
  - Calcium is a perfect example, it is preferentially absorbed by bones.



- These chemicals can be designed so that they include radioisotopes.
- These chemicals can be administered; the chemical with the radioisotope is thus sent to a specific part of the body. If the radioisotope is a γ-emitter, it is possible to measure the γs with a detector outside the body.
- Since the detectors are very sensitive, it is possible to use very small amounts of radioactive materials in these procedures. Radioactive tests seldom require more than a microgram (one millionth of a gram) (*Radiation and Life,* Hall, p. 106)
- In many instances, the diagnostic equipment converts the gamma radiation being emitted into a computer-enhanced image of the tissue and/or organs in question.
- A bone scan is a perfect example of a diagnostic use of internally administered nuclear medicine. Radioactive Technetium-99 in a "metastable" state is administered to the patient, and the gamma radiation emitted is used to create a real-time picture of the patient's bones. This technique can be better than traditional x-rays at detecting hairline bone fractures, for instance.