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Conventional Radiography Tomography and Their Biological Effects

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The purpose of this paper is two-fold. First, it is our aim to explore conventional radiography and to give some thought to the science of x-ray and other radiation, with reference to medical uses. Secondly, it is our hope to investigate some biological effects of radiography. The reason for our concern of the latter is to raise the level of consciousness in dealing with the various types of radiological processes and adverse effects. Sometimes a lack of information is just as detrimental as too much information.

It is our hope to present our research in such a way as to improve attitudes about the medical use of radiography and to point out that the advancement made in medical technology is staggering. Much innovation and technical expertise have been devoted to the improvement of x-ray machine design and in the safety of its use.

Because approximately half of the entire population of the United States receives a radiological procedure each year, there is concern about the long-term effects of so much radiation. The possibility of radiation injury cannot be ignored and represents the risk that must be weighed against the benefit that occurs to society from the speed and accuracy of x-ray diagnostic techniques. We would be remiss if we did not point out that x-ray is one of the most powerful tools available in medicine to diagnose disease, but we must be aware of its biological effects.

The last twenty years have been unparalleled in medical history, but it is likely that by the twenty-first century, medicine will have changed human life. It is our duty as educators to inform students of the rapid changes in medicine that are taking place and to raise a career conscious level with students at an earlier age.

Our goal is to write a curriculum in radiography. The unit will be watered down to accommodate middle school students, grades six through eight. The unit will be introduced so that the science and math teachers can use a team teaching approach. There will be vocabulary, lesson plans, activities, and enrichment exercises for each objective as well as lists of related careers, and required education for each career. The paper will also include a list of speakers, reading list for teachers and students, resource materials and recommended field trips.

For the purpose of the unit we will have six specific short term objectives to develop; they are as follows:

1. To introduce to students the background on radiography. (Medical Imaging)
2. The use of radiography in our system.
3. To enable students to relate in different aspects of radiography.
4. To explain conventional radiography and tomography.
5. To increase students' level of awareness of the changing picture of health, especially as regards the use of new technical equipment, methodology and personnel.
6. To introduce health related careers.

This unit will be set up as a challenge to youths. It will be designed to interest youths in health careers while providing them with information regarding health and radiography.

The students will learn the different parts of the body and its functions. They will be able to look at slides to see how different parts of the body look under radiography. Since the primary function of a radiographer is to aid doctors in the diagnosis of diseases, some slides of abnormal growth in the body will be viewed.

Introduction

The work of radiologists today is very different from what it was only one generation ago. New medical breakthroughs and technology have made a great impact in the area of radiology. Today's youth are not aware of what is going on in this important area and how they might fit into it. They lack information of the broad world of work in medicine and specifically in the area of medical imaging. These students have very little, if any, contact with the actual work experiences and hands on experiences. They have not given much thought to appraising themselves in terms of their abilities to fit into specific career areas. They have not been exposed to decision making processes in previous school experiences.

To address these needs, educators must assume a great deal of the responsibility to provide a curriculum which will offer students various learning experiences.

It is our aim to develop a curriculum on Conventional Radiology, Tomography and Their Biological Effects. This curriculum will be geared toward students in grades six through eight with a strong interest and motivation to deal with math, science, and computer concepts.

Curriculum development is a continuous process and must be, if we are to provide skills and career education for students in the world of work. More direction should be given to understanding self and developing positive attitudes toward work.

Medical Imaging is a field that is not new, but has taken on a new image because of new medical research and breakthroughs. Come and discover the science of radiography with us.

Marcella—Many people are talking about medical imaging. All of this stuff is enough to blow your mind. I feel as though I am Rip Van Winkle—I must have slept through a generation.

Carolyn—Yes Marcella, there has been a great change in the area of medical imaging. It is about time we wake up and investigate some of these changes.

Marcella—Where do we start? There is so much to talk about.

Carolyn—Marcella, why don't we take a look at conventional radiography first, then tomography and, last but not least, their biological effects.

Marcella—That's great! Who will go first?

Carolyn—Well, since I've been around longer, perhaps I'll talk first.

Marcella—Carolyn, I thought you might say that.

Carolyn—Well Marcella, why don't you sit back and observe as we discover together some facts about conventional radiography.

I guess a good way for me to start is by defining a radiograph. Marcella do you know that a radiograph is a visible photographic record on film produced by the passage of x-rays through an object or body?

Marcella—Carolyn, then a radiograph makes it possible to study the inner structure of the human body.

Carolyn—Yes, x-rays can penetrate body tissues, they have a photographic effect and they cause certain substances to fluoresce (light up) making the object under examination more visible.

Marcella—Carolyn, do you know that new developments are making the procedure even safer and more effective—producing clearer radiographs with less exposure to radiation?

Carolyn—Marcella, that's great.

Marcella—When you finish with the discussion on x-rays, let me talk about their biological effects.

Carolyn—Marcella that's a deal!

Conventional Radiography

X-rays are the principal form of radiation used in radiodiagnosis. X-rays were discovered in 1895 by the German physicist Wilhelm Conrad Roentgen. The story goes that Roentgen was experimenting with Crookes' tubes and discovered that a combination of low pressure of gas inside the tube and a high voltage across the tube caused mysterious rays to be emitted from the anode, or positive terminal of the tube. These rays which Roentgen called x-rays could blacken photographic film and pass through materials opaque to visible light such as paper, wood, or thin metal sheets. Roentgen also found that the rays would pass through his hand when he inserted it between the tube and a plate. The developed photograph indicated that the bones stood out clearly as dark shadows as compared with the flesh.

This means that the bones, more dense than the flesh, blocked the rays, whereas the rays could pass more easily through less dense materials, such as portions of the hand where there is no bone. As x-rays pass through the body, radiation is absorbed by denser parts and easily penetrates the less dense parts. The result is an image on the film placed on the other side of the body. The x-ray picture, called a radiograph, is a permanent picture of the internal body. It looks like a photo negative. Dark areas represent the least dense structures; white areas, the most dense structures. (See Figure 1 at end of unit.)

To produce usable roentgenographic images, it is necessary to produce and control roentgen rays of varying wavelengths and direct them to a recording instrument so that the image can be visualized. The source of roentgen rays is an x-ray tube; and images may be visualized on roentgenographic films, fluoroscopic screens, television or movie films.

Roentgen rays are forms of electromagnetic energy similar to visible light and radio and television signals, but with a shorter wavelength—the shorter the wavelength, the more energy the x-ray wave has. Therefore, the greater the energy, the better the wave will be able to penetrate matter. Longer wavelengths may be reflected from the surface of an object. There are different wavelengths to roentgen rays; in medical roentgenography, roentgen rays appear as a group, or spectrum, of energy levels or wavelengths. Roentgen rays travel at the speed of light and usually have a wavelength of 1/10,000 that of visible light.

To demonstrate waves—tie a 3-m length of clothes line to a doorknob of a closed door. Take the opposite end of the rope and stretch it across the room. Hold the rope loosely at the height of your waist. Flip the rope up and down several times. The rope makes a number of waves. The rope will form hills (crests) and valleys. The faster the rope flips, the more waves and the closer they are together. The distance from crest to crest is called wavelength. The number of crests that pass a given point in a second is called frequency. (See Figure 2 at the end of this unit.)

The x-ray tube is the source of the radiation. The tube is composed of an anode (+) and a cathode (-) enclosed in an evacuated glass container and surrounded by a lead housing. The cathode usually contains two different sizes of filaments and a focusing device which is a hollowed out metallic well into which the filaments are positioned.

To produce roentgen rays, electrons must be available. It is hard to explain where the x-ray comes from without going inside the atom. Inside the atom, the nucleus is the core with electrons in orbit around it. To make x-rays, the target is bombarded by electrons from the cathode. It takes alot of energy to disturb the electrons in the atoms of the target. The greatest amount of energy is needed to eject an electron from the inner shell which is close to the nucleus. The electrons cannot exist in this unbalanced state. An electron from a shell further away from the nucleus will replace the vacant space and give up energy during this shift in the form of x-radiation. Balance is regained when the atom picks up a free electron and all its orbits are filled. X-rays are the result of innershell disturbance. (See Figure 4 at end of unit). A more thorough discussion of this will be included in the unit by Zelda Kravitz.

The x-ray tube filament is composed of tightly wound tungsten wires and electrons form a cloud around the filament when electric current is passing through the wire. The electron cloud is focused to a small beam and is attracted to the anode of the x-ray tube by a voltage differential between the electrodes. The cathode of an x-ray tube can be compared to a floodlight. The reflector of the floodlight corresponds to the focusing cup of the x-ray tube.

The x-ray machine is a delicate instrument that sends out x-rays in a controlled manner, so that a small carefully calculated amount of radiation is directed toward a specific part of the body. Some of the radiation emitted from the target (anode) is scattered in all directions. This form of radiation, which is not useful in the making of the x-ray, is called scattered radiation.

Because of its adverse effect of the image, it is necessary to minimize scattered radiation. There are several devices which can be attached to the x-ray to contain the x-radiation to the proper area being examined.

Marcella—Carolyn, talking about medical imaging in diagnostic radiography has been exciting.
Carolyn—Marcella, I know we did not cover all the possible areas, but I hope that we enlightened some teachers and students. It is very important for all of us to become aware of how x-rays affect our lives.
Marcella—Do you know that there is more background radiation introduced in the body than x-rays?
Carolyn—Yes, that means that background radiation is from a natural source and is in our environment. It is everywhere.
Marcella—If all of us are aware of the good that x-rays have done in the diagnosis of diseases, and the special care that is given to assure little or no risk in getting x-rayed, then we can spend more time in aiding doctors in making a good decision in diagnosing x-rays to help treat diseases.
Carolyn—I think you are right.
Marcella—Do you know that we did not talk about cost?
Carolyn—What about the cost?
Marcella—Most costs are covered by health insurance.
Carolyn—Diagnostic X-ray costs usually include hospital or lab charges for use of equipment, supplies, facilities, personnel and soforth. The radiologist charges for professional and consultation services.
Marcella—Costs are based on the procedures; however, earlier detection and more effective treatment may result in fewer procedures having to be done.
Carolyn—So what does this mean? Let's summarize together.
Carolyn & Marcella—Diagnostic X-ray plays an important part in our total medical treatment process. It helps discover diseases and abnormal growths before they reach dangerous levels. It helps to diagnose specific problems in the functioning of body tissues and organs. It can help doctors provide the best treatment for you.
Remember: Be aware of what to expect and cooperate fully.
Marcella—Carolyn, I've learned so much about radiography. Conventional radiography certainly

has and still is serving a vital function to mankind.
Carolyn—Gee Marcella, there is so much more that we did not discuss. Perhaps we can learn some more from other related units in medical imaging.
Marcella—Isn't it great that we decided to do this unit?
Carolyn—Yes, I hope that the students and other teachers will have as much fun as we are having.
Marcella—Do you know that tomography has so much potential? I am amazed over what that modality does. It is God sent to the medical profession.
Carolyn—I am really excited about reading the unit on Computed Tomography developed by Glen Ann Hagemann and Joe Cummins. two more teachers from our Medical Imaging Team.
Marcella—Carolyn, Dr. Ablow, a physician that specialized in radiography, at Yale-New Haven Hospital is doing a fantastic job in preparing and motivating teachers to bring this information to students.
Carolyn—It is great that we can be a part of making students aware of the education and job opportunities that exist in this field.
Marcella—Many radiologists have saved lives of many people. They understand the seriousness of their jobs. They are trained to use very safe measures in administering radiation.
Carolyn—You are absolutely correct Marcella. Much research and concern has gone into this area.
Marcella—Well, then let's talk about the biological effects. Carolyn, after researching the biological effects of radiography, I must tell you that my attitude has somewhat changed.
Carolyn—Why do you feel that your attitude has changed?
Marcella—Do you know that the benefits that we receive from radiography far outweigh the risks? So many people are being cured and so much more is known about cell activity. The amount of radiation received as background radiation is higher in dose than the amount you will receive in some radiological procedures. Background radiation is other kinds of natural radiation caused by energy from the sun or other natural sources. It is a part of our environment. Carolyn, this does not mean that we don't have to be careful. It means that you should make sure there is a real need for the x-ray and that it is explained fully. It is a patient's right to question the doctor about this.
Carolyn—Marcella, gee, now I am really eager to learn more.
Marcella—Great, then I will tell you a little more about the biological effects of radiography.

Biological Effects

X-rays have an effect on living things. As x-rays are absorbed, they change the structure of tissues, and may cause burns or destruction if the exposure is long enough. Some types of x-rays are able to affect the genes, the elements in the germ cells or reproductive organs by which hereditary traits are passed on from generation to generation. This can effect the total picture of heredity.

At the present time, the genetic effects of diagnostic radiology are thought to be undetectable hazards. The radiation dose of genetic significance from diagnostic radiology is estimated to be about twenty millirem/year.

Many physicians believe that at the present, the total benefits of diagnostic x-rays are often misused and over-used by some physicians. X-ray studies have been of great benefit to many people, but the possibility for harm must be discussed before a decision to do an x-ray examination is made.

Some physicians proclaim that there is no proof that the low levels of radiation involved in diagnostic x-rays have ever harmed anyone.

The ultraviolet radiation from the sun and the x-rays produced in a machine have like properties, but medical x-rays are more energetic and more penetrating.

There is no precise evidence that diagnostic x-rays of other regions besides the trunk are harmful to adults. Some scientists believe that x-rays may cause damage in proportion to the quantity of dose involved, and if the reproductive organs are in the direct x-ray beam, such x-rays may possibly damage future generations as well as exposed individuals. If risk is related to dose, then there is not a safe level. Therefore, every examination should be carefully considered.

Other risks related to the x-ray examinations include the injections of contrast media used to outline certain organs, arteries, or blood vessels. Most of the time, the risks are low and consist of mild allergic reaction to the contrast medium. However, we must bear in mind that some contrast studies, like those of the heart or brain, can cause strokes or other serious complications if not done with special care.

Medical professionals, who insist that x-ray examinations are completely harmless are either remiss or misinformed. High dose procedures should not be done ordinarily or without special concern on the part of the patient and administering physician.

The possible danger from x-rays and other forms of radiation has a great deal of the time gone unnoticed in the past because the damaging radiation cannot be seen or felt. Unless people are exposed to large quantities of radiation, any indications of damage are not seen until a while after exposure, maybe a number of years and even then it is hard to prove that x-ray exams caused it.

There are three units commonly discussed in dealing with possible biological effects of x-rays and other types of radiation. They are the roentgen, the rad, and the rem. The roentgen is an estimated measure of the radiant energy to which an individual or object is exposed, meanwhile the rad and rem provide a measure of the quantity of energy actually absorbed by an exposed object. One roentgen, rad, or rem represents a huge amount of radiation when compared to the average natural background dose received annually. The prefix milli means 1/1000 so that 1 rem = 1000 Mrem. Used in terms of the smaller units, the average whole body dose in the U.S. due to background radiation is 84 millirems per year.

The average abdominal dose used from diagnostic x-ray is just slightly less than the abdominal dose received from natural background radiation in the U.S.

Known effects that are associated with diagnostic x-rays are of two types. One set of effects directly affects the health of the exposed individual. We term these somatic effects. The set that affects the health of the off-spring is termed genetic effects, which are produced when the reproductive organs are exposed to radiation.

When very high doses of radiation are absorbed radiation sickness and sometimes death occurs within a few days or weeks after exposure.

It is believed that radiation to the reproductive organs of humans can cause offspring to have a higher rate of mental retardation, cancer, ill health, and birth abnormalities.

It is difficult to establish an exact relationship between biological damage and dose for low levels of radiation. It is assumed under the linear non-threshold hypothesis any amount of radiation absorbed by an individual, no matter how small, involves some risk to the health of that individual and/or his or her potential offspring. Some people believe the threshold hypothesis is closer to the truth. It is believed with the threshold hypothesis that radiation does not involve a health risk until a person is exposed to a certain amount. Below this, there is no damage over the threshold, there might be. (See Figure 8 and end of unit.)

When ionizing radiation, like an x-ray passes through a cell, the cell may be damaged or destroyed. With both ionizing radiation and x-ray the amount of cell damage is approximately proportional to the amount of radiant energy or dose absorbed, regardless of how small.

Each x-ray examination adds directly to an individual's risk in proportion to the dose to which a patient is subjected. It is desirable to keep the total radiation dose received by a patient as low as possible. It is necessary to realize that the risks associated with each x-ray examination must be considered in regards to the potential benefits of that same examination. Past history of radiation exposure should not influence a decision to conduct an examination if needed.

There are substantial benefits of diagnostic x-rays. They may save your life. However, avoid routine examinations or prescribing x-ray examination for yourself. Do not avoid an x-ray examination if your physician can adequately explain why there is a real need for it.

Here are several suggestions you can use when dealing with x-rays.

1. Ask your physician to explain what identifiable benefit will result from an x-ray.
2. Ask if it is possible to use the results of previous x-ray diagnosis instead of new ones.
3. If you are a woman you should avoid x-rays of lower back unless there is a serious condition.
4. Avoid fluoroscopy if your physician acknowledges that ordinary x-ray film will provide necessary information.
5. Check out equipment and facilities. In general you will receive significantly less radiation exposure at a facility which is under the supervision of a full-time radiologist.
6. Check out the x-ray machine operator. Try to discourage operator from doing repeated x-rays due to sloppy techniques.
7. Co-operate with the operator during x-ray exposures.

Exposing sex cells to radiation is like firing a bullet into a computer. There is no way to tell what change will result, or whether it will be harmful.

Fortunately, most people are not exposed to too much radiation. The most cautious health experts stress that there is no safe dose of ionizing radiation. We will always live with some natural background radiation, but we must be more alert to other human-made sources that have become common in this century.

Despite the gains made in x-ray technology, many people are still exposed to unnecessary risk from x-rays. An estimated third of all diagnostic x-rays are not needed.

Although there is growing concern about the misuse of x-rays, no one doubts that they are the most valuable tools in medicine.

Doses for Typical X-Ray Examinations in Millirads

	Average no. of films per exam (a)	Estimated "effective" dose per exam (c)
Mammography	2*/per breast	300-600
Upper GI	4.3	150-400
Thoracic Spine	3*	150-400
Lower GI	2.9	90-250
Lumbosacral Spine	3.4	70-250
Lumbar Spine (LS)	2.9	50-180
Intravenous Pyelogram (IVP)	5.3	50-150
Cervical Spine	3.7	40-80
Cholecystography	3.3	25-60
Abdomen or KUB	1.6	10-60
Skull	4	20-50
Lumbo-pelvic	1.4	5-35
Chest (radiographic)	1.6	5-35
Dental (whole mouth)	16*	10-30*
Hip or Upper Femur (thigh)	3*	2-25*
Shoulder	2*	2-25*
Dental (bitewing)	3*	5*
Extremities	2.7	5*

(a) U.S., Department of Health, Education, and Welfare (FDA) Publication 73-8047, Population Exposure to X-rays U.S. 1970, (Rockville, MD.: Public Health Service, November 1973).
(c) Preliminary estimates based on work in progress: P.W. Laws and M. Ross, "A Somatic Dose Index for Diagnostic Radiology," to be presented at the second Annual Meeting of the Health Physics Society (Atlanta, GA.: 3/77).
*Estimated by author.

High Risk Contrast X-Ray Examinations*

Type of Study	*Method*	*Uses*
Bronchogram	dye** injected in to lung bronchi (air passages)	outlines bronchial tree
Cerebral angiogram (arteriogram)	dye injected into carotid and/or vertebral arteries in neck	outlines blood vessels in neck and brain
Coronary angiogram (arteriogram)	dye injected into chambers of heart	outlines heart chambers, valves, and surrounding arteries and veins
Pulmonary angiogram (arteriogram)	dye injected into pulmonary arteries as they leave heart	outlines blood vessels (arteries and veins) in lungs

*Source: Arthur Levin, Talk Back To Your Doctor (New York: Doubleday, 1975).
**Dye is an obsolete term. “Contrast agent” is preferable.

Contrast Materials

A major limitation inherent in conventional x-ray technology is the inability to show the difference between soft tissues (e.g., blood vessels, muscles and intestines). Basically, a radiograph shows the difference between bone, air and in certain situations fat. Some soft tissues such as the pancreas are not recognized at all, this is why contrast materials have to be used often.

About thirty percent of all radiological examinations use the addition of a contrast media to the body in order to visualize different systems. Contrast media are put in a class with pharmaceuticals by the Federal Food and Drug Administration, and so it is very important to have a knowledge of agents in order to predict their effect on the patient and to be able to evaluate the advisability of using them in a procedure.

In radiology, contrast means density difference. Contrast agents usually add density to the x-ray film by absorbing more radiation than the surrounding tissue. In other words the contrast agent will make the film brighter than the neighboring areas where there is no contrast present.

Example—If you have a bottle filled with milk, you can visualize the milk clearly. You may have a problem seeing where the bottle surface is, but you would not have a problem with seeing the milk. Barium sulfate, a contrast material, is injected into the body to outline the intestine. Much in the same way as the milk is seen in the bottle, barium defines the intestine so that it can be visualized better. It is difficult to differentiate the intestine from surrounding tissue without a contrast media. (See Figure 5 and X-ray Package at end of unit.)

Contrast agents injected into the blood stream usually contain iodine. The more iodine in the compound use, the greater the radio-density of the contrast agent. Visualization of blood vessels is clearer and interpretation of the roentgenograms is enhanced. (See IVP Arteriography in X-ray Package at end of unit.)

Tomography

Another major limitation of conventional radiography is the inability to display within the framework of two-dimensional x-ray picture all the information found in the three-dimensional figure under view. Objects seen in the third dimension superimpose losing detail. This is why tomography is used. Tomography is the procedure used when visualizing selected planes within the patient examined. Conventional radiography is a two-dimensional picture of a three-dimensional object. Images of all structures throughout the thickness of the patient in the direction of the x-ray beam are superimposed on the same film. In tomography, a single plane is selected and kept in focus, as structures above and below are blurred and out of focus. This is done by moving the x-ray tube in one direction over the patient. The tube and film are linked and synchronized to move in opposite directions. (See Figures 6 and 7 at end of unit.)

> Carolyn—Marcella, do you know that I will be a better patient? I feel that my attitude has changed too. I think we are in agreement.
> Marcella—Carolyn, don’t get too excited. Now we have the honorable task of creating lesson plans, activities, and hands on experiences for students.
> Carolyn—I know. Let’s pre-test to see how much our students already know about the subject. Then we can start from there.
> Marcella—Let’s drink milk to that. You know we have to keep up our image.

Medical Imaging
Questions Pre—Post Test *Answers*
1. What is a radiograph?

a) a radio

b) an x-ray picture b
c) radiation
2. What are x-rays?

a) sound waves

b) artificial light used in photography c
c) electromagnetic radiation

3. A convex lens

a) bends light rays to meet at a point

b) spreads parallel rays outward b
c) produces colors

4. A concave lens

a) bends light rays to meet at a point

b) spreads parallel rays outward a
c) produces colors

5. Millimeter

a) is the smallest unit for measuring length in the metric system

b) is the largest unit for measuring length in the metric system a

c) is the smallest unit of measuring weight in the metric system

6. Roentgen rays are used in reference to

a) color

b) x-rays b
c) sound waves

7. Radiation is not given off by

a) toasters

b) manual toys b
c) television sets

8. X-rays

a) because of their extremely short wavelength, are able to penetrate materials that absorb or reflect visible light

b) do not obey the laws of light a
c) do not produce biological changes in cells

9. The x-ray tube

a) is the fundamental property of x-ray

b) the most efficient means of generating x-rays b
c) is one of the dual natures of x-ray

10. One must be an M.D. to

a) be a radiation therapy technologist

b) be a radiologist b

c) be a nuclear medicine technologist

True or False

11. Roentgenographic examination is another name for x-ray or radiography.	T
12. Persons less trained in radiology than radiologists sometimes tend to allow a primary x-ray beam that gives unnecessary primary and scattered radiation to patients.	T
13. X-rays should be taken on a monthly basis.	F
14. Improper equipment may lead to poor diagnostic film and cause more x-rays to be taken.	T
15. One should always demand an x-ray when a fall has taken place.	F
16. X-rays are not potentially harmful to pregnant women.	F
17. Lead aprons are unnecessary for protection in the x-ray room.	F
18. Scattered radiation can be reduced by beam limitation.	T
19. The linear non-threshold hypothesis in radiation exposure argues that any level of radiation, no matter how small is dangerous.	T
20. The threshold hypothesis in radiation exposure argues that low levels of radiation are safe, radiation does not become dangerous until larger quantities are used.	T

Vocabulary

1. Anode—One of the two important parts on the x-ray tube that is a positive electrode.
2. Cathode—The negative terminal of the x-ray tube.
3. Centiliter—1/100 of a liter.
4. Centimeter—1/100 of a meter.
5. Concave lens—Cause light rays to spread out.
6. Contrast materials—density difference.
7. Convex lens—bends light rays to meet at a point.
8. Deciliter—1/10 of a liter.
9. Decimeter—1/10 of a meter.
10. Electromagnetic spectrum—The spectrum of long wavelengths, low frequency, low energy to shorter wavelengths with high frequency and high energy.
11. Fluorescence—When x-rays incident to certain materials emit radiation of longer wavelengths.
12. Frequency—The number of crests that pass a given point in a second.
13. Hertz—In the U.S. almost all electrical energy is supplied in cycles per second; this means that the direction of electron inflow or current is reversed 60 times every second.
14. Hertz, Heihrish R. (1857—1894)—He developed the electromagnetic theory of light and discovered radio waves, occasionally called hertzian waves.

15. Identify—Diagnose.
16. Ionized gases—When x-rays remove electrons from atoms to form ions.
17. Lens—When glass is shaped with curved sides to bend light the way we want it to go.
18. Liter—A metric measurement pertaining to liquids.
19. Medical Imaging—The science of seeing inside the human body with the use of modalities such as conventional x-ray, tomography and fluoroscopy.
20. Meter—A unit of measurement pertaining to length or height.
21. Milliliter—1/1000 of a liter.
22. Millimeter—1/1000 of a meter.
23. Newton, Issac (1642-1727)—Born in England, was considered to be one of the greatest scientists who ever lived. In the field of light, he discovered the nature of white light and explained the spectrum.
24. Opticians—Lens makers.
25. Photographic process—High speed film that requires less radiation.
26. Principal focus—The point at which the convex-bent light rays meet.
27. Radiograph—A visible photographic record on film produced when x-rays pass through an object or a body. This is the x-ray picture.
28. Radiography—The science of x-rays with reference to diagnosis.
29. Radiologic technologist—A skilled medical person certified by the American Registry of Radiologic Technologists.
30. Radiologist—A physician trained in radiologic with at least four years of training after medical school
31. Refraction—The bending of light rays.
32. Ršntgen, Wilhelm Conrad—A German physicist who discovered x-rays in 1895.
33. Scattered radiation—Excess radiation given off from the x-ray machine not utilized to take the actual radiograph.
35. Tomography—A technique that provides an image of any selected plane through the body while blurring out images of structures that lie above or below that plane.
36. Transparent—Clear.
37. Virtual object—An image not real.
35. Wavelengths—The distance from crest to crest.
39. X-ray—A form of electromagnetic radiation which is invisible for it is comprised of shorter wavelengths than visible light.
40. X-ray machine—An instrument that sends out x-rays that are carefully calculated and controlled. This radiation is directed toward a specific part of the body in an effort to get a picture of that specific body part.
41. X-ray room—A room in which x-rays are taken. The floors and walls are shielded.
42. X-ray tube—The source of x-rays. Allows fast moving electrons to collide with the tungsten target producing x-radiation.

Lesson Plan: What is Medical Imaging ?

Objective Many students are totally unfamiliar with the term medical imaging.
This lesson will cause the students to attend to a particular body part and draw conclusions based on what he/she is able to see and what is implied but not seen. The teacher may use this exercise to explain that medical imaging allows radiologists to go far beyond what the students have experienced and see images of the patient's insides without cutting them open.

Materials Needed Flashlight, dimly lit room. (See Figure 9 at end of unit.)

Procedure:
1. Close the curtains.

2. Turn on the flashlight.

3. Hold the flashlight in one hand.

4. Place the palm of the free hand over the face of the flashlight.

Observations and Analysis

1. Students will notice the webbing between their fingers.
2. Students will notice that more light comes through the webbing than the fingers or hand.
3. The students will see the hand as being quite red and will probably associate that redness with the fact that there is blood inside the hand.
4. Have students discuss what they feel the flashlight has enabled them to see or think about, that they would have otherwise ignored.

Vocabulary
1. Medical Imaging

Lesson Plan: Adding Contrast

Objective The aim of this lesson is to introduce students to the role of contrast materials in medical imaging. It will help students to understand how contrast materials aid in making internal organs and their functions more visible.

Materials Needed Milk bottles, food coloring, eye droppers, water.

Procedure

1. Have students place an empty milk bottle on the opposite end of the room.
2. Have students fill a second milk bottle with clear water next to the bottle.
3. Have students observe from the opposite side of the room while one student uses a dropper to add a dark colored food coloring to the bottle with water.

Observations and Analysis

1. Students will be able to see the outline of the empty bottle.
2. As the coloring is added, the students will find the bottle is given more definition.
3. The bottle with the colored water will allow the students to see the outline of the bottle more clearly.

Vocabulary

1. Contrast

2. Medical Imaging

3. Internal Organs

***Lesson Plan III: Can Light Rays Bend Through Solid Materials* ?**

Objective The concept of projecting an image on another surface is abstract to many students. This lesson is designed to show that light rays do not have the ability to bend. It will help students to understand why x-ray machines aim radiation directly at the object as opposed to attempting to curve the rays.

Procedure

1. Set up a flashlight at one end of a piece of rubber garden hose about 90 cm. Long. Curve the hose. Explain the light rays are being emitted from the flashlight. Ask students if they are able to see the light through the opposite end of the hose.
2. Straighten the tube by fastening it to a measuring stick with rubber bands. Have another student shine the light into it. Ask students to explain what they see.

Observations and Analysis When light travels through a substance, it usually travels in straight lines. Light usually does not bend, it does not turn corners.

1. When the garden hose is curved, the student will not be able to see the light rays being emitted from the other end.
2. When the garden hose is straight, the student will be able to see direct light coming from the opposite end.

Vocabulary

1. Cm.—centimeter

2. Bend

3. Substance

Materials Needed Flashlight, rubber garden hose approximately 90 cm. Long, measuring stick, rubber bands.

Lesson Plan IV: Magic Camera

Objective Many middle school students have not had the opportunity to take a photography class and have difficulty perceiving how one can get an image of an actual object on a plane different from that object.

This lesson will help students understand how one is able to project an image of an object. This will make the concept of medical imaging more concrete.

Materials Needed Cereal box or tin can, wax paper or tracing paper, rubber bands, needle.

Procedure

1. Remove end of a box or tin can.
2. Cover the open end with wax paper or tracing paper.
3. Secure the paper with a rubber band.
4. Prick a hole in the center of the opposite end of the can with a needle.
5. Slightly elevate the can on a small hard covered book.
6. Place a lighted candle about four decimeters from the can.
7. Place the side with wax paper toward you and the other end toward the candle.
8. Observe the image on the wax paper end.

Observations and Analysis ***Unlike sound, light has the ability to travel in a vacuum. Light usually travels in straight lines. Although this is not like a regular camera, it does form an image.***

1. The image is made because the rays of light travel in straight lines.
2. As this “magic camera” is moved back and forth, the size of the image changes.

Lesson Plan: Can We Restrict Light ?

Objective ***The restriction of x-radiation to only the desired body part during an x-ray may not be clear to many students.***
This lesson will allow students to restrict light, thus drawing a parallel between the light that is allowed to pass to an object, with the radiation that is allowed to pass from an x-ray machine to a designated body part.

Materials Needed ***Large flashlight or floodlight, black construction paper, scissors, tape, large doll, ruler.***

Procedure

1. Have students cut six strips from the construction paper. Two strips should be 3” wide, two at 2” and two at 1” width.
2. Have students shine the flashlight on the chest area of the doll.
3. Have students then tape the 1” strips on the face of the flashlight near the edges to block the light. Repeat step 2.
4. Have students replace the 1” with 2” strips and repeat step 2.
5. Have students replace the 2” with 3” strips and repeat step 2.

Observations and Analysis

1. As the strips are applied to the flashlight, the students will see that light can be blocked.
2. The wider the strip, the narrower the amount of light that is allowed to shine on the chest of the doll.

This is similar to how x-radiation is restricted in taking radiographs.

Lesson Plan: Can We See Bent Light ?

Objective Although convex and concave lenses are concrete objects, the notion of what they do to light rays is very abstract.

This lesson will give concreteness to the path of light through lenses. It will show the principal of light refraction and how this is done on an angle. It will also show that light rays are straight. This lesson will help students understand how the x-ray technician is able to acquire accuracy when taking a radiograph. It will help students to know that the light beam emitted from the x-ray machine will be emitted in a straight line, thus allowing the technician great area accuracy.

Materials Needed Fifty pound fish tank, water, iodine or mercurochrome, a flashlight with a slit over the glass.

Procedure

1. Place a 50-L fish tank on a table. Fill it with water to about 5 cm. from the top. Color the water with iodine or mercurochrome.
2. Fit a flashlight with a top that has a slit over the glass.
3. Shine the light straight down into the water.
4. Shine the light at a slant through the water (for refraction).

Observations and Analysis

1. When the light shines straight down into the water, the light beam is straight.
2. When the light sines into the water at a slant, the light beam bends.
3. All surfaces of matter reflect light. Light is bent when it passes at a slant from one transparent material to another transparent material.
4. Light can be bent (refracted) when it is slowed down or speeded up.

Vocabulary

1. Liter

2. Decimeter

3. Refracted

4. Transparent

Lesson Plan: What is Known About Light Rays ?

Objective Since light rays are intangible, many students find it difficult to comprehend crests and wavelengths.
This lesson will give students the ability to bring concreteness to these abstract concepts. The students will be able to see and identify crests and wavelengths.

Material Needed Closed door, with a doorknob, 3-meter length of rope.

Procedure

1. Tie one end of the 3-meter rope to the doorknob of a closed door.
2. Hold the rope loosely at the height of your waist.
3. Flip the rope up and down until the rope makes waves.

Observations and Analysis

1. The hills formed by the rope are called crests.
2. The faster the rope is flipped, the more waves are formed. These waves are also closer together.
3. The distance from crest to crest is called wavelength.
4. The number of crests that pass a given point in a second is called frequency.
5. One theory of light is that light travels in the form of waves at a speed of 300,000 km/second in a vacuum.

Vocabulary:
1. Intangible

2. Crest

3. Wavelength

4. Frequency

5. Meter

Vocabulary Study
Hi, boys and girls! My name is Mr. Meter. I am used to measure the length of objects. Have you ever seen a yardstick? Well, I'm just about that long. I am most useful if you need to measure something that is rather long, like the door in your classroom or your teacher's desk. If you want to measure something smaller, then it would be better for you to use one of my children. Here, I'll introduce you to them.

This is my oldest child, Deci. Deci is bigger than my other two children. Deci means ten. I named her Deci because I'm ten times larger than she is. It would be best to use Deci if you wanted to measure the length of a book, or the height of a medium sized stuffed animal.

My middle child is Centi. Centi means one hundred. I named him Centi because I'm one hundred times bigger than him. I'm ten times bigger than Deci, and Deci is ten times bigger than Centi. If you wanted to measure the length of a pencil, Centi is the one you would probably use.

Last but not least is Milli. Milli is so very tiny. Milli is a prefix that means one thousand. I named her Milli because I'm one thousand times larger than she is. Milli enables people to measure the very tiny things in life, like the eraser on a pencil or the button on a baby's coat.

Now that you've met us all, decide which of us you would use to measure

1. A dresser

2. A baby's shoe

3. A wedding ring

4. A pencil eraser

5. A drinking glass

6. A full size bed

Lesson Plan: Metrics—Part I

Objective The Metric System is a world accepted means of measurement.
This lesson will enable students to use basic metric measurements. This lesson will focus on the prefixes milli, centi, and deci.

Materials Needed Meter stick or metric measuring tape, yardstick.

Procedure

1. Have students compare the meter stick to the yardstick.

2. Explain that the metric system is based on a system of ten.
3. Identify the millimeter, centimeter and decimeter for students.
4. Have students measure their pencil, shoe, other students, desks, etc. in appropriate units of measurements.
5. Have students write their observations.

Observations and Analysis

1. A millimeter is one thousandth of a meter (1/1000).

2. A centimeter is one hundredth of a meter (1/100).

3. A decimeter is one tenth of a meter (1/10).

4. There are one thousand millimeters in a meter.

5. There are one hundred centimeters in a meter.

6. There are ten decimeters in a meter.

Vocabulary

1. Meter

2. Millimeter

3. Centimeter

4. Decimeter

Lesson Plan: Metrics—Part II

Objective:

This lesson will reinforce the prefixes milli, centi, and deci. The students will be able to use their knowledge in a fun way and increase their vocabulary at the same time.

Procedure

1. Review prefix meanings.
2. Tell students that “meter” is derived from the Latin word for measure.
3. Have students read the vocabulary study.
4. Form two teams.
5. A member from each team gets a chance to define the word placed on the board.
6. The team with the highest number of points wins.

Vocabulary

1. Millisecond 11. Centuple
2. Centipede 12. Decimal
3. Millennium 13. Decade
4. Millennarian 14. Centimeter
5. Millipede 15. Centiliter
6. Milligram 16. Decimeter
7. Millimeter 17. Deciliter
8. Century
9. Centenarian
10. Centennial

Lesson Plan: Metrics—Part III

Objective Students will be able to apply knowledge of the metric system to perform metric conversions.

Procedure
1. Review metric prefixes

2. Write the following problems on the board.

3. Correct the problems with the students.

Problems

1. 10 decimeters = ___ meter/s

2. 20 decimeters = ___ meter/s
3. 10 centimeters = ___ meters/decimeters
4. 20 centimeters = ___ meters/decimeters
5. 100 centimeters = ___ meters/decimeters
6. 10 millimeters = ___ meter/decimeter/centimeter
7. 100 millimeters = ___ meters/decimeters/centimeters
8. 1,000 millimeters = ___ meters/decimeters/centimeters
9. 3,000 millimeters = ___ meters/decimeters/centimeters
10. 400 centimeters = ___ meters/decimeters/centimeters

Answer Key:

1. 1 meter
2. 2 meters
3. 1 decimeter
4. 2 decimeters
5. 1 meter or 10 decimeters
6. 1 centimeter
7. 1 decimeter
8. 1 meter
9. 3 meters
10. 4 meters

Careers In Radiography

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1. Radiologist—Highly trained physician, specialist in radiologic diagnosis. This person needs at least 4 years of training after medical school, and must be certified by the American Board of Radiology or the American Osteopathic Board of Radiology.

Duties:

He/she is in charge of all x-ray procedures, such as, consulting with attending physicians to prescribe specific diagnostic examinations. Examining and interpreting all radiographs (as well as making radiographs, directing the technologist). Recommending further exams or treatment if needed, writing reports on the entire procedure and conferring with doctors on diagnostic x-ray results.

2. Radiologic Technologist—Radiographers, formerly called x-ray technicians or radiologic technologists, perform diagnostic studies on patients to produce visual images of internal structures and organs of the body end thereby assist physicians in diagnosing disease or injury. These vital health care professionals are taught to operate a wide variety of x-ray-producing equipment, some of which is highly sophisticated in nature—e.g., the computerized tomography (CT) scanner. Continuing discoveries in research, along with increasingly complex equipment and procedures, make radiography one of the most exciting and challenging of the allied health professions.

To be effective in this field, one must be able to work independently, exercising initiative and judgment, yet perform as a team member when dealing with patients, physicians, and other health care professionals. Therefore, students seeking entry into the associate degree program in radiography should have good communications skills, creativity, and a sufficient background in math and the sciences.

This program has been designed to prepare students for employment as entry-level radiographers in hospitals, clinics, and physicians' offices. The three-year curriculum includes one year of academic preparation followed by two years of clinical instruction and internship in a participating A.M.A.-accredited hospital-based program. Graduates are eligible to write the examination for professional certification administered by the American Registry of Radiologic Technologists.

3. X-ray Therapist—uses x-ray in the treatment of cancer.
4. Medical doctor (physician)—is responsible for diagnosis, prevention and treatment of disease and disorders in human beings.
5. Medical Illustrator—designs pictures to be used in medical publications.
6. Medical Laboratory Assistant—certified lab assistant, medical lab aide, medical lab technician—is trained to perform simple routine procedures in approved supervised laboratories.
7. Medical Photographer—takes pictures that will be used in medical publications.
8. Medical Record Administrator—supervises the administration of Medical Records and patient information.
9. Medical Records Clerk—assists the medical librarian in the technical aspects of maintaining patients records, statistical reports, and disease indexes in hospitals and clinics.
10. Medical Secretary—(medical transcriptionist, medical assistant)—assists the physician in the operation of his office and maintenance of equipment and supplies; or is employed as a secretary in health facilities such as hospitals, health departments and clinics.
11. Medical Technologist—performs a wide spectrum of laboratory procedures utilizing complex scientific instruments.

Field Trips and Resources

Hospitals

Saint Raphael's Hospital—Department of Radiology

Yale New Haven Hospital—Department of Diagnostic Radiography

Colleges

Greater New Haven State Technical College

University of New Haven

Quinnipiac College (New Haven)

Yale University (New Haven)

South Central Community College (New Haven)

Mattatuck Community College (Waterbury)

Middlesex Community College (Norwich)

These places are chosen because they are easy to reach and have excellent facilities for students to view in seeking information.

Teachers using this unit will contact the place directly and a resource person will accommodate you according to your needs.

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Figure 1 Schematic diagram showing the fundamentals of a radiographic exposure.

(figure available in print form)

Figure 2 The distance from one point in a wave pattern to another point where the pattern begins to repeat itself is called a wavelength.

(figure available in print form)

Figure 3

(figure available in print form)

Figure 4

(figure available in print form)

Figure 5 As the contents of a milk bottle make the outline of the milk bottle more visible from a distance, contrast materials make the lining of the intestines more visible

(figure available in print form)

Figure 6 In linear tomography, the pivot point remains stationary, while the x-ray tube and film are moved horizontally in opposite directions.

(figure available in print form)

Figure 7 This drawing shows four different letters on four different planes.

(figure available in print form)

Figure 7A Shows one would get a blurred image to those letters if a picture were taken from the top of the object going from plane A to plane D.

(figure available in print form)

Figure 7B Shows how linear tomography allows one to take a picture of the letter on the third plane while totally blurring out the letters on the other three planes.

(figure available in print form)

Figure 8 This diagram shows the linear hypothesis vs. the threshold hypothesis. Advocates of the linear hypothesis argue that any amount of radiation is harmful, while advocates of the threshold hypothesis argue that any amount of radiation under a certain level produces undetectable effects.

(figure available in print form)

Figure 9

(figure available in print form)