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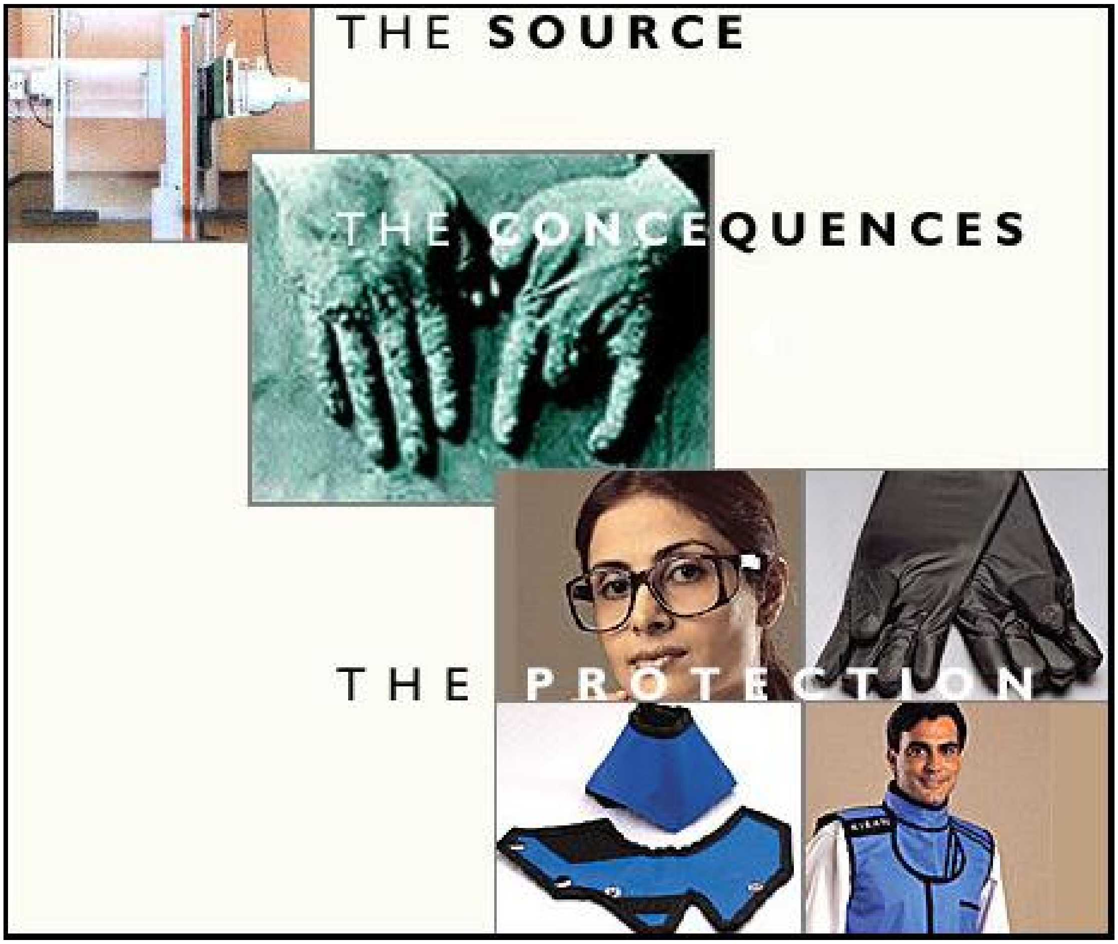
KIRAN

RADIOLOGY **SAFETY GUIDE**



Although an integral part of modern medical science, radiation and x-rays can be lethal if proper protective apparel is not used. Many of the earliest practitioners of this science, including Madam Marie Curie and Thomas Edison, learnt this truth the hard way.

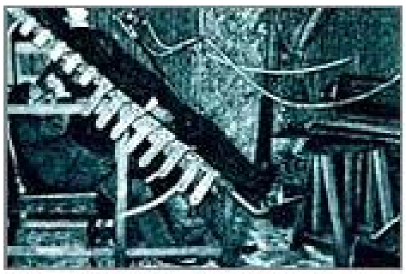
As part of our endeavour to present a complete picture of the science of radiology, KIRAN presents the "Radiation Safety Guide", a compilation of articles and case studies from around the world, with an introduction to *radiation*, notes on *biological* and *genetic effects* of radioisotopes, and a practical guide to *choosing protective apparel*.

Compiled by KIRAN

Radiation

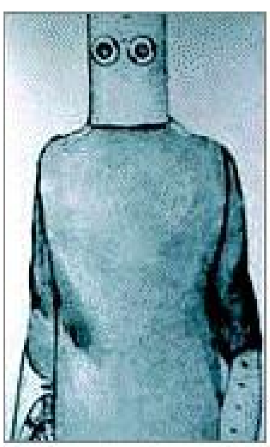
Playing Games with Radiation...

Patients and their Doctors have a right to obtain accurate X-ray dosage information recorded directly from the applied radiation at the time of exposure…



Madame Marie Curie's curiosity about radiation killed her, but her discoveries of radium and radioactivity made playing the game worth it for the world of science. A human sacrifice. At the turn of the last century, X-rays were hot, in more ways than one, but nobody knew this until horrible things started happening. Can you imagine how Thomas Edison felt when he learned about X-rays? "Hey! This is great stuff, let's make X-ray machines. Clarence, put your hand in front of the X-ray tube and we'll demonstrate how you can see the insides of the human body." Edison's assistant, Clarence Madison Dally, died after first losing his hands and then having his arms amputated from the effects of X-rays. After Edison's eyesight was impaired by radiation, he never permitted anybody to use X-rays on him again. Playing games with X-rays meant people were dying, losing fingers and getting burned.

The new science of radiology was born, but the radiologists decided that they did not want to dissolve into a mushy mass of disintegrating human tissue. The solution was to wear body armor resembling that of King Arthur's Knights. As time went by, more harmful things occurred. After prolonged X-ray exposures, the tongue of this patient ulcerated, bled and cracked, progressing through a prolonged healing of diminishing symptoms until only the gouged scars from the tissue destroying radiation remained as visible evidence.



Dentists began losing thumbs and fingers from holding film in patients' mouths. Nobody really wanted to give up playing games with X-rays. Cosmeticians applied X-rays to enhance womens' appearance by removing facial hairs. Dr. Albert C. Geyser, M.D., Professor of Physiological Therapy, Fordham University and Chief of the Electro and Roentgenray Clinic at Cornell College developed the X-ray hair removal system to prevent women from resorting to "futile, dangerous and injurious means of removing disfiguring superfluous hair." The treatments resulted in wrinkling atrophy, keratoses, ulcerations, carcinoma, and death. Most victims were young women (really aged) from 18 to 30 years. Throughout medical history, doctors have gained credibility with the public and the medical profession by lecturing and training other doctors in the wonders of misconceived practices.

Radiation

Meanwhile, kids watched their toes wiggle in their shoes through the use of shoe fitting X-ray machines. At the same time, doctors were burning out childrens' tonsils, and dermatologists were drying up acne using X-rays. Everything was fine according to the professionals…until people started developing cancers and dying. Well, the excuses and game playing have been going on ever since the discovery of X-rays… "no it can't hurt you." Remember all the X-ray devices and methods that couldn't harm anybody? Let's cite a recent example. A dentist became aware that by not heeding several patients' advice against prolonging exposures to the whole head and eyes of an X-ray sensitive patient, he would place the patient's health at risk. Yet, during a moment of impulsive anger, termed by the patient as RAD RAGE, this dentist duplicated the dangerous method of exposure: thus, turning the clock back a century. (SOUND AND FURY page). What a shock when he found out what he had done by playing games with his x-ray machine. Fair complexioned people medicated with antibiotics may be especially radiosensitive. Radiosensitivity increases as a result of many factors such as a previous exposure history, age, complexion, drug usage and even emotional stress causing changes in oxygen levels within the cells. While watching local T.V., the irradiated patient viewed a concerned dentist speaking about the use of X-rays. He appeared on the screen stating that he does not administer X-rays because any X-ray does harm. This was the judgment of a convention of world renowned scientists, reiterating that ionizing radiation does damage at all levels. Of course this concept cannot be accepted by the X-ray machine manufacturers, film makers, radiation professionals and the whole network composing the radiation lobby. Their attitude toward victims might well be expressed as, "Fry 'em, Try 'em, and Buy 'em." As one scientist said to a burned patient, "They're murdering you and you can't do anything about it.”

Scarred Tongue After Radiation Ulcerations

Radioisotopes

Biological Effects

Exposure of the human body to ionizing radiation can result in harmful biological effects. The nature and severity of the effects depends primarily on the dose of radiation absorbed and the rate at which it is received. Exposure to radiation can result in radiation burns and sickness, cancer, genetic defects, and abnormalities in unborn children. Very large doses of radiation to the whole body can result in death. These effects have been observed in people exposed to radiation in a variety of situations including therapeutic x-rays, radiation accidents, and the Japanese A-bomb survivors.

Radiation Burns

Radiation burns were first noted within a month of Roentgen's discovery of x-rays. Within a year, it was widely known that radiation workers had to take precautions to avoid injury. Today, great efforts are made to protect workers from accidental exposure but radiation induced injuries still occur. Severe local injury may result when a worker is exposed to a high dose of radiation for a short period of time. Symptoms may range from reddening of the skin, swelling and blistering, to tissue death and amputation of the affected area.

For example accidental exposure to the primary beam from analytical x-ray equipment may result in high radiation doses to localized areas of the body. The smallest does to the skin that will result in visible damage is approximately 300 rem. Reddening of the skin, called erythema, may occur 2-3 weeks after the exposure in highly susceptible individuals. Usually the dose must exceed 600 rem before radiation burns become apparent. These burns are equivalent to first-degree thermal burns similar to a mild sunburn. There are no initial symptoms from the over-exposure and the worker may be unaware of an injury. These types of injury, however, are typically not seen in radioisotope laboratories.

Radiation Sickness

Radiation burns occur when a large dose of radiation is received by a small part of the body. Severe damage and tissue death may occur but the exposed person usually survives. If a large dose of radiation is delivered to the whole body of an individual in a short period of time, severe illness or death may occur. The sequence of events that follows exposure to high levels of radiation to the whole body is termed radiation sickness or the "acute radiation syndrome.”

Radiation doses to the whole body greater than 100 rem delivered within a few hours, are usually necessary produce noticeable symptoms. Changes in the blood, however, can be observed from exposures as low as 25 rem. Symptoms usually become apparent within a few hours or days depending on the dose received. The first stage of radiation sickness is often characterized by nausea, vomiting, and diarrhea. Following this initial period of sickness, symptoms may subside and the individual may feel well. This stage can last from hours to weeks, and while no symptoms are present, changes are occurring in the internal organs.

Following this asymptomatic period, other symptoms may appear. Loss of hair and appetite, fatigue, fever, severe diarrhea, vomiting, internal bleeding, and death may occur, depending on the dose received. If a whole-body dose of 4-00-500 rem is received, approximately 50% of those exposed will die within 30 days if untreated. Recovery is likely with medical care although the exposed individual will suffer several months of illness. If the radiation dose is spread over several weeks, a person may survive a whole-body dose or large as 1000 to 2000 rem. Exposure to a dose in excess of 700 rem to the entire body in a short period of time will likely result in death within a few weeks. This dose of radiation kills cells in the bone marrow and the body can no longer produce enough red blood cells to survive. Doses of the magnitude necessary to cause radiation sickness are not typically seen in radioisotope laboratories.

Radioisotopes

Biological Effects

Cancer

Exposure to chronic small doses of radiation over long periods of time can result in delayed effects that may become apparent years after the initial exposure. These effects may also occur after acute exposure to high doses and include carcinogenesis, life span shortening, and cataract formation.

The principle delayed effect from chronic exposure to radiation is an increased incidence of cancer. Ionizing radiation is a well known carcinogenic agent in animals and humans and has been implicated as capable of inducing all types of human cancers. Those types of cancer with the strongest association with radiation exposure include leukemia, cancer of the lung, bone, female breast, liver, skin and thyroid gland.

By 1905 it was widely known that exposure to radiation could cause cancer. Many of the early researchers who were exposed to large repeated doses of radiation died from fatal skin cancer and leukemia. Marie and Pierre Curie, for example, both developed leukemia, probably from their experiments with radium.

Further evidences that ionizing radiation can induce cancer in humans has been demonstrated among radiation workers, children exposed in-utero to diagnostic x-rays, patients receiving therapeutic x-rays and internal radiation exposure, individuals exposed to fallout, and the Japanese A-bomb survivors. Some of these evidences are summarized below:

Increased incidences of cancer have been noted among several groups of radiation workers exposed to high doses. Among these were the early radiologists, uranium miners, and radium watch dial painters. The early radiologists were often exposed to large doses of radiation without the benefit of protective devices. Many developed cancerous skin lesions on the hands and suffered from radiation burns. Higher incidences of leukemia were also demonstrated in this group. In the early 1990's, 50% of the uranium miners in some European mines died from lung cancer. Radium-dial painters at the beginning of this century, hand painted the luminous numerals on watches and clocks with a paint containing radium. The workers would put the brush on their lips to draw the bristles to a fine point. Increased incidences of bone cancer and other malignancies were seen in these workers.

Increased incidences of cancer have been demonstrated from exposure to diagnostic x-rays. Children exposed to radiation as a result of abdominal x-rays to the mother during pregnancy have shown an increase in leukemia. An increase in breast cancer was noted among women with tuberculosis who received repeated fluoroscopic examinations.

Exposure to therapeutic x-rays has resulted in increased incidences of cancer among patients treated for scalp ringworms, arthritis of the spine, and enlargement of the thymus glands. To reduce the size of the thymus gland, for example, doses of 120 to 6,000 rad were often given to infants. Increases were seen in thyroid cancer and leukemia.

Mortality from liver cancer was increased among patients who received a radio-contrast material, Thorotrast. This compound contained thorium, a naturally occurring alpha emitting radioisotope.

Increased incidences of thyroid cancer were demonstrated in residents of the Marshall Islands who were accidentally exposed to radioactive fallout from a nuclear bomb test. Children in Utah and Nevada exposed to fallout in the 1950's also demonstrated increases in thyroid cancer.

The strongest evidence for radiation induced carcinogenesis in humans has come from studies of the Japanese A-bomb survivors. These data have suggested that radiation may be a general carcinogenic agent capable of inducing all types of cancers. Increased incidences of leukemia, cancer of the breast, respiratory organs, digestive organs, and urinary organs have been reported. In addition, the data has demonstrated a linear relationship between dose and radiation induced leukemia.

Radioisotopes

Biological Effects

Cancer (contd.)

It is not known how radiation induces cancer. Several theories have been proposed to explain the carcinogenic properties of radiation. Cancer is characterized by the uncontrolled growth of cells. According to one theory, radiation damages the chromosomes in the nucleus of a cell resulting in the abnormal replication of that cell. Another theory postulates that radiation decreases the overall resistance of the body and allows existing viruses to multiply and damage cells. A third theory suggests that as a result of irradiation of water molecules in the cells, highly reactive and damaging agents called "free radicals" are produced which may play a part in cancer formation.

Approximately 25% of all adults between the ages of 20 and 65 will develop cancer during their lifetime. It is not known what an individual's chances are of developing cancer from exposure to ionizing radiation. However, risk estimates can be made based on statistical increases in the incidence of cancer among populations exposed to large doses of radiation.

The Nuclear Regulatory Commission (NRC) has adopted a linear, non-threshold model for calculating the cancer risks associated with low level radiation exposure. According to the NRC, this model neither seriously underestimates nor overestimates the risks involved from radiation exposure. Using this model, the risks decrease proportionally to the does of radiation. Thus, a worker who receives 5,000 mR/yr is assumed to incur ten times the risk as a worker who receives 500 mR/yr. Because no threshold is assumed, theoretically all radiation exposures have the potential to cause cancer. Based on this model, the best risk estimates available today are that an additional 3 cancers would occur in a group of 10,000 radiation workers exposed to 1,000 mR each. This should be compared to the 2,500 cancer cases that would be expected to occur from other causes. It is important to realize that these risk estimates are extrapolated from high doses and may not apply to low doses. Increases in cancer have not been clearly demonstrated at levels below the occupational limit of 5,000 mR/yr.

Recent controversial studies have suggested that linear extrapolation from high doses may significantly underestimate the actual risks involved from chronic low doses of radiation. Other studies have indicated that extrapolation may overestimate these risks. Both sets of data, however, lack sufficient validity to be used with confidence for the estimation of cancer risks at this time.

Genetic Effects

Radiation exposure to the reproductive cells can alter the genetic code, resulting in damaged or defective genes that can be passed on to future generations. It has been known since 1927 that radiation can cause genetic defects in the descendants of insects. Experiments with other animals have shown similar results. These studies demonstrated that radiation does not increase the types of mutations seen in nature, only the frequency.

Genetic mutations, however, have not been demonstrated in human populations exposed to radiation. For example, studies of the children of the A-bomb survivors in Japan have not detected any more genetic defects than expected. It is very difficult to determine if a person has a particular genetic defect. Usually there are no easily detectable signs and several generations and large populations may be necessary before the mutation becomes visible.

Radioisotopes

Genetic Effects

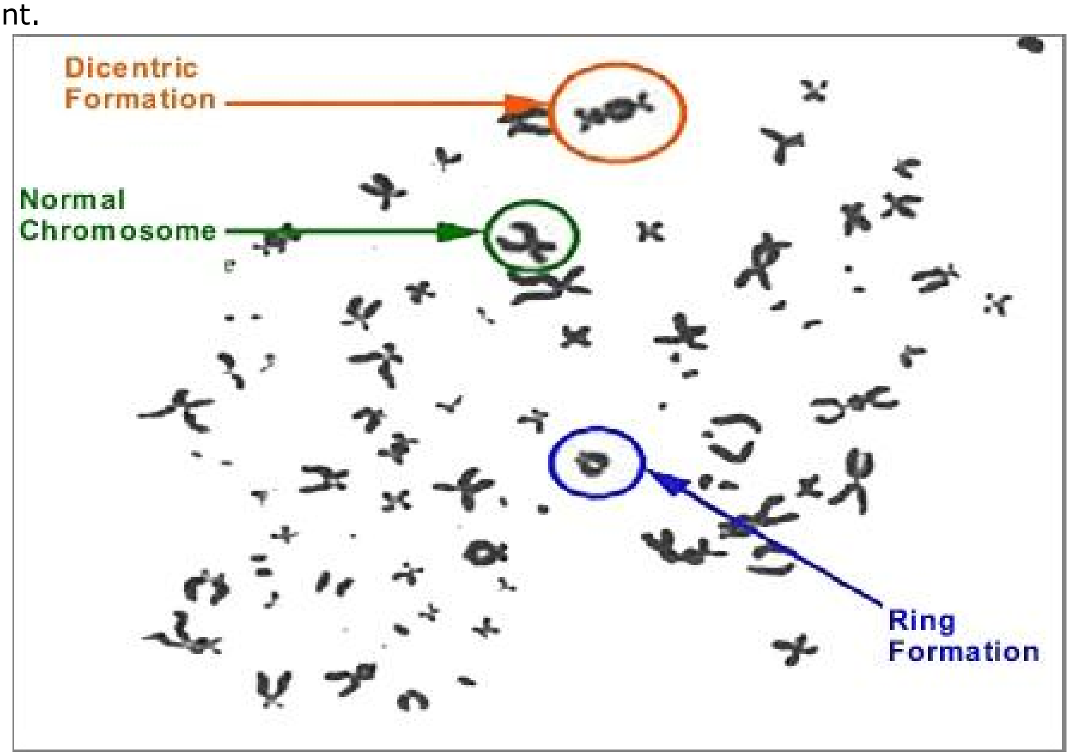
Most effects will probably be seen in subsequent generations as minor impairments that lead to higher spontaneous abortions, shorter life spans, increases in diseases, and ill health. Serious genetic defects usually do not manifest themselves because the person does not survive to reproduce

Based on the irradition of animals, the following inferences can be made regarding genetic effects in humans:

Radiation is a powerful mutagenic agent and any amount of radiation can potentially damage a reproductive cell.
The vast majority of genetic mutations are recessive. Both a male and female must possess the same genetic alteration in their chromosomes in order for the mutation to be expressed.
Most genetic mutations are harmful and decrease the overall biological fitness of a species.

Because genetic mutations are usually undesirable, the level of genetic defects in the population should kept as low as possible. This can be accomplished by avoiding any unnecessary radiation exposure.

The risk of a genetic defect in a child of a person exposed to one rem of radiation is approximately one-third that of developing cancer. Thus, there would be about one chance in 10,000 that the child would have a genetic defect. Because genetic defects are less likely than cancer, and not as serious, the risk of developing cancer from radiation exposure is more significant.



Fluoroscopy

Radiation-induced Skin Injuries from Fluoroscopy

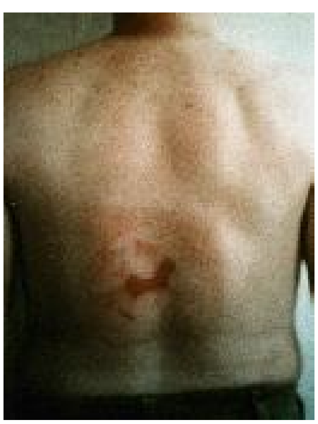
Thomas B. shope, Ph.D
Office of Science and Technology
Center for Devices and Radiological Health
Food and Drug Administration
Rockville, Maryland 20857

Note

This paper was presented as Scientific Exhibit 060PH at the 81st Scientific Assembly and Annual Meeting of the Radiological Society of North America, November 26 December 1, 1995. Radiology vol 197 (P) supplement, P449. This paper has also been accepted for publication in Radiographics scheduled for September 1996. Files containing JPEG digital versions of Gifures 2(a) 2(e) are provided via the links below. Additional information regarding radiation injuries from flouroscopy is available from the CDRH home page.

Example of Injury

An example of a skin injury attributable to x-rays from fluoroscopy is shown in Figure 2. This case, patient A in Table 2, is that of a 40-year-old male who underwent coronary angiography, coronary angioplasty and a second angiography procedure due to complications, followed by a coronary artery by-pass graft, all on March 29, 1990. Figure 2(a) shows the area of injury six to eight weeks following the procedures. The injury was described as "turning red about one month after the procedure and peeling a week later." In mid-May 1990, it had the appearance of a second-degree burn. Figure 2(b) shows the condition in late summer 1990, exact date unknown, with the appearance of a healed burn, except for a small ulcerated area present near the center. Skin breakdown continued over the following months with progressive necrosis, Figure 2 (c and D). The injury eventually required a skin graft as shown in figure 2(e). The magnitude of the skin dose received by this patient is not known. However, from the nature of the injury, it is probable that the dose exceeded 20 Gy. (6).



Fluoroscopy

Radiation-induced Skin Injuries from Fluoroscopy

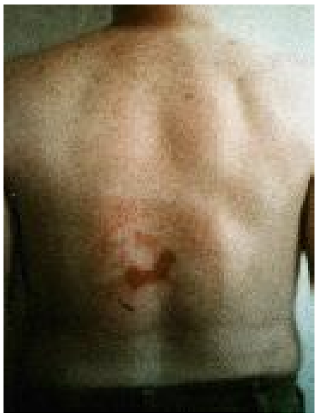


Figure [2a]

Condition of patient's back six to eight weeks following multiple coronary angiography and angioplasty procedures.

Figure [2b]

Appearance of skin injury approximately 16 to 21 weeks following the procedures with small Incerated area present.

Figure [2c]

Appearance of skin injury approximately 18 to 21 months following procedures, evidencing tissue necrosis.

Fluoroscopy

Radiation-induced Skin Injuries from Fluoroscopy

Figure [2d]

Close-up view of lesion shown in 2c

Figure [2e]

Appearance of patient's back following skin grafting procedure.

Appearance of skin injury approximately 18 to 21 months following procedures, evidencing tissue necrosis.