Radiation Exposure and Cancer

Radiation is the emission (sending out) of energy from any source. The light that comes from the sun is a source of radiation, as is the heat that is constantly coming off our bodies. When talking about radiation, however, most people think of specific kinds of radiation such as that produced by radioactive materials or nuclear reactions. Most forms of radiation have not been linked to cancer. Only high frequency radiation (ionizing radiation and ultraviolet radiation) has been proven to cause genetic damage, which can lead to cancer.

The hazards of exposure to some kinds of radiation were recognized shortly after the discovery of the x-ray in 1895. Skin reactions were observed in many people working with early x-ray generators, and by 1902 the first radiation-caused cancer was reported in a skin sore. Within a few years, a large number of such skin cancers had been observed. The first report of leukemia (a cancer of the bone marrow) in radiation workers appeared in 1911. Marie Curie, the discoverer of radium, and her daughter are believed to have died of radiation-caused leukemia. Since that time, many studies have confirmed the cancer-causing effects of some types of radiation.

Ionizing Radiation

Radiation can generally be defined as being ionizing or non-ionizing. Ionizing radiation consists of high-energy waves that are able to penetrate cells and can cause ionization in different parts of the cell. Ionization is the development of a positive charge in a molecule (group of atoms) that is normally neutral (without a charge). Ionized molecules are unstable and quickly undergo chemical changes. This can lead to the formation of free radicals that can damage the molecule or other molecules around it.

One type of molecule that is sensitive to ionizing radiation is DNA, the part of the cell that contains the genes (blueprints) for each person's characteristics. Ionizing radiation can lead to a mutation (change) in a cell's DNA, which could contribute to cancer, or to the death of the cell. All cells in the body can be damaged by ionizing radiation. The amount of damage is related to the dose of radiation received by the cell. While the process of cellular change from radiation takes only a fraction of a second, other changes such as the beginning of cancer may take years to develop.

Types of ionizing radiation include x-rays, gamma rays, cosmic rays, and particles given off by radioactive materials such as alpha particles, beta rays, and protons. These forms of radiation have different energy levels and can penetrate cells to different extents, but all are capable of causing ionization.

People may be exposed to 3 main types of ionizing radiation:

- **Natural background radiation** comes from cosmic rays from our solar system and radioactive elements normally present in the soil. This is the major contributor to worldwide radiation exposure.

- **Non-medical synthetic radiation** occurs as a result of above ground nuclear weapons testing that took place before 1962 as well as occupational and commercial sources.

- **Medical radiation** comes in the form of diagnostic x-rays and other tests, as well as from radiation therapy. Radiation therapy is currently used to treat some types of cancer and involves dosages many thousand times higher than those used in diagnostic x-rays.

Does Ionizing Radiation Cause Cancer?

Ionizing radiation has been shown to induce (cause) cancer in many different species of animals and in almost all parts of the body. It is one of the few scientifically proven carcinogens (cancer-causing agents) in human beings, although it appears to be a relatively weak carcinogen compared to many chemical agents. Many years may elapse between the radiation exposure and the appearance of the cancer.

The types of cancer that can be caused by radiation can also occur naturally (without increased exposure to radiation), but some occur more frequently as a result of radiation. For example, a higher percentage of small cell lung cancers occur in uranium miners as a result of exposure to alpha radiation (a form of highly ionizing radiation).

Organs differ in their sensitivity to the effects of radiation. The thyroid gland and bone marrow are most sensitive to radiation, while the kidney, bladder, and ovary seem to be least affected. Some forms of leukemia, a type of cancer that arises in the bone marrow, appear to be the most common radiation-induced cancers.

Evidence that ionizing radiation causes cancer comes from studies of atomic bomb survivors in Japan, persons exposed to large amounts of x-rays, and from certain occupational exposures, such as workers with lung exposure to alpha radiation. These studies, however, generally involved relatively high-dose exposure - greater than 10 centigray. (A centigray (cGy) is a standard unit of radiation dose.) Therefore, the risk estimates for lower doses of radiation have to be estimated from the high-dose data, and may not be accurate.

Dose-Related Radiation Effects

Ionizing radiation is probably the only carcinogen with evidence that its effects are related to dose exposure. The probability that cancer will result from radiation exposure increases as the dose increases. However, there is no evidence to suggest that the grade (tendency to grow and spread) of the resulting cancer is affected by the dose. In other words, higher doses of radiation do not cause more aggressive cancers.

Low-Dose Radiation Exposure

A number of studies over the past 20 years have looked at the impact of environmental radiation exposure in the dose range of 10 cGy or less. Careful analysis of this research revealed no significant increase in the incidence of all cancers combined, or of cancers in specific parts of the body. Research in this area is continuing.

Types of Cancer Associated With Ionizing Radiation

Leukemia was at one time thought to be the major cancer to arise from high-dose radiation exposure, based on the experience with people exposed to the atomic blasts in Japan. It is now known that other cancers can result from radiation exposure, although they may take longer to develop (usually at least 10 to 15 years). Leukemias, by contrast, begin appearing as early as 2 years after acute radiation exposure.

Studies of the survivors of the atomic blasts have demonstrated that high-dose radiation (at least 100cGy) increases the risk of developing several types of cancer.

- For these survivors, the risk of developing leukemia is five and a half times greater than in the general public. Children appear to be twice as sensitive as adults to the leukemia-causing effects of radiation, and unborn children exposed to radiation in the uterus are even more sensitive.
- The risk for developing any type of cancer in those highly exposed to an atomic blast is about 50% higher than the risk in those not exposed.
- Female breast cancer risk is more than twice as high as normal, and women who are exposed when under the age of 20 are found to be at higher risk than older women.
- The risk of developing lung cancer is 50% higher, and the risk for multiple myeloma is more than twice as high as in the general population.

Some people serving in the armed forces were exposed to radiation in nuclear weapons testing during the Cold War era. Information on this topic is available in our document, "Cancer Among Military Personnel Exposed to Nuclear Weapons."

Cancers Caused by Radiation Therapy

Ionizing radiation is an effective way to treat certain kinds of cancer. During radiation therapy, high doses of ionizing radiation are directed at the cancer, resulting in the death of the cancer cells. However, this can lead to DNA mutations in cells that survive the radiation, which can eventually lead to the development of another cancer (called a second primary cancer).

An increase in second primary tumors in the area being irradiated has been observed in patients with several types of cancer following radiation therapy and/or chemotherapy. Some studies have associated radiation therapy with an increased incidence of thyroid cancer and early-onset breast cancer. Overall, however, radiation alone does not appear to be a very potent cancer-causing agent in second tumors. This is probably due to the fact that it is often used in a localized area, which means fewer normal cells are exposed to radiation.

However, treatment for Hodgkin disease, a type of lymphoma, often delivers lower radiation doses to many areas of the body. These treated areas include large amounts of normal tissue. Patients with Hodgkin disease who are treated with radiation therapy are at an increased risk for developing second primary tumors.

When considering radiation exposure from radiation therapy treatment, the benefits generally

outweigh the risks. However, some combinations of radiation therapy and chemotherapy are more risky than others. Additional research is needed in this area so that optimal treatment can be given that minimizes the risk of the development of secondary cancers.

Genetic Susceptibility to Radiation-Caused Cancer

Scientists are making great progress in understanding how certain changes in DNA can cause cells to become cancerous. DNA is the chemical that carries the instructions for nearly everything our cells do. We usually resemble our parents because they are the source of our DNA. However, DNA affects more than our outward appearance.

Some genes (parts of DNA) contain instructions for controlling when our cells grow, divide, and die. Certain genes that promote cell division are called oncogenes. Others that slow down cell division, or cause cells to die at the right time, are called tumor suppressor genes. It is known that cancers can be caused by DNA mutations (changes) that "turn on" oncogenes or "turn off" tumor suppressor genes. Certain inherited DNA changes can lead to a high risk for developing cancer and are responsible for the cancers that run in some families.

Now that specific genes have been discovered that are associated with cancer, there is renewed interest in whether some people are more likely to develop cancers when exposed to radiation. There are some rare cancers where the interaction between radiation and genetic factors can be seen. Children treated with radiation therapy for hereditary retinoblastoma, a malignant eye tumor, are at an increased risk for developing a certain type of bone cancer called an osteosarcoma. Similarly, people who have nevoid basal cell carcinoma syndrome, a type of skin cancer, are at high risk for development of basal cell cancers in irradiated areas.

Non-Ionizing Radiation

Non-ionizing radiation is low-frequency radiation that does not have enough energy to cause ionization in tissues, but may cause adverse health consequences in other ways. Common types of non-ionizing radiation include ultraviolet rays, visible light, electromagnetic fields, infrared radiation, microwaves, and radiofrequency radiation (radio waves). Electrical appliances, heaters, and cellular phones emit (send out) non-ionizing radiation waves. Of all the types of non-ionizing radiation, only ultraviolet rays have been established as a cancer-causing agent.

Ultraviolet (UV) Radiation

The sun is the major source of ultraviolet (UV) radiation. Most skin cancers are a direct result of sunlight exposure. Both basal cell and squamous cell cancers (the most common types of skin cancer) are found on sun-exposed parts of the body, and their occurrence is related to lifetime sun exposure. Melanoma, a potentially fatal type of skin cancer, is less dependent on sun exposure and can develop on any area of the body.

If you live in the mid-United States, being in direct sunlight for 30 minutes creates a buildup of a lethal dose of UVR for human cells not protected by sunscreen. The only other exposure to a carcinogen approaching this level of exposure is cigarette smoke in very heavy smokers.

Ultraviolet radiation is divided into three wavelength ranges:

- UVA rays are involved in the aging of cells and produce some damage to DNA.
- UVB rays are in the wavelength range mainly responsible for direct damage to the DNA, and are thought to cause most skin cancers.
- UVC rays are not present in sunlight, but are present in mercury lamps.

While UVA and UVB rays make up only 1/10,000,000th of the sun's wavelengths, they are primarily responsible for the damaging effects of the sun on the skin.

More information on ultraviolet radiation is available in our document "Skin Cancer: Prevention and Early Detection."

Electromagnetic Fields

Electromagnetic radiation is produced by moving electric charges and may be of natural origin (the sun) or human origin (electronic devices or power lines). Electromagnetic fields have been the subject of much controversy. Recent extensive studies of electric utility workers showed a minimal increase in the risk of brain tumors and leukemia. However, either of these increases may have been due to chance. Results from studies on magnetic fields and childhood leukemia have been suggestive but inconsistent.

While smaller studies have observed a link between cancer and activities such as the use of electric blankets and television watching, the most recent and largest study did not find a connection between electromagnetic fields and cancer.

Additionally, in 1999 the National Institute of Environmental Health Sciences (NIEHS) released results of an extensive 6-year study stating that the evidence for a risk of cancer and other human disease from the electric and magnetic fields (EMF) around power lines is "weak" but could not totally be discounted, and efforts to reduce exposures when possible should continue.

Video display terminals: Video display terminals (VDTs), or computer screens, give off several kinds of radiation, most of which is in the extremely low frequency (ELF) range. Questions have been raised about possible health problems associated with the use of VDTs, including cancer and birth defects.

The amount of energy given off by VDTs is far below government exposure standards, and at this time the available evidence does not support links to either of these health problems. Research in this area continues.

Other health-related issues linked to long-term use of VDTs may be of greater concern, including problems with vision, backaches and other muscle problems, and stress.

The conflicting data concerning electromagnetic fields will undoubtedly continue to generate controversy. Clearly, the question of whether or not electromagnetic fields can cause cancer needs to be answered.

Other Sources of Non-Ionizing Radiation

Radiofrequency radiation (radio waves): Radiofrequency radiation is emitted from radio broadcast transmitters, citizen band radios, and heaters. Generally speaking, the potential risk from this type of radiation exposure is thought to be minimal.

Microwaves: Microwaves have energy levels similar to radio waves and infrared waves but are of a different frequency. Microwave radiation is used not only in microwave ovens, but also in navigational technology such as radar.

Many materials absorb microwave energy, causing them to become hot. This is how food is cooked in microwave ovens. Microwaves do not make food radioactive. When microwave ovens are used according to instructions, there is no evidence that they pose a risk of radiation exposure to people.

Exposure to high levels of microwaves can have effects on health. Such exposure can lead to a painful burn or to the development of cataracts in the lenses of the eyes. Because the testes are very sensitive to changes in temperature, exposure to high levels of microwaves can alter or kill sperm. These injuries are caused only by exposure to large amounts of microwave radiation, however, and the small amount that can leak from a microwave oven does not cause these problems.

Some pacemakers can be affected if the person with the pacemaker gets too close to a microwave oven while it is on. This can happen with other kinds of electronic equipment as well.

Radar and radar guns: Most forms of radar use waves in the microwave range. Questions have been raised about exposure to radar and the risk of developing cancer, such as in police officers who use radar guns in traffic enforcement. To date there is very little evidence to support such a connection, but studies to look at this possibility are ongoing, and governmental recommendations have been made to reduce any possible risk.

Cellular phones: Cellular phones give off small amounts of low frequency electromagnetic radiation. People have raised questions about possible links between the use of cellular phones and cancer, brain cancer in particular. For more detailed information about cellular phones, refer to our document, "Cellular Phones."

Additional Resources

National Organizations and Web Sites*

In addition to the American Cancer Society, other sources of patient information and support include:

Centers for Disease Control and Prevention (CDC)
1600 Clifton Road, NE
Atlanta, GA 30333
Telephone: 1-800-CDC-INFO (1-800-232-4636)
Internet Address: www.cdc.gov

**Inclusion on this list does not imply endorsement by the American Cancer Society.*

The American Cancer Society is happy to address almost any cancer-related topic. If you have any more questions, please call us at 1-800-ACS-2345 at any time, 24 hours a day.

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Last Revised: 02/06/2006