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TOPICS

Ionizing Radiation and Breast Cancer Risk

Everyone is exposed to ionizing radiation from natural and medical sources. In fact, ionizing radiation may be the most studied cancer-causing agent in humans with scientific committees on radiation continuously reviewing and evaluating adverse health outcomes for over 70 years. The female breast is known to be highly susceptible to the cancer-causing effects of radiation when exposure occurs before menopause. This fact sheet will discuss what is known about radiation-induced breast cancer and what factors influence or modify the effects of exposure. Most people are not exposed to the high levels of radiation that are known to cause breast cancer, and accordingly, radiation is not considered a major cause of breast cancer. Although unnecessary exposures should be avoided, diagnostic or therapeutic procedures should not be refused because of possible radiation risk.

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CORNELL

What is ionizing radiation?

Radiation is the emission of energy in the form of waves or particles. Radiation that is so powerful that it can remove electrons from atoms is called ionizing. Examples of types of ionizing radiation are x-rays from medical machines and gamma rays from radioactive substances.

How do people get exposed to radiation?

We live in a sea of low-level radiation from natural sources. These natural sources include radioactive radon gas that we breathe, radioactive elements such as potassium-40 that is found in many foods (including salt), uranium and thorium which are found in soils and building materials, and cosmic rays that continually bombard us from outer space.

However, there are other sources of man made ionizing radiation. These sources include medical x-rays which are used to both diagnose disease and to treat cancer; occupational radiation which is experienced during employment in certain industries and professions; radioactive fallout from nuclear weapons testing or reactor accidents; and radioactive emissions from the normal operation of nuclear facilities such as those used to produce electrical power.

In terms of exposure to the entire population, natural sources contribute by far the largest radiation dose to people, with medical radiation contributing the next largest amount. For individual women the amount of radiation experienced throughout life is influenced by her access to medical care, illnesses requiring diagnosis or treatment, residence that is related to levels of background radiation, and occupation in a profession with possible radiation exposure.

Is ionizing radiation a cause of breast cancer?

Yes. Studies of groups of people exposed to ionizing radiation have conclusively found that sufficiently large radiation doses can cause breast cancer. These groups include: 1) the female survivors of the atomic bombings in Japan during World War II; 2) women given radiation therapy to treat Hodgkin's disease and both malignant and benign breast disease; 3) girls treated as infants or children for several non-malignant conditions such as enlarged thymus glands; and 4) young adolescents and women who received large numbers of diagnostic x-ray examinations to monitor tuberculosis treatments or to monitor the curvature of the spine during treatment for severe scoliosis. In fact, more is probably known about the patterns of breast cancer following radiation exposure than of any other cancer, including leukemia.

What have all these studies shown about radiation-induced breast cancer?

These studies have revealed a number of things about radiation-induced breast cancer. First, female breast tissue is highly susceptible to radiation effects. Second, it takes a minimum of about 5-10 years for a radiation-induced breast cancer to develop. Third, greater levels of radiation exposure lead to greater risk of breast cancer, i.e., there is a direct dose and effect relationship. Finally, women's age at the time of exposure is also very important.

What are the important characteristics of radiation-induced breast cancer?

First, the breast tissue of young women is one of the most sensitive tissues to the carcinogenic action of ionizing radiation. Only the bone marrow (where exposure can result in leukemia) and the infant thyroid gland are more sensitive to the cancer-causing effects of radiation.

Second, it takes a minimum of about 5-10 years after exposure before a radiation-induced breast cancer would develop, and usually many more years. In fact, the time between radiation exposure and breast cancer development is longest in young women and shortest for older women; young children do not show a detectable elevation in breast cancer occurrence for some 35 to 40 years after exposure. Radiation-induced breast cancers appear to occur later in life during the same ages when breast cancer rates, in general, begin to increase. It appears that a single exposure of sufficient dose during early life can increase breast cancer risk even 50 years later.

Third, the relationship between radiation dose and breast cancer risk can be described by a straight line which implies that no matter how low the dose, there is some small risk associated with the exposure. Fortunately, for a very small exposure (detailed in question 7 below), the risk is essentially negligible and would not be related to detectable increases in breast cancer risk even if millions of women were studied. Nonetheless, it is important to minimize all unnecessary radiation exposure. The linear relationship of radiation dose and breast cancer risk does not extend to the highest radiation exposures, such as those which might be experienced following therapeutic treatments. The risk of subsequent breast cancer from very high doses is lower than that which might be expected from the effects of lower doses. This is because radiation at high doses is an effective killer of cells and

dead cells are not able to develop into cancer. There are several other observations of interest: if the total radiation dose is split into many smaller doses, the risk of radiation-induced breast cancer is nearly the same as if the dose were given all at once. However, it may be that these smaller doses have to be given during a relatively short period of time. Recent studies of infants treated with radiation suggest a reduced risk of radiation-induced breast cancer when the exposure is delivered gradually over time.

Fourth, age at exposure is one of the most important determinants of the future risk of developing breast cancer due to radiation later in life. Young girls are at highest risk and women irradiated around the menopausal ages are at low risk. In fact, for exposure after the age of about 45 years there is little evidence that radiation increases the occurrence of breast cancer. Why might this be so? One theory is that for radiation damage of breast tissue to develop into a cancer, there is the need for estrogen stimulation and tissue proliferation that occurs during monthly menstrual cycles. Once the menopausal ages have been reached, there is a decrease in this tissue proliferation and damaged cells fail to develop into cancers. Conversely, when a young girl is exposed to radiation, she will have menstrual cycles for several decades that might enhance the development of any underlying damage caused by the radiation. There is evidence to suggest that exposure to the immature breast during early development, and around the age of beginning menstruation, carries a higher risk than at other times of a woman's life. It is unclear how radiation exposure of the breast during pregnancy affects a woman's breast cancer risk. However, a recent study of women treated for Hodgkin's disease concluded that pregnancy might be a time of increased sensitivity of breast tissue to the cancer-causing effects of radiation.

Fifth, the vast majority of persons exposed to radiation do not develop a cancer related to this exposure. Even among the nearly 25,000 female atomic bomb survivors in Japan who have now been followed for over 50 years, only 173 breast cancer deaths occurred and only 41 (or 24 percent) were attributed to the radiation received in 1945.

How does the risk of radiation-induced breast cancer compare with other factors that increase the occurrence of breast cancer?

A saying in occupational medicine is that the "poison is in the dose". This might be extended to radiation with the awareness that the effect of the dose is modified by age. In other words, a moderate dose to a young girl might carry more of a risk than a high dose received by an elderly woman. Nonetheless, comparisons with other risk factors can be informative.

But first, what is the risk of breast cancer following relatively high radiation doses of the order of 100 cGy (100 rad) (cGy and rad are units of radiation exposure)? This amount of radiation is about 1000 times higher than received annually from all sources of natural background radiation (about 0.1 cGy) and is 50 times higher than the annual occupational standard for radiation workers (2 cGy in most countries). Thus, 100 cGy is not a "low" dose and quite a number of human studies have determined the risk from exposures at this level. Keeping in mind that the risk of radiation-induced breast cancer varies by age at exposure and over time, 100 cGy received by young Western women has been reported in several studies to increase the risk of developing breast cancer by about 40% on average, that is to say, the associated "relative risk" would be 1.40. Thus, this level of exposure would not be sufficient to double a woman's risk of developing breast cancer later in life (a relative risk of 2.0 indicates a doubling of risk and a dose of 100 cGy is below 2.0). There are several common conditions or life style factors that increase a woman's risk of breast cancer by about 40%, and these include never being pregnant or not having children (nulliparity), having a very early age at first menstrual period (under age 11 years at menarche), and having a very late age at menopause. Even higher risks are associated with having a family history of breast cancer, namely, having several first degree relatives with breast cancer, possessing a damaged or mutated "breast cancer" gene such as BRCA1, and having a prior history of breast cancer (developing a second breast cancer is related in part to the same factors associated with developing the initial cancer).

Is it true that while ionizing radiation can definitely cause breast cancer, it is not a major source of breast cancer cases?

Yes. It has been estimated that less than one percent of all breast cancer cases might be attributed to ionizing radiation. Since most of this radiation comes from natural sources, which we have little control over, and from medical sources, which are for our benefit, there are few opportunities to reduce exposure and thus reduce risk. It should be noted though, that a few groups of women are at high risk of radiation-induced breast cancer for whom surveillance for early detection should be considered.

What groups of women are at especially high risk of developing radiation-induced breast cancer?

Perhaps the group that is at highest risk is children who received radiation treatments for malignant and non-malignant conditions. It has been estimated that up to 50% of young girls treated for Hodgkin's disease in the past with very high radiation doses may develop breast cancer in later life. Infants treated for enlarged thymus glands, children treated for various forms of cancer, and women irradiated for benign breast conditions, including breast inflammation after giving birth, also are at high risk. Most of these types of radiation treatments for non-malignant conditions are no longer given. During treatments for cancer medical oncologists continue to strive to reduce radiation exposures to all healthy tissue, including the breast.

What should a woman do if she received radiation treatments to the chest as a young woman?

Women exposed to high levels of radiation in the past (e.g., radiotherapy to the chest for non-malignant or malignant conditions), should make sure they bring this information to the attention of their health care provider. Together they can then decide upon a medical strategy that might include periodic breast examinations, including mammography or other appropriate breast imaging procedures, to detect any problems early so that treatment might be more effective.

Does x-ray mammography put women at an even higher risk of developing a radiation-induced breast cancer?

In 1977, the US National Cancer Institute held its first "consensus" conference and the topic chosen was mammography screening of healthy women for the early detection of breast cancer. Since that time, there have been notable improvements in the imaging capabilities of the x-ray units and an appreciable lowering of radiation dose to breast tissue - by more than ten times. The controversy today surrounding screening of healthy women is not whether the radiation exposures are hazardous, but whether young women, under the age of 50, benefit from mammograms. A 30 percent reduction in death from breast cancer has been convincingly demonstrated in randomized trials of women over the age of 50. The benefit for younger women is less clear, but apparently lower. The possible hazard from mammography x-rays is very low and should not be a factor in individual decisions to undergo this procedure. The same is true for most diagnostic x-ray procedures. Nonetheless, unnecessary radiation exposures should be avoided and continued vigilance is required to ensure that the benefits associated with specific procedures outweigh the future risks.

When the mammography is performed because of symptoms that may be cancerous or because risk factors place a woman at especially high risk of breast cancer, such as known genetic conditions or prior high dose radiation to the chest, the benefit from the low dose radiation procedure substantially outweighs the possible future risk. And if you are over the age of 50, the risk-benefit equation is clearly in your favor since radiation exposures at these ages are thought to have little connection to increases in breast cancer later in life. In other words, the small presumed risk is more than offset by the benefit of the procedure, and this is especially true for women at high risk for breast cancer.

Should women be concerned about the radiation they receive when having periodic mammography x-rays or other procedures involving chest irradiation?

As stated earlier, cancer risk is related to age at the time of radiation exposure and the dose of radiation received. A mammography x-ray might result in a breast tissue dose of about 0.3 cGy. If a woman received 10 mammograms as a young woman, the total dose would be about 3 cGy. What is the risk associated with such exposure? Keeping in mind that epidemiologic studies have not detected statistically significant increases below a dose of about 20 cGy, we do know that 100 cGy increases risk by about 40%. One can estimate that the 3 cGy from periodic mammography screenings would increase your risk by about 1.2% or a relative risk of 1.012. Such low risks are not detectable in human studies. Nonetheless, all unnecessary radiation should be avoided and although the presumed risk is very small, it should be clear that the benefit from the medical exposure would far outweigh it. Decisions to have diagnostic procedures because of medical symptoms, however, should not be delayed because of the concern over presumed radiation risk.

Are women who work with radiation at high risk of developing breast cancer?

There have been studies of female medical radiation technologists, studies of female workers in the nuclear industry, and studies of women who painted watch dials with radium paint. No study has found convincing or consistent evidence that women in professions that involve radiation exposure have experienced unusually

high rates of breast cancer. Why might this be so? It seems that the radiation dose received, in contrast to the other studies mentioned above, was not sufficient to result in an elevated occurrence of breast cancer. There was a hint that women who worked as radiological technologists prior to World War II as well as pioneering Chinese medical radiation workers might have experienced higher breast cancer rates than normal, but no radiation doses were measured and the numbers were small. Young women who painted watch dials were at high risk of developing cancer of the bone but not breast cancer, most likely because the ingested radium, which similar to calcium, goes to the bone but not breast tissue.

Should women who live near a nuclear facility, such as an electrical power plant or national laboratory, be concerned about getting breast cancer from environmental radiation releases?

The radiation from the normal operation of nuclear facilities is regulated and only small levels are allowed to be released. Thus the dose of radiation for near-by residents would be expected to be much lower than from other sources of radiation such as natural background levels. Nonetheless, comprehensive studies have been conducted by the US National Cancer Institute to learn whether populations living near nuclear facilities in the United States were at increased risk of developing and dying from cancer. These studies found no evidence for increases in childhood cancer, leukemia or breast cancer among residents in counties with nuclear installations.

Recently, there have been reports that radioactive strontium has been found in teeth lost by children living near nuclear power plants and that this exposure may be responsible for increases in childhood cancer, breast cancers and other malignancies. The US Nuclear Regulatory Commission reviewed these claims in response to a request from the New Jersey Department of Environmental Protection and concluded that these claims were unfounded. The major source of radioactive strontium in the environment comes not from the operation of nuclear power plants, which produce miniscule amounts, but from earlier above ground testing of nuclear weapons. Nuclear power plant emissions of radioactive strontium are "inconsequential compared with other man-made sources and should be undetectable in deciduous teeth." Finally, strontium is unlikely to be associated with breast cancer. Its chemical properties are similar to calcium and it accumulates in bone rather than breast tissue.

If I eat food that has been irradiated, am I at increase risk of developing breast cancer or any other health condition?

Food is irradiated to kill bacteria and other food bourn pathogens to prevent the transmission of infection. Irradiated food contains no residual radioactivity that would be harmful. An analogy might be when you turn off a light in a room; once the switch is off there is no longer any exposure or exposure effects. Studies of animals fed irradiated meat have revealed no increases in health problems of abnormalities in offspring, even when such foods made up a substantial proportion of their diet throughout their life.

Are frequent flyers or airplane cabin crew at risk of developing breast cancer because of the increased exposure to cosmic rays?

It is true that frequent flying at high altitudes, similar to living at high altitudes such as in Denver, increases your exposure to cosmic rays and total radiation dose. However, the additional amount of radiation received is relatively small even among the most frequent flyers. There have been numerous studies of female cabin crew members throughout the world, and radiation has not been implicated as a cause of breast cancer in this profession. While a few studies have reported increased breast cancer rates, it is now generally accepted that the increases are likely to be related to lifestyle factors, such as delayed childbearing, and not to increased exposure to cosmic radiation.

Are there some women who are more susceptible to developing radiation-induced breast cancer than others?

There are several factors that influence the risk of developing breast cancer in general such as whether or not a woman has had children, her age when her first child was born, and a family history of breast cancer. The manner in which these factors might modify risk from radiation is not known. Other than age, i.e., being a young woman at the time of exposure to radiation, there are currently no known susceptibility states or conditions that make a woman at especially high or low risk of radiation-induced breast cancer. Studies of women with inherited susceptibility are ongoing so more definitive answers might be possible in the future.

Is a woman who received surgical and radiation treatment for breast cancer at higher risk of developing a second breast cancer?

Women, who have been treated for breast cancer, are at high risk of developing a second breast cancer, but not necessarily from the radiation treatment. Other than possessing a mutated cancer gene such as BRAC1 or BRAC2, having a history of breast cancer puts these women at the highest known risk of developing a new breast cancer. This is probably because the factors operating in the development of the first cancer are still operating in the development of a second. There have been large-scale studies, however, of women with breast cancer to learn what the level of risk might be from the radiation exposure to the other unaffected breast. All women in the state of Connecticut and all women in the country of Denmark were studied. Overall, there was no significant increase in breast cancer risk that could be tied to the radiation treatments received. This was probably because most women who develop breast cancer are over the age of 50 when the breast is less vulnerable to the carcinogenic action of ionizing radiation. But there was a radiation-related increase found for women who were under the age of 45 when first treated with radiation. Radiation therapy has been much improved so the dose to the healthy breast is much lower and, accordingly, so is the breast cancer risk related to treatment. However, it is accepted that radiation exposure of premenopausal women does increase the risk of developing a new breast cancer in the future but this risk should be balanced or placed in perspective with the survival benefit from receiving the treatment.

How does exposure to "non-ionizing" radiation, such as from microwave ovens, affect breast cancer risk?

Non-ionizing radiations do not possess enough energy to remove electrons from atoms. Examples of non-ionizing radiation are the electromagnetic fields from electrical power lines, radio and television waves, radar, cellular telephones and microwave ovens. The mode of interaction of non-ionizing radiation with the body is much different from the way ionizing radiation interacts. Most importantly, ionizing radiation can directly damage DNA and cellular molecules whereas non-ionizing radiation cannot. The concern over non-ionizing radiation is related to the heating effects of this type of radiation. Exposure standards are set to keep exposures well below the level that might shock or heat tissue to an unacceptable level. They are thus set to reduce the occurrence of rapidly occurring effects and not effects which require long periods of time to develop such as cancer. While there is overwhelming evidence from human investigations, animal experiments and cellular studies proving that ionizing radiation is a cause of cancer, there is no such evidence for the non-ionizing radiations. There is a world of difference between the radiation from an x-ray machine and the non-ionizing electromagnetic fields from say an electric blanket, and care should be taken not to confuse the two.

Conclusions

Women with clinical symptoms of a serious disease should not refuse an x-ray diagnostic procedure because of possible radiation risk (the risk associated with these procedures is very low and the immediate benefit may be great).

Most women who received radiation exposures in the past will not develop a radiation-related breast cancer. ■

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A complete bibliography of references used in the preparation of this fact sheet is available on the BCERF web site at http://envirocancer.cornell.edu

We hope you find this fact sheet to be informative. We welcome your comments. (BCERF, Sprecher Institute for Comparative Cancer Research, Vet Box 31, Cornell University, Ithaca, NY 14853-6401; phone (607) 254-2893, FAX: (607) 254-4730, Email: breastcancer@cornell.edu).