Help us expose and eliminate the environmental causes of breast cancer. Together we can stop this disease before it starts.

Ionizing Radiation

CATEGORY*: IARC known, NTP known

USED IN: Medical radiological procedures, such as X-rays, CT scans, fluoroscopy; also from nuclear power plants, radionuclide research, military weapons testing

THE GIST: Evidence from studies of medical exposures to radiation as well as large-scale tragedies such as the atomic bomb in Japan have demonstrated that radiation can cause breast cancer.

"More is known about the relationship between radiation dose and cancer risk than any other human carcinogen, and female breast cancer is the best quantified radiation-related cancer." —Charles E. Land

STATE OF THE EVIDENCE ON IONIZING RADIATION

Ionizing radiation is any form of radiation with enough energy to break off electrons from atoms (that is, to ionize the atoms). This radiation can break the chemical bonds in molecules, including DNA molecules, thereby disturbing their normal functioning. X-rays and gamma rays are the only common forms of radiation with sufficient energy to penetrate and damage body tissue below the surface of the skin.

TIPS FOR PREVENTION

Discuss with your medical care team whether or not X-rays and CT scans are necessary and whether there are radiation-free alternatives.

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Among the many sources of ionizing radiation are traditional X-rays, computed tomography (CT) scans, fluoroscopy, and other medical radiological procedures. A newer source of X-rays is the use of backscatter scanners in airport security (Brenner, 2011). Sources of gamma rays include emissions from nuclear power plants, scientific research involving radionuclides, military weapons testing, and nuclear medicine procedures such as bone, thyroid and lung scans (EPA, 2005).

In 2005, the National Toxicology Program classified X-radiation and gamma radiation as known human carcinogens. Although some scientists challenge this premise (e.g., Habron, 2012), most agree that there is no such thing as a safe dose of radiation (Brenner, 2003; NRPB, 1995). A 2005 National Research Council report confirms this finding, stating that "the risk of cancer proceeds in a linear fashion at lower doses [of ionizing radiation] without a threshold and ... the smallest dose has the potential to cause a small increase in risk to humans" (NRC, 2005).
Ionizing radiation is cumulative over a lifetime (Boice, 2001). Repeated low-dose exposures over time may have the same harmful effects as a single high-dose exposure.

Exposure to ionizing radiation is the longest-established and most firmly established environmental cause of human breast cancer in both women and men. Ionizing radiation can increase the risk for breast cancer through a number of different mechanisms, including direct mutagenesis (causing changes in the structure of DNA), genomic instability (increasing the rate of changes in chromosomes, therefore increasing the likelihood of future mutations) (Broeks, 2010; Goldberg, 2003; Morgan, 2003; Wright, 2004), and changes in breast cell microenvironments that can lead to damaged regulation of cell-to-cell communication within the breast (Barcellos-Hoff, 2005; Tsai, 2005). Ionizing radiation not only affects cells that are directly exposed, but can also alter the DNA, growth, and cell-to-cell interactions of neighboring cells, a phenomenon referred to as the “bystander effect” (Little, 2003; Murray, 2007b).

Interactions between Ionizing Radiation and Other Factors

There are a number of factors that may interact with radiation to increase the potency of its carcinogenic effect. Some of these factors include a woman’s age at exposure, her genetic profile, and possibly her estrogen levels. As examples:

a. It has been well established in a number of studies of women exposed to military, accidental or medical sources of radiation that exposure in children and adolescents confers greater increased risk than exposure in older women (Boice, 2001).

b. Recent genetic data indicate that women with some gene mutations (such as ATM, TP53 and BRCA1/2) are more likely to develop breast cancer and may be especially susceptible to the cancer-inducing effects of exposures to ionizing radiation (Andrieu, 2006; Berrington de Gonzales, 2009a; Pepe, 2012; Turnbull, 2006).

c. Studies using animal tumor cells and in vitro human breast tumor cells have demonstrated that the effects of radiation on mammary carcinogenesis may be additive with effects of estrogens (Calaf, 2000; Imaoka, 2009; Segaloff, 1971). This is of particular concern given the widespread exposure to estrogen-mimicking chemicals in our environment and the multiple sources of ionizing radiation. In a mouse model, radiation exposure increased blood serum estradiol levels and estrogen associated activation of cell-proliferation pathways (Suman, 2012).

Evidence Linking Ionizing Radiation and Breast Cancer Risk

The link between radiation exposure and breast cancer has been demonstrated in atomic bomb survivors (Goto, 2012; Land, 1995; Pierce, 1996; Tokunaga, 1994). Rates of breast cancer were highest among women in Hiroshima and Nagasaki who were younger than age 15 when the United States dropped atomic bombs there (Land, 1998). Recent analysis of tumor subtypes and tissue DNA from survivors of the atomic bombs indicate that radiation-associated breast tumors are quite aggressive and are associated with increased levels of genomic instability (too many genes, mutations or incomplete replication of genes, etc.), a trait that has been associated with the development of cancer (Oikawa, 2011). In addition, scientists reported a statistically significant association between ionizing radiation exposure and the incidence of male breast cancer in Japanese atomic bomb survivors (Ron, 2005).

Use of X-rays to examine the spine, heart, lungs, ribs, shoulders and esophagus also exposes parts of the breast to radiation. X-rays and fluoroscopy of infants irradiate the whole body (Gofman, 1996). Decades of research has confirmed the link between radiation and breast cancer in women who were irradiated for many different medical conditions, including tuberculosis (MacKenzie, 1965), benign breast disease (Golubicic, 2008; Mattson, 1995), acute postpartum mastitis (Shore, 1986), enlarged thymus (Adams, 2010; Hildreth, 1989), skin hemangiomas (Lundell, 1999), scoliosis (Morin-Doody, 2000), Hodgkin’s disease (Bhatia, 2003; Guibout, 2005; Horwich, 2004; Wahner-Roeller, 2004), non-Hodgkin’s lymphoma (Tward, 2006) and acne (El-Gamal, 2006). A dose-response relationship
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(meaning a higher dose of radiation is related to a higher incidence of breast cancer) was found in women who had been treated with X-rays and who had a family history of breast cancer (Ronckers, 2008). Evidence from almost all conditions suggests that exposure to ionizing radiation during childhood and adolescence is particularly dangerous with respect to increased risk for breast cancer later in life (e.g., John, 2007).

Female radiology technologists who had sustained daily exposures to ionizing radiation demonstrated an increased risk of breast cancer if they began working during their teens or, independent of age, worked in the field before the 1940s, when exposure levels were substantially higher than they have been in more recent decades (Doody, 2006; Simon, 2006). The susceptibility of radiologists to later diagnosis of breast cancer may be affected by common variants in particular genes that are involved in the metabolism of circulating estrogens (Sigurdson, 2009). A review and analysis of all existing related studies found that women who work as airline flight attendants had increased levels of breast cancer. Factors that could explain this increase may include lifestyle and reproductive histories as well as increased exposures to cosmic (atmospheric) ionizing radiation (Ballard, 2000).

Medical Radiation: Risks and Benefits

Computed tomography (CT) Scans
There is considerable evidence that medical X-rays, which include mammography, fluoroscopy and computed tomography (CT) scans are an important and controllable cause of breast cancer (Gofman, 1999; Ma, 2008). Although there has been a substantial decrease in exposures to ionizing radiation from individual X-rays over the past several decades, there has been a sixfold increase in exposure to medical sources of radiation from the mid-1980s through 2007, with an annual increase of 16 percent, primarily arising from the increased use of CT scans and nuclear medicine (Larson, 2011; Linet, 2012). In 2007, approximately 72 million CT scans were conducted in the United States (Berrington de Gonzales, 2009b). When a CT scan is directed to the chest, the individual receives the equivalent radiation of 30 to 442 chest X-rays (Redberg, 2009). Recent modeling estimates that use of chest CTs and CT angiography in 2007 alone will lead to an additional 5,300 cases of lung and breast cancer within the next two to three decades (Berrington de Gonzales, 2009b). Other modeling suggests that 1 in 150 women who are 20 years old when they undergo CT angiograms of the chest, and 1 in 270 women (of all ages) having the procedure, will subsequently develop cancers of the chest, including breast cancer (Smith-Bindman, 2009).

Recent modeling of the long-term effects of cardiac CT angiography, a source of comparably high radiation to the chest, demonstrates a statistically significant increase in risk for breast cancer, especially in pre-menopausal women (Huda, 2011).

Mammography
Many experts believe that the low-dose exposures to radiation received as a result of mammography procedures are not sufficient to increase risk for breast cancer. However, damage from lower-energy sources of X-rays, including those used in mammography, cannot be predicted by estimating risk from models based on higher doses (Heyes, 2009; Millikan, 2005). Recent evidence indicates that the lower-energy X-rays provided by mammography result in substantially greater damage to DNA than would be predicted by these models. Evidence also suggests that risk of breast cancer caused by exposure to mammography radiation may be greatly underestimated (Heyes, 2009).

As with other risk factors for breast cancer, evidence indicates that both age at exposure and the individual’s genetic profile influence the degree of increased risk for disease in women exposed to multiple mammograms. For example, women who had multiple mammograms more than five years prior to diagnosis had an increased risk for breast cancer, but the effect was only statistically significant for women whose first mammograms occurred before the age of 35 (Ma, 2008).

This age effect is of particular concern, since it is often recommended that high-risk women, including those with either of the BRCA mutations, begin annual mammography screening at ages 25 to 30. Further complicating this
age-related finding are the data now demonstrating that young women with the very mutations that lead them to begin mammography screenings at earlier ages are actually more vulnerable to the cancer-inducing effects of early and repeated exposures to mammograms. This increased vulnerability has been found in women with BRCA mutations (Berrington de Gonzales, 2009a; Jansen-Van der Weide, 2009) as well as in women with other relatively uncommon variations in genes known to be involved in the process of DNA repair (Millikan, 2005). A recent study found that diagnostic radiation exposure before age 30 increased risk of breast cancer in a dose-dependent manner among women with BRCA mutations (Pijpe, 2012).

The detrimental risks from mammography might also be heightened in older women, whose breast epithelial cells have gone through several decades of cell division. Cells derived from older women’s breast tissue were more sensitive to the DNA-damaging effects of low-energy radiation, increasing the likelihood of later conversion to cancerous cells (Soler, 2009).

In 2009 the U.S. Preventive Services Task Force recommended against the use of routine mammography screening for women under 50 (Nelson, 2009; USPSTF, 2009) and recommended that women 50 to 75 get screened every two years. The Task Force concluded that for women 40 to 49 the benefits of mammograms do not outweigh the harms, which include false-positive results that lead to unneeded breast biopsies and follow up-imaging, and to unnecessary anxiety and distress. Also, the Task Force found that mammograms play an extremely modest role in reducing the likelihood of dying from breast cancer. Among women 40 to 49, who tend to have low rates of breast cancer to begin with, the procedure is responsible for saving very few lives. A different analysis suggests that for women over the age of 40 who are not at high risk, the trade-offs between diagnostic efficacy of mammography and radiation exposure suggest that annual or biennial screening with mammography lean more in the favor of regular mammography screening (Yaffe, 2011). As women are now facing the need to make their own decisions about whether to undergo routine screening mammography, it is critical that both physicians and women are better educated about mammography’s potential harms, along with its potential benefits (Gotzsche, 2009; Jansen-van der Weide, 2010).

Radiation Therapy
Some studies suggest that doctors and patients should carefully evaluate the risks and benefits of radiation therapy for survivors of early-stage breast cancer, particularly older women. Women older than 55 derive less benefit from radiation therapy in terms of reduced rate of local recurrence (Veronesi, 1999) and may face increased risks of radiation-induced cardiovascular complications (EBGTCG, 2000), as well as secondary cancers such as leukemias and cancers of the lung, esophagus, stomach and breast (Mellemkjaer, 2006; Roychoudhuri, 2004). Using the National Cancer Institute’s Surveillance, Epidemiology and End Results (SEER) data, researchers showed a 16-fold increased relative risk of angiosarcoma of the breast and chest wall following irradiation of a primary breast cancer (Huang, 2001).

More recent data indicate that women younger than 45 who received the higher radiation exposure associated with post-lumpectomy radiotherapy (as compared to post-mastectomy radiation) had a 1.5-fold to 2.5-fold increase in later contralateral breast cancer diagnoses. This effect was especially prominent in younger women with a substantial family history of breast cancer (Hooning, 2007; Ng, 2009; Stovall, 2008).

Backscatter X-rays
The implementation of X-ray backscatter technology at airport security sites is so recent that there are no data on links to breast cancer, either positive or negative. One recent conservative study that has modeled the effects of exposures to radiation through backscatter technologies, estimates that for every 2 million young girls who travel by airplane once a week, one will develop breast cancer as a result (Mehta, 2012). Others are less sanguine and urge application of a precautionary approach until we understand better the possible health consequences of routine exposures to this new source of radiation (Brenner, 2011), particularly since millimeter wave screening provides an equally effective whole-body screening mechanism that does not rely upon ionizing radiation. In January 2013, the TSA said they would be removing all backscatter scanners from airports by June 2013.
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- **Lower your exposure to radiation**
- **View references**

*For chemicals that have been shown to be carcinogens, we provide classifications from two authoritative bodies: the International Agency for Research on Cancer (IARC, an international body) and the National Toxicology Program (NTP, a division of the U.S. Department of Health and Human Services). We have categorized endocrine-disrupting compounds where the body of peer-reviewed research indicates a strong foundation for doing so.*

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