Ontario
Cancer Care Ontario
Action Cancer Ontario

Cancer Risk Factors in Ontario

Other Radiation

OTHER RADIATION

Risk factor/ exposure	Cancer	The context where high risks were reported	Magnitude of risk*	Strength of evidence[a]
Radon-222 and decay products	Lung	Occupational Environmental	1.2–3.2[b] 1.1–1.4[c]	Sufficient
	Leukemia	Occupational Environmental	… …	Limited
X-radiation, gamma radiation	Salivary gland	Atomic bomb survivors Medical	*1.4–3.8*[d] *0.8*[d]	Sufficient
	Esophagus	Atomic bomb survivors Medical	*0.4–1.4*[d] *0.17–0.3*[d]	
	Stomach	Atomic bomb survivors	*0.1–0.5*[d]	
	Colon	Atomic bomb survivors Occupational	*0.5–1.2*[d] *2.6*[e]	
	Lung	Atomic bomb survivors Medical Occupational	*0.3–1.5*[d] *0.1–0.4*[d] *0.1–0.6*[d]	
	Bone	Atomic bomb survivors Medical	*1.2–3.3*[d] *0.02–0.2*[d]	
	Skin (BCC)	Atomic bomb survivors	*0.9–1.5*[d]	
	Breast	Atomic bomb survivors Medical	*1.3–2.0*[d] *0.06–0.4*[d]	
	Bladder	Atomic bomb survivors Medical Occupational[†]	*0.8–1.4*[d] *0.07–0.4*[d] *1.4*[e]	
	Kidney	Atomic bomb survivors Medical	*0.2–1.2*[d] *0.1–0.7*[d]	
	Brain and central nervous system	Atomic bomb survivors Medical	*0.4–2.6*[d] *0.07–4.6*[d]	
	Thyroid	Atomic bomb survivors Medical exposures	*1.0–3.2*[d] *3.0–12*[d]	
	Leukemia (excluding chronic lymphocytic leukemia)	Atomic bomb survivors Medical Occupational	*3.0–6.3*[d] *0.1–0.7*[d] *1.0–16*[d]	
	Liver, multiple myeloma, non-Hodgkin lymphoma, ovary, pancreas, prostate, rectum	Atomic bomb survivors, medical, occupational	…	Limited

Abbreviations: BCC= Basal cell carcinoma

Sources: [a]IARC, 2012; [b]Lubin et al., 1995; [c]Krewski et al., 2005; [d]UNSCEAR Report, 2006; [e]Sont et al., 2001

* For occupational radon-222 and its decay products, risk estimates are relative risks (RR) for exposures of 100 working-level months; for environmental radon-222 exposure, the lower RR estimate displayed is for exposures of 25–75 Bq/m^3 and the higher RR estimate displayed in the range is for exposures ≥ 200 Bq/m^3; *for X- and gamma radiation, risk estimates are the excess relative risk (ERR) at 1 sievert (Sv).*

…Magnitude of risk not shown in table if strength of evidence is "probable" or "limited."

[†] Excess relative risk estimate for males only.

RADON-222 AND ITS DECAY PRODUCTS

Background

» Radon is a colourless, odourless radioactive gas released from the decay of uranium and thorium and their radioactive products (called "daughters").[91]

» The most common isotope is radon-222, which emits (radioactive) alpha particles.[91]

» Highest levels of exposure occur in an occupational setting in mines where uranium and thorium are present. Naturally occurring radon can also accumulate in workplace and residential buildings, especially in basements.[107]

» The primary route of human exposure is inhalation into the lungs.[108]

- In 1987, the International Agency for Research on Cancer (IARC) first stated that radon causes lung cancer in humans,[109] based largely on studies of underground haematite miners with high exposures to radon (specifically radon-222 and its decay products).[110] There is now evidence from studies of residential radon exposure within the general population that further supports a causal association between radon exposure and an increased risk of lung cancer.[110] There is some, but not sufficient, evidence that radon-222 causes leukemia.[91]
- A pooled analysis of 11 cohort studies found a 1.2–3.2 times greater risk of lung cancer at 100 working-level months among radon-exposed underground miners; a consistent dose-response relationship with cumulative radon exposure was also apparent.[111] Residential exposure to radon has been associated with a 10%–40% increase in lung cancer risk, from lower through higher exposures,[112] with pooled analyses from North America,[112,113] Europe[114,115] and China[116] demonstrating a consistent dose-response relationship.
- An interaction between radon exposure and tobacco smoking is generally seen for lung cancer risk[14,91] (see tobacco section on page 7).

X-RADIATION, GAMMA RADIATION

Background

» X-rays and gamma rays are types of ionizing radiation that are mainly distinguished by their origin.[91]

» X-rays are used in many medical applications, including diagnostic imaging and in therapy, mainly in cancer treatments to destroy malignant cells. Gamma rays are used in medicine, the nuclear power industry and in the production of nuclear weapons.[108]

» Environmental sources of X- and γ-radiation exposure include background radiation from terrestrial and cosmic sources,[91] as well as atmospheric nuclear weapons tests and nuclear power accidents, such as the Chernobyl and Fukashima disasters.

» The main route of exposure for X- and gamma radiation is absorption by bones and surrounding tissue after they have penetrated the skin (e.g., during diagnostic imaging).[110] Ingestion of food or water contaminated with radionuclides in areas where radioactive materials have been released into the environment, such as nearby rivers, is also a possible exposure route.[91]

- IARC first classified X-radiation and gamma radiation as carcinogenic to humans in 1999.[110] It is now well recognized that X-radiation and gamma radiation are multi-organ carcinogens. The epidemiologic evidence for carcinogenicity comes from studies of atomic bomb survivors, of people exposed during medical procedures, and of occupational or environmental exposures.[110]

Detonation of atomic bombs

- Evidence for risk from atomic bomb detonation comes largely from the Life Span Study, a population-based study of survivors of the atomic bomb attacks on Hiroshima and Nagasaki. Survivors were mainly exposed to gamma radiation and had significant increases in the incidence of leukemia and cancers of the salivary gland, esophagus, stomach, colon, skin, thyroid, brain and central nervous system, bladder, kidney, breast, lung and bone and connective tissue.[91] Slightly elevated incidence of liver and ovarian cancer were also seen.[91]
- Excess relative risks as high as 6 at 1 sievert have been observed among atomic bomb survivors, with the greatest risks observed for leukemia.[117] A dose-response relationship is apparent between estimated exposure dose, and risk of leukemia[118] and cancer of the salivary gland.[119]

Medical exposures

- Strong evidence exists of increased risk from medical X- and gamma radiation exposure for cancers of the esophagus, lung, thyroid, breast, bone and connective tissue, brain and central nervous system, bladder, salivary gland, kidney and leukemia. This evidence comes from studies of patients exposed to X- or gamma radiation for medical treatment or diagnostic purposes.[110]
    - Patients may be treated with radiotherapy, predominantly X-radiation, for malignant diseases, including cancer of the breast, ovary, cervix and Hodgkin disease,[91,110] which may lead to second primary cancers later in life.
    - There is also evidence of cancer following radiotherapy for benign disease, such as benign breast disease, ankylosing spondylitis or peptic ulcer. Increased risk of certain cancers has also been associated with diagnostic X-radiation, including multiple adult chest fluoroscopies for pulmonary tuberculosis, multiple childhood X-rays for scoliosis and prenatal X-ray exposure, with lower doses than those used for treatment.[110]
- The cancers described above have mostly demonstrated excess relative risks up to 5 at 1 sievert from medical exposures to X- and gamma radiation.[117] The exception is thyroid cancer, for which excess relative risk estimates as high as 12 at 1 sievert have been observed.[117] Significant dose-response relationships are apparent at high doses of radiotherapy for many cancer sites including brain, thyroid and bone. Dose-response relationships have also been seen for cancer of the salivary gland in patients who received radiation therapy as children for conditions in the head and neck area[120] and for cancer of the breast.[91]

Occupational exposures

- The evidence for cancer comes from studies of medical personnel, such as radiologists and X-ray technologists, Chernobyl clean-up workers, and nuclear industry workers in the US and UK and in the Mayak nuclear complex in the Russian Federation.
- Occupational studies have not demonstrated significantly increased risk for most cancer sites.[91,110] The exception is leukemia, for which excess relative risks of 1–16/sievert have been observed across occupational studies, depending on the occupational groups examined.[117]
- Lung cancer had an excess relative risk of 0.1–0.6 at 1 sievert in occupational groups, such as the Chernobyl clean-up workers and US radiation workers.[117] A positive dose-response relationship was observed for lung cancer in a 15 country study of cancer risk among nuclear industry workers.[121] A Canadian cohort study of occupational exposure to ionizing radiation found a greater excess relative risk of 3/sievert.[122]

BIOLOGIC MECHANISMS

- All types of ionizing radiation, including X- and gamma radiation, and alpha-emitters, such as radon, transfer energy, leading to DNA damage. This is followed by repair responses, such as apoptosis, changes to the number or content of chromosomes to produce abnormal chromosomes (chromosomal aberrations), mutations or transformation of the cell, all of which can induce carcinogenesis.[107]