Health effects of ionizing radiation

Under what circumstances are people likely to be exposed to chronic dosages of ionizing radiation? How about acute dosages?

Are there any effective health precautions you can take if you are exposed to higher than normal levels of ionizing radiation? What factors affect the risk of long-term health effects such as cancer due to radiation exposure? The World Health Organization names the following factors:

- **Sensitivity of tissues and organs (cancer sites)**
  Tissues with cells that divide more often are more susceptible to cancer. The bone marrow, thyroid, and breast tissues are the most radiosensitive ‘cancer sites’. From studies of Japanese atomic bomb survivors, other susceptible cancer sites have been identified, such as the oral cavity, stomach, colon, liver, lung, ovary, and urinary bladder.

- **Age at exposure**
  In general, children and adolescents are more vulnerable than older people because the cells and tissues of younger people divide more actively. Additionally, radionuclides absorbed by children will stay longer inside the body due to their longer remaining lifespan. This means that the same intake in a younger person can result in a higher internal dose than in an older person. Exposure to radioactive iodine at a young age increases the risk of thyroid cancer in particular.

The significance of radiation-induced cancer risk diminishes with age. As you get older, your likelihood of getting cancer increases in general. Since a child is highly unlikely to get cancer in the first place, even a small added risk due to radiation exposure would be significant in relative terms. However, as this child ages, the significance of this added risk diminishes. By age 80, she would be much more likely to get cancer from some other cause than from her exposure to radiation in childhood.

- **Sex differences in cancer risk**
  At a given dose of radiation, women are more likely to be at a greater risk of cancer than men. From the studies of Japanese atomic bomb survivors, it is estimated that solid cancers are about 50% higher for women than for men. However, there is no strong difference in leukaemia. Additionally, no systematic differences have been observed at lower environmental and occupational exposure levels.

**Risk factors**

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Ionizing radiation affects cells

The radiation that most people are afraid of is called ‘ionizing’ radiation as it can damage or kill cells.

How cells are harmed

Ionizing radiation can cause cell damage or even cell death when it acts on biological cells.

Cell damage

- If the radiation dose is below a critical level (called a ‘threshold’ dose), cellular damage can be repaired to the extent that no clinical effects can be observed.
- Radiation might damage a cell’s DNA, which holds the instructions telling the cell how to function and reproduce. If the damage cannot be repaired, the cell may continue to work using faulty instructions, leading it to turn cancerous.

Cell death

- If sufficient number of cells is affected by ionizing radiation, the functioning of the exposed tissues or organs may be impaired.
- At high enough ionizing radiation doses, death occurs. A dose of 4 Gy will kill about 50% of healthy adult people.

Types of health effects

The type of health effects that occur after exposure to radiation depends on the intensity and duration of the dosage. Scientists use a number of terms to characterise radiation dosage, the likelihood of damage, and nature of radiation-related health effects:

- Chronic vs. acute, deterministic vs. stochastic, and somatic vs. genetic. The box on the bottom right explains what they mean, while the diagram above illustrates the interactions between them.

Deterministic vs. stochastic effects

Deterministic effects are health effects that are to some degree certain to occur above a critical dosage threshold. Over that threshold, the body is not able to repair the damage to the cells, and changes to the tissues or organs (‘tissue reactions’) occur, leading to clinical symptoms including acute radiation sickness, cataracts of the eyes, hair loss and skin redness.

Stochastic effects are random, and result from damage to cells’ DNA, taking the form of cancers and hereditary abnormalities. Although their likelihood increases with dosage, they are not certain to occur. Scientists use the language of probability to describe them, e.g. ‘a 2% likelihood.’ There is no clear threshold below which stochastic effects will not occur.

Somatic vs. genetic effects

Somatic effects are simply effects on the body of the person who was exposed to the radiation. Somatic effects include both radiation sickness caused by acute exposure, and the health problems (including cancers) caused by chronic dosage.

Genetic effects occur in the exposed person’s descendants due to damage to the DNA or chromosomes of the ‘germ cells’ (cells involved in passing genetic material to offspring). Genetic effects are passed down through generations, so that the negative health effects of radiation can last for a very long time.

Relationship between dosage, risk and effects

Intensity of dosage

Risk of damage

Effect on body

Examples of health impacts

Acute vs. chronic dosage

An acute dosage is a large dose of radiation absorbed by the body (0.1 Gy or more to the whole body) over a short time. Acute dosages mainly cause deterministic health effects which appear within a few hours to several weeks. Stochastic effects may surface in the long term.

A chronic dosage is a small amount of radiation absorbed over a long period of time, such as those absorbed occupationally by nuclear industry workers, miners, and airline crews. Health effects are mainly stochastic, and may take many years or decades to appear.

Acute radiation sickness

Acute radiation sickness may occur after exposure to radiation at doses greater than 0.1 Gy. Symptoms may appear within hours or days after exposure, and may include:

- Radiation burns: skin becomes red and inflamed, and dead skin cells are shed. Hair will drop off.
- Vomiting and bloody diarrhoea.
- Damage to gastrointestinal tract.
- Damage to bone marrow, resulting in bleeding. Greater susceptibility to infection and anaemia.

Chronic radiation exposure

Chronic radiation exposure occurs after exposure to radiation at doses of less than 0.1 Gy. Symptoms may include:

- Inflammation of the lungs and kidneys.
- Damage to the thyroid gland.
- Increased risk of cancer: Studies of Japanese atomic bomb survivors, miners and animals suggest that the most likely forms of cancer are leukaemia (cancer of the bone marrow), lung cancer caused by the inhalation of radon gas, and thyroid cancer caused by the ingestion of radioactive iodine.

Radiation-related health symptoms

Acute dosage

‘Radiation burns’ occur, in which the skin becomes red and inflamed, and dead skin cells are shed. Hair will drop off.

As the dosage rises, acute radiation sickness develops.

Symptoms of acute radiation sickness

<table>
<thead>
<tr>
<th>Whole body radiation dosage</th>
<th>Effects</th>
<th>Time of death after exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 Gy-1 Gy</td>
<td>Damage to bone marrow, resulting in bleeding. Greater susceptibility to infection and anaemia.</td>
<td>30-60 days</td>
</tr>
<tr>
<td>1.5 Gy-3 Gy</td>
<td>Damage to gastrointestinal tract. Vomiting and bloody diarrhoea.</td>
<td>7-30 days</td>
</tr>
<tr>
<td>&gt;3 Gy</td>
<td>Damage to lungs and kidneys.</td>
<td>60-150 days</td>
</tr>
</tbody>
</table>

Chronic dosage

Exposure to lower levels of radiation produces both somatic and genetic damage.

Radiation cataracts: The clouding of the lenses in the eyes may be seen in workers occupationally exposed to radiation.

Hereditary abnormalities: Genetic effects result from radiation damage to the DNA or chromosomes in ‘germ cells’, resulting in hereditary abnormalities being passed on to the exposed person’s descendants. While observed extensively in plants and animals, the risk in humans is significantly lower than for somatic effects.

Examples of health impacts

<table>
<thead>
<tr>
<th>Acute radiation sickness</th>
<th>Infertility</th>
<th>Hair loss</th>
<th>Radiation burns</th>
<th>Cataracts of the eyes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute effect</td>
<td></td>
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<tr>
<td>Chronic effect</td>
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Source: ICRP (2007)