

**Radiation poisoning**, also called **radiation sickness** or a **creeping dose**, is a form of damage to organ tissue due to excessive exposure to [ionizing radiation](#). The term is generally used to refer to [acute](#) problems caused by a large dosage of [radiation](#) in a short period, though this also has occurred with long term exposure. The clinical name for radiation sickness is *acute radiation syndrome* (ARS) as described by the [CDC](#).<sup>[1][2][3]</sup> A [chronic](#) radiation syndrome does exist but is very uncommon; this has been observed among workers in early [radium](#) source production sites and in the early days of the [Soviet](#) nuclear program. A short exposure can result in acute radiation syndrome; chronic radiation syndrome requires a prolonged high level of exposure.

Radiation exposure can also increase the probability of contracting some other diseases, mainly [cancer](#), [tumours](#), and [genetic damage](#). These are referred to as the [stochastic](#) effects of radiation, and are not included in the term radiation sickness.

The use of [radionuclides](#) in science and industry is strictly regulated in most countries (in the U.S. by the [Nuclear Regulatory Commission](#)). In the event of an accidental or deliberate release of radioactive material, either evacuation or [sheltering in place](#) are the recommended measures.

Radiation sickness is generally associated with acute (a single large) exposure.<sup>[4][5]</sup> Nausea and vomiting are usually the main symptoms.<sup>[5]</sup> The amount of time between exposure to radiation and the onset of the initial symptoms may be an indicator of how much radiation was absorbed.<sup>[5]</sup> Symptoms appear sooner with higher doses of exposure.<sup>[6]</sup> The symptoms of radiation sickness become more serious (and the chance of survival decreases) as the dosage of radiation increases. A few symptom-free days may pass between the appearance of the initial symptoms and the onset of symptoms of more severe illness associated with higher doses of radiation.<sup>[5]</sup> Nausea and vomiting generally occur within 24–48 hours after exposure to mild (1–2 [Gy](#)) doses of radiation. Headache, fatigue, and weakness are also seen with mild exposure.<sup>[5]</sup> Moderate (2–3.5 [Gy](#) of radiation) exposure is associated with nausea and vomiting beginning within 12–24 hours after exposure.<sup>[5]</sup> In addition to the symptoms of mild exposure, fever, hair loss, infections, bloody vomit and stools, and poor wound healing are seen with moderate exposure.<sup>[5]</sup> Nausea and vomiting occur in less than 1 hour after exposure to severe (3.5–5.5 [Gy](#)) doses of radiation, followed by diarrhea and high fever in addition to the symptoms of lower levels of exposure.<sup>[5]</sup> Very severe (5.5–8 [Gy](#) of radiation) exposure is followed by the onset of nausea and vomiting in less than 30 minutes followed by the appearance of dizziness, disorientation, and low blood pressure in addition to the symptoms of lower levels of exposure.<sup>[5]</sup> Severe exposure is fatal about 50% of the time.<sup>[5]</sup>

Longer term exposure to radiation, at doses less than that which produces serious radiation sickness, can induce [cancer](#) as cell-cycle genes are mutated. If a cancer is radiation-induced, then the disease, the speed at which the condition advances, the [prognosis](#), the degree of pain, and every other feature of the disease are **not** functions of the radiation dose to which the sufferer is exposed. In this case, function of dose is the probability chronic effects will develop.

Since [tumors](#) grow by abnormally rapid cell division, the ability of radiation to disturb cell division is also used to treat cancer (see [radiotherapy](#)), and low levels of [ionizing radiation](#) have been claimed to lower one's risk of cancer (see [hormesis](#)).

## **TREATMENT:**

Treatment reversing the effects of irradiation is currently not possible. [Anaesthetics](#) and [antiemetics](#) are administered to counter the symptoms of exposure, as well as [antibiotics](#) for countering secondary infections due to the resulting immune system deficiency.

There are also a number of substances used to mitigate the prolonged effects of radiation poisoning, by eliminating the remaining radioactive materials, post exposure.

### **Whole Body vs. Part Body**

In the case of a person who has had only part of their body irradiated then the treatment is easier, as the human body can tolerate very large exposures to the non-vital parts such as [hands](#) and [feet](#), without having a global effect on the entire body. For instance, if the hands get a 100 Gy dose which results in the body receiving a dose (averaged over the entire body of 5 Gy) then the hands may be lost but radiation poisoning would not occur. The resulting injury would be described as localized [radiation burn](#).

As described below, one of the primary dangers of whole-body exposure is [immunodeficiency](#) due to the destruction of [bone marrow](#) and consequent shortage of [white blood cells](#). It is treated by maintaining a sterile environment, bone marrow transplants (see [hematopoietic stem cell transplantation](#)), and blood transfusions.

### **Experimental Treatments Designed to Mitigate Effects**

[Neumune](#), an [androstenediol](#), was introduced as a radiation countermeasure by the [US Armed Forces Radiobiology Research Institute](#), and was under joint development with [Hollis-Eden Pharmaceuticals](#) until March, 2007. Neumune is in [Investigational New Drug](#) (IND) status and [Phase I trials](#) have been performed.

Some work has been published in which [Cordyceps sinensis](#), a [Chinese Herbal Medicine](#) has been used to protect the [bone marrow](#) and digestive systems of [mice](#) from whole body irradiation.<sup>[18]</sup>

Recent lab studies conducted with [bisphosphonate](#) compounds have shown promise of mitigating radiation exposure effects.

### **Doses**

Annual limit on intake (ALI) is the derived limit for the amount of [radioactive material](#) taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the reference man that would result in a committed effective dose equivalent of 5 rems (0.05 [Sievert](#)) or a committed dose equivalent of 50 rems (0.5 [Sievert](#)) to any individual organ or tissue.<sup>[20]</sup> Dose-equivalents are presently stated in [sieverts](#) (Sv):

#### **0.05–0.2 Sv (5–20 rem)**

No symptoms. Potential for [cancer](#) and mutation of genetic material, according to the [LNT model](#): this is disputed (Note: see [hormesis](#)). A few researchers contend that low dose radiation may be beneficial.<sup>[21][22][23]</sup> 50 mSv is the yearly federal limit for radiation workers in the United States. In the [UK](#) the yearly limit for a classified radiation worker is 20 mSv. In Canada and Brazil, the single-year maximum is 50 mSv (5,000 millirems), but the maximum 5-year dose is only 100 mSv. Company limits are usually stricter so as not to violate federal limits.<sup>[24]</sup>

#### **0.2–0.5 Sv (20–50 rem)**

No noticeable symptoms. [White blood cell](#) count decreases temporarily.

### **0.5–1 Sv (50–100 rem)**

Mild radiation sickness with headache and increased risk of infection due to disruption of immunity cells. Temporary male sterility is possible.

### **1–2 Sv (100–200 rem)**

*Light radiation poisoning, 10% fatality after 30 days (LD 10/30).* Typical symptoms include mild to moderate nausea (50% probability at 2 Sv), with occasional [vomiting](#), beginning 3 to 6 hours after irradiation and lasting for up to one day. This is followed by a 10 to 14 day latent phase, after which light symptoms like general illness and [fatigue](#) appear (50% probability at 2 Sv). The [immune system](#) is depressed, with convalescence extended and increased risk of infection. Temporary male sterility is common. [Spontaneous abortion](#) or [stillbirth](#) will occur in pregnant women.

### **2–3 Sv (200–300 rem)**

*Moderate radiation poisoning, 35% fatality after 30 days (LD 35/30).* Nausea is common (100% at 3 Sv), with 50% risk of vomiting at 2.8 Sv. Symptoms onset at 1 to 6 hours after irradiation and last for 1 to 2 days. After that, there is a 7 to 14 day latent phase, after which the following symptoms appear: loss of hair all over the body (50% probability at 3 Sv), fatigue and general illness. There is a massive loss of [leukocytes](#) (white blood cells), greatly increasing the risk of infection. Permanent female sterility is possible. [Convalescence](#) takes one to several months.

### **3–4 Sv (300–400 rem)**

*Severe radiation poisoning, 50% fatality after 30 days (LD 50/30).* Other symptoms are similar to the 2–3 Sv dose, with uncontrollable bleeding in the mouth, under the skin and in the kidneys (50% probability at 4 Sv) after the latent phase.

[Anatoly Dyatlov](#) received a dose of 390 rem during the [Chernobyl disaster](#). He died of heart failure in 1995 due to [radioactive exposure](#).

### **4–6 Sv (400–600 rem)**

*Acute radiation poisoning, 60% fatality after 30 days (LD 60/30).* Fatality increases from 60% at 4.5 Sv to 90% at 6 Sv (unless there is intense medical care). Symptoms start half an hour to two hours after irradiation and last for up to 2 days. After that, there is a 7 to 14 day latent phase, after which generally the same symptoms appear as with 3–4 Sv irradiation, with increased intensity. Female sterility is common at this point. Convalescence takes several months to a year. The primary causes of death (in general 2 to 12 weeks after irradiation) are infections and [internal bleeding](#).

### **6–10 Sv (600–1,000 rem)**

*Acute radiation poisoning, near 100% fatality after 14 days (LD 100/14).* Survival depends on intense medical care. [Bone marrow](#) is nearly or completely destroyed, so a [bone marrow transplant](#) is required. Gastric and intestinal tissue are severely damaged. Symptoms start 15 to 30 minutes after irradiation and last for up to 2 days. Subsequently, there is a 5 to 10 day latent phase, after which the person dies of infection or [internal bleeding](#). Recovery would take several years and probably would never be complete.

[Devair Alves Ferreira](#) received a dose of approximately 7.0 Sv (700 rem) during the [Goiânia accident](#) and survived, partially due to his [fractionated exposure](#).

### **10–50 Sv (1,000–5,000 rem)**

*Acute radiation poisoning, 100% fatality after 7 days (LD 100/7).* An exposure this high leads to spontaneous symptoms after 5 to 30 minutes. After powerful fatigue and immediate nausea caused by direct activation of chemical receptors in the brain by the irradiation, there is a period of several days of comparative well-being, called the latent (or "[walking ghost](#)") phase.<sup>[citation needed]</sup> After that, cell death in the gastric and intestinal tissue, causing massive [diarrhea](#), intestinal bleeding and loss of water, leads to water-electrolyte imbalance. Death sets in with [delirium](#) and coma due to breakdown of circulation. Death is currently inevitable; the only treatment that can be offered is [pain management](#).

[Louis Slotin](#) was exposed to approximately 21 Sv in a [criticality accident](#) on 21 May 1946, and died nine days later on 30 May.

### **More than 50 Sv (>5,000 rem)**

A worker receiving 100 Sv (10,000 rem) in an accident at [Wood River](#), Rhode Island, USA on 24 July 1964 survived for 49 hours after exposure. Cecil Kelley, an operator at the [Los Alamos National Laboratory](#), received between 60 and 180 Sv (6,000–18,000 rem) to his upper body in an accident on 30 December 1958, surviving for 36 hours.<sup>[25]</sup>

An episode of *MythBusters* exposed insects to the [Cobalt-60](#) source at the [Pacific Northwest National Laboratory](#) facility. At 10,000 rad, 70% of [cockroaches](#) were dead after 30 days, and 30% survived. At 100,000 rad, 90% of [flour beetles](#) were dead after 30 days, with only 10% surviving.<sup>[26]</sup>

### **Cutaneous radiation syndrome**

The concept of cutaneous radiation syndrome (CRS) was introduced in recent years to describe the complex pathological syndrome that results from acute radiation exposure to the [skin](#).<sup>[3]</sup>

Acute radiation syndrome (ARS) usually will be accompanied by some skin damage. It is also possible to receive a damaging dose to the skin without symptoms of ARS, especially with acute exposures to beta radiation or X-rays. Sometimes this occurs when radioactive materials contaminate skin or clothes.<sup>[3]</sup>

When the [basal cell](#) layer of the skin is damaged by radiation, [inflammation](#), [erythema](#), and dry or moist [desquamation](#) can occur. Also, [hair follicles](#) may be damaged, causing [hair loss](#). Within a few hours after irradiation, a transient and inconsistent erythema (associated with [itching](#)) can occur. Then, a latent phase may occur and last from a few days up to several weeks, when intense reddening, [blistering](#), and [ulceration](#) of the irradiated site are visible. In most cases, healing occurs by regenerative means; however, very large skin doses can cause permanent hair loss, damaged sebaceous and sweat glands, atrophy, fibrosis, decreased or increased skin pigmentation, and ulceration or [necrosis](#) of the exposed tissue.<sup>[3]</sup>

### **History**

Although radiation was discovered in late 19th century, the dangers of radioactivity and of radiation were not immediately recognized. Acute effects of radiation were first observed in the use of X-rays when the Serbo-American electric engineer [Nikola Tesla](#) intentionally

subjected his fingers to X-rays in 1896. He published his observations concerning the burns that developed, though he attributed them to ozone rather than to X-rays. His injuries healed later.

The genetic effects of radiation, including the effects on cancer risk, were recognized much later. In 1927 [Hermann Joseph Muller](#) published research showing genetic effects, and in 1946 was awarded the [Nobel prize](#) for his findings.

Before the biological effects of radiation were known, many physicians and corporations had begun marketing radioactive substances as [patent medicine](#) and [radioactive quackery](#). Examples were radium [enema](#) treatments, and radium-containing waters to be drunk as tonics. [Marie Curie](#) spoke out against this sort of treatment, warning that the effects of radiation on the human body were not well understood. Curie later died of [aplastic anemia](#) due to radiation poisoning. [Eben Byers](#), a famous American socialite, died in 1932 after consuming large quantities of [radium](#) over several years; his death drew public attention to dangers of radiation. By the 1930s, after a number of cases of bone necrosis and death in enthusiasts, radium-containing medical products had nearly vanished from the market.

Nevertheless, dangers of radiation weren't fully appreciated by scientists until later. In 1945 and 1946, [two U.S. scientists died](#) from acute radiation exposure in separate [criticality accidents](#). In both cases, victims were working with large quantities of fissile materials without any shielding or protection.

[Atomic bombings of Hiroshima and Nagasaki](#) resulted in a large number of incidents of radiation poisoning, allowing for greater insight into its symptoms and dangers.

## DEMON CORE

The **Demon Core** was the nickname given to a 6.2-kilogram (14 lb) [subcritical mass](#) of [plutonium](#) that [accidentally](#) went [critical](#) on two separate instances at the [Los Alamos laboratory](#), in 1945 and 1946. Each incident resulted in the acute [radiation poisoning](#) and subsequent death of a scientist. After these incidents, the core was referred to as the Demon Core.

### Harry Daghlian

On August 21, 1945, the plutonium core produced a burst of neutron radiation that irradiated [Harry Daghlian](#), a physicist who made a mistake while working alone doing neutron reflection experiments on the core. The core was placed within a stack of neutron-reflective bricks, and the addition of each brick moved the assembly closer to criticality. Daghlian, while attempting to stack another brick around the assembly, accidentally dropped one of the bricks onto the core, thereby making it critical. Despite moving the brick off the assembly quickly, Daghlian received a fatal dose of radiation. He died 28 days later.

### Louis Slotin

On May 21, 1946, physicist [Louis Slotin](#) and other scientists were in a Los Alamos laboratory conducting an experiment that involved creating a [fission reaction](#) by placing two half-spheres of [beryllium](#) (a neutron reflector) around the same plutonium core. Slotin's hand holding a screwdriver separating the hemispheres slipped, the beryllium neutron reflector hemispheres closed, and the core went [supercritical](#), releasing a very high dose of radiation. He quickly pulled the two halves apart, stopping the chain reaction and hence saving the lives of the seven other men in the laboratory. Louis Slotin himself, however, died 9 days later from acute [radiation poisoning](#). The scientist assisting received sufficient radiation dosage to cause serious injuries and some permanent partial disability, while the others in the room suffered no permanent injuries from the accident.

## Fat Man and Little Boy

After six months of intense strategic [fire-bombing of 67 Japanese cities](#) the [Hirohito regime ignored](#) an ultimatum given by the [Potsdam Declaration](#). By [executive order](#) of [President Harry S. Truman](#) the U.S. dropped the [nuclear weapon Little Boy](#) on the city of [Hiroshima](#) on Monday, August 6, 1945,<sup>[1][2]</sup> followed by the detonation of the bomb [Fat Man](#) over [Nagasaki](#) on August 9. These are the only attacks with nuclear weapons in the history of warfare.<sup>[3]</sup>

The bombs killed as many as 140,000 people in Hiroshima and 80,000 in Nagasaki by the end of 1945,<sup>[4]</sup> with roughly half of those deaths occurring on the days of the bombings. Amongst these, 15–20% died from injuries or the combined effects of flash burns, trauma, and [radiation](#) burns, compounded by illness, malnutrition and [radiation sickness](#).<sup>[5]</sup> Since then, more have died from [leukemia](#) (231 observed) and solid [cancers](#) (334 observed) attributed to exposure to radiation released by the bombs.<sup>[6]</sup> In both cities, most of the dead were civilians.<sup>[7][8][9]</sup>

Six days after the detonation over Nagasaki, on August 15, Japan announced its [surrender](#) to the [Allied Powers](#), signing the [Instrument of Surrender](#) on September 2, officially ending the [Pacific War](#) and therefore World War II. [Germany](#) had signed its unavoidable<sup>[2]</sup> [Instrument of Surrender](#) on May 7, ending the [war in Europe](#). The bombings led, in part, to [post-war Japan](#) adopting [Three Non-Nuclear Principles](#), forbidding the nation from nuclear armament

“**Little Boy**” was the [codename](#) of the [atomic bomb](#) dropped on [Hiroshima](#) on August 6, 1945 by the [B-29 Superfortress Enola Gay](#), piloted by [Colonel Paul Tibbets](#) of the [393d Bombardment Squadron, Heavy](#), of the [United States Army Air Forces](#).<sup>[1]</sup> It was the first atomic bomb to be used as a weapon. The second, the “[Fat Man](#)”, was dropped three days later on [Nagasaki](#).<sup>[2]</sup>

The weapon was developed by the [Manhattan Project](#) during [World War II](#). It derived its explosive power from the [nuclear fission](#) of [uranium 235](#). The [Hiroshima bombing](#) was the second artificial [nuclear explosion](#) in history, after the [Trinity test](#), and the first [uranium](#)-based detonation. Approximately 600 milligrams of mass were converted into energy. It exploded with a destructive power equivalent to between 13 and 18 [kilotons of TNT](#) (54 and 75 TJ) (estimates vary) and killed approximately 140,000 people.<sup>[3]</sup> Its design was not tested in advance, unlike the more complex plutonium bomb (Fat Man). The available supply of enriched uranium was very small at that time, and it was felt that the simple design of a uranium “gun” type bomb was so sure to work that there was no need to test it at full scale. (Small-scale experiments were used to determine the [critical mass](#) and other properties).

“**Fat Man**” is the [codename](#) for the [atomic bomb](#) that was detonated over [Nagasaki, Japan](#), by the [United States](#) on August 9, 1945, at 11:02 (JSP). It was the second of the only two nuclear weapons to be used in [warfare](#) and was the third man-made nuclear explosion. The name also refers more generically to the early [nuclear weapon designs](#) of U.S. weapons based on the “Fat Man” model. It was an [implosion-type](#) weapon with a [plutonium](#) core, similar to [the Trinity device](#) tested only a month earlier in New Mexico.<sup>[1]</sup>

*Fat Man* was possibly named after [Winston Churchill](#),<sup>[2]</sup> though [Robert Serber](#) said in his memoirs that as the “Fat Man” bomb was round and fat, he named it after [Sydney Greenstreet](#)'s character of “Kasper Gutman” in [The Maltese Falcon](#). The design of “Fat Man” nuclear assembly was substantially the same as “[the gadget](#)” detonated at the [Trinity test](#) in July 1945.

“Fat Man” was detonated at an altitude of about 1,800 feet (550 m) over the city, and was dropped from a [B-29](#) bomber [Bockscar](#), piloted by Major [Charles Sweeney](#) of the [393d](#)

[Bombardment Squadron, Heavy](#). The bomb had a yield of about 21 kilotons of TNT or 88 terajoules.<sup>[3]</sup> Because of Nagasaki's hilly terrain, the damage was somewhat less extensive than that in relatively flat [Hiroshima](#). An estimated 39,000 people were killed outright by the bombing at Nagasaki, and a further 25,000 were injured.<sup>[4]</sup> Thousands more died later from related blast and burn injuries, and hundreds more from [radiation illnesses](#) from exposure to the bomb's initial radiation. The aerial bombing raid on [Nagasaki](#) had the third highest fatality rate in [World War II](#)<sup>[5]</sup> after the [nuclear strike on Hiroshima](#)<sup>[6][7][8][9]</sup> and the [March 9/10 1945 fire bombing raid on Tokyo](#).

### **Acute Radiation Syndrome: A Fact Sheet for Physicians**

Acute Radiation Syndrome (ARS) (sometimes known as radiation toxicity or radiation sickness) is an acute illness caused by irradiation of the entire body (or most of the body) by a high dose of penetrating radiation in a very short period of time (usually a matter of minutes). The major cause of this syndrome is depletion of immature parenchymal stem cells in specific tissues. Examples of people who suffered from ARS are the survivors of the Hiroshima and Nagasaki atomic bombs, the firefighters that first responded after the Chernobyl Nuclear Power Plant event in 1986, and some unintentional exposures to sterilization irradiators.

#### **The required conditions for Acute Radiation Syndrome (ARS) are:**

- **The radiation dose must be large** (i.e., greater than 0.7 Gray (Gy)<sup>1,2</sup> or 70 rads).
  - Mild symptoms may be observed with doses as low as 0.3 Gy or 30 rads.
- **The dose usually must be external** ( i.e., the source of radiation is outside of the patient's body).
  - Radioactive materials deposited inside the body have produced some ARS effects only in extremely rare cases.
- **The radiation must be penetrating** (i.e., able to reach the internal organs).
  - High energy X-rays, gamma rays, and neutrons are penetrating radiations.
- **The entire body** (or a significant portion of it) must have received the dose<sup>3</sup>.
  - Most radiation injuries are local, frequently involving the hands, and these local injuries seldom cause classical signs of ARS.
- **The dose must have been delivered in a short time** (usually a matter of minutes).
  - Fractionated doses are often used in radiation therapy. These are large total doses delivered in small daily amounts over a period of time. Fractionated doses are less effective at inducing ARS than a single dose of the same magnitude.

#### **The three classic ARS Syndromes are:**

- **Bone marrow syndrome** (sometimes referred to as hematopoietic syndrome) the full syndrome will usually occur with a dose between 0.7 and 10 Gy (70 – 1000 rads) though mild symptoms may occur as low as 0.3 Gy or 30 rads<sup>4</sup>.
  - The survival rate of patients with this syndrome decreases with increasing dose. The primary cause of death is the destruction of the bone marrow, resulting in infection and hemorrhage.
- **Gastrointestinal (GI) syndrome:** the full syndrome will usually occur with a dose greater than approximately 10 Gy (1000 rads) although some symptoms may occur as low as 6 Gy or 600 rads.

- Survival is extremely unlikely with this syndrome. Destructive and irreparable changes in the GI tract and bone marrow usually cause infection, dehydration, and electrolyte imbalance. Death usually occurs within 2 weeks.
- **Cardiovascular (CV)/ Central Nervous System (CNS) syndrome:** the full syndrome will usually occur with a dose greater than approximately 50 Gy (5000 rads) although some symptoms may occur as low as 20 Gy or 2000 rads.
  - Death occurs within 3 days. Death likely is due to collapse of the circulatory system as well as increased pressure in the confining cranial vault as the result of increased fluid content caused by edema, vasculitis, and meningitis.

**The four stages of ARS are:**

- **Prodromal stage (N-V-D stage):** The classic symptoms for this stage are nausea, vomiting, as well as anorexia and possibly diarrhea (depending on dose), which occur from minutes to days following exposure. The symptoms may last (episodically) for minutes up to several days.
- **Latent stage:** In this stage, the patient looks and feels generally healthy for a few hours or even up to a few weeks.
- **Manifest illness stage:** In this stage the symptoms depend on the specific syndrome (see [Table 1](#)) and last from hours up to several months.
- **Recovery or death:** Most patients who do not recover will die within several months of exposure. The recovery process lasts from several weeks up to two years.

**Table 1: Acute Radiation Syndromes**

| Syndrome  | Dose*  | Prodromal Stage   | Latent Stage   | Manifest Illness Stage  | Recovery   |
|---|--|---|--|---|--|
| Hematopoietic (Bone Marrow)                       | > 0.7 Gy (> 70 rads)<br><i>(mild symptoms may occur as low as 0.3 Gy or 30 rads)</i> | <ul style="list-style-type: none"> <li>• Symptoms are anorexia, nausea and vomiting.</li> <li>• Onset occurs 1 hour to 2 days after exposure.</li> <li>• Stage lasts for minutes to days.</li> </ul>  | <ul style="list-style-type: none"> <li>• Stem cells in bone marrow are dying, although patient may appear and feel well.</li> <li>• Stage lasts 1 to 6 weeks.</li> </ul>                               | <ul style="list-style-type: none"> <li>• Symptoms are anorexia, fever, and malaise.</li> <li>• Drop in all blood cell counts occurs for several weeks.</li> <li>• Primary cause of death is infection and hemorrhage.</li> <li>• Survival decreases with increasing dose.</li> <li>• Most deaths occur within a few months after exposure.</li> </ul> | <ul style="list-style-type: none"> <li>• in most cases, bone marrow cells will begin to repopulate the marrow.</li> <li>• There should be full recovery for a large percentage of individuals from a few weeks up to two years after exposure.</li> <li>• death may occur in some individuals at 1.2 Gy (120 rads).</li> <li>• the LD50/60<sup>†</sup> is about 2.5 to 5 Gy (250 to 500 rads)</li> </ul> |
| Gastrointestinal (GI)                             | > 10 Gy (> 1000 rads)<br><i>(some symptoms may occur as low as 6 Gy or 600 rads)</i> | <ul style="list-style-type: none"> <li>• Symptoms are anorexia, severe nausea, vomiting, cramps, and diarrhea.</li> <li>• Onset occurs within a few hours after exposure.</li> <li>• Stage lasts about 2 days.</li> </ul>   | <ul style="list-style-type: none"> <li>• Stem cells in bone marrow and cells lining GI tract are dying, although patient may appear and feel well.</li> <li>• Stage lasts less than 1 week.</li> </ul> | <ul style="list-style-type: none"> <li>• Symptoms are malaise, anorexia, severe diarrhea, fever, dehydration, and electrolyte imbalance.</li> <li>• Death is due to infection, dehydration, and electrolyte imbalance.</li> <li>• Death occurs within 2 weeks of exposure.</li> </ul>   | <ul style="list-style-type: none"> <li>• the LD100<sup>‡</sup> is about 10 Gy (1000 rads)</li> </ul>   |
| Cardiovascular (CV)/ Central Nervous System (CNS) | > 50 Gy (5000 rads)<br><i>(some symptoms may occur as low as 20 Gy or 2000 rads)</i> | <ul style="list-style-type: none"> <li>• Symptoms are extreme nervousness and confusion; severe nausea, vomiting, and watery diarrhea; loss of consciousness; and burning sensations of the skin.</li> <li>• Onset occurs within minutes of exposure.</li> <li>• Stage lasts for minutes to hours.</li> </ul> | <ul style="list-style-type: none"> <li>• Patient may return to partial functionality.</li> <li>• Stage may last for hours but often is less.</li> </ul>  | <ul style="list-style-type: none"> <li>• Symptoms are return of watery diarrhea, convulsions, and coma.</li> <li>• Onset occurs 5 to 6 hours after exposure.</li> <li>• Death occurs within 3 days of exposure.</li> </ul>  | <ul style="list-style-type: none"> <li>• No recovery is expected.</li> </ul>   |

\* The absorbed doses quoted here are “gamma equivalent” values. Neutrons or protons generally produce the same effects as gamma, beta, or X-rays but at lower doses. If the patient has been exposed to neutrons or protons, consult radiation experts on how to interpret the dose.

† The LD50/60 is the dose necessary to kill 50% of the exposed population in 60 days.

‡ The LD100 is the dose necessary to kill 100% of the exposed population

## **Cutaneous Radiation Syndrome (CRS)**

The concept of cutaneous radiation syndrome (CRS) was introduced in recent years to describe the complex pathological syndrome that results from acute radiation exposure to the skin.

ARS usually will be accompanied by some skin damage. It is also possible to receive a damaging dose to the skin without symptoms of ARS, especially with acute exposures to beta radiation or X-rays. Sometimes this occurs when radioactive materials contaminate a patient's skin or clothes.

When the basal cell layer of the skin is damaged by radiation, inflammation, erythema, and dry or moist desquamation can occur. Also, hair follicles may be damaged, causing epilation. Within a few hours after irradiation, a transient and inconsistent erythema (associated with itching) can occur. Then, a latent phase may occur and last from a few days up to several weeks, when intense reddening, blistering, and ulceration of the irradiated site are visible.

In most cases, healing occurs by regenerative means; however, very large skin doses can cause permanent hair loss, damaged sebaceous and sweat glands, atrophy, fibrosis, decreased or increased skin pigmentation, and ulceration or necrosis of the exposed tissue.

## **Patient Management**

**Triage:** If radiation exposure is suspected:

- Secure ABCs (airway, breathing, circulation) and physiologic monitoring (blood pressure, blood gases, electrolyte and urine output) as appropriate.
- Treat major trauma, burns and respiratory injury if evident.
- In addition to the blood samples required to address the trauma, obtain blood samples for CBC (complete blood count), with attention to lymphocyte count, and HLA (human leukocyte antigen) typing prior to any initial transfusion and at periodic intervals following transfusion.
- Treat contamination as needed.
- If exposure occurred within 8 to 12 hours, repeat CBC, with attention to lymphocyte count, 2 or 3 more times (approximately every 2 to 3 hours) to assess lymphocyte depletion.

## **Diagnosis**

The diagnosis of ARS can be difficult to make because ARS causes no unique disease. Also, depending on the dose, the prodromal stage may not occur for hours or days after exposure, or the patient may already be in the latent stage by the time they receive treatment, in which case the patient may appear and feel well when first assessed.

If a patient received more than 0.05 Gy (5 rads) and three or four CBCs are taken within 8 to 12 hours of the exposure, a quick estimate of the dose can be made (see [Ricks, et. al.](#) for details). If these initial blood counts are not taken, the dose can still be estimated by using CBC results over the first few days. It would be best to have radiation dosimetrists conduct the dose assessment, if possible.

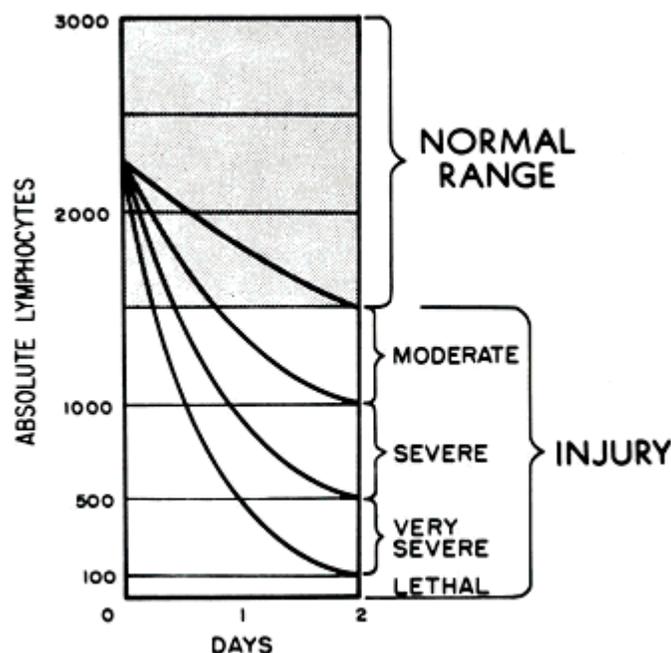
If a patient is known to have been or suspected of having been exposed to a large radiation dose, draw blood for CBC analysis with special attention to the lymphocyte count, every 2 to 3 hours during the first 8 hours after exposure (and every 4 to 6 hours for the next 2 days). Observe the patient during this time for symptoms and consult with radiation experts before ruling out ARS.

If no radiation exposure is initially suspected, you may consider ARS in the differential diagnosis if a history exists of nausea and vomiting that is unexplained by other causes. Other indications are bleeding, epilation, or white blood count (WBC) and platelet counts abnormally low a few days or weeks after unexplained nausea and vomiting. Again, consider CBC and chromosome analysis and consultation with radiation experts to confirm diagnosis.

### Initial Treatment and Diagnostic Evaluation

Treat vomiting<sup>5</sup>, and repeat CBC analysis, with special attention to the lymphocyte count, every 2 to 3 hours for the first 8 to 12 hours following exposure (and every 4 to 6 hours for the following 2 or 3 days). Sequential changes in absolute lymphocyte counts over time are demonstrated below in the Andrews Lymphocyte Nomogram (see Figure 1). Precisely record all clinical symptoms, particularly nausea, vomiting, diarrhea, and itching, reddening or blistering of the skin. Be sure to include time of onset.

Figure 1: Andrews Lymphocyte Nomogram



From Andrews GA, Auxier JA, Lushbaugh CC. *The Importance of Dosimetry to the Medical Management of Persons Exposed to High Levels of Radiation*. In *Personal Dosimetry for Radiation Accidents*. Vienna : International Atomic Energy Agency; 1965.

Note and record areas of erythema. If possible, take color photographs of suspected radiation skin damage. Consider tissue, blood typing, and initiating viral prophylaxis. Promptly consult with radiation, hematology, and radiotherapy experts about dosimetry, prognosis, and treatment options. Call the Radiation Emergency Assistance Center/Training Site (REAC/TS) at (865) 576-3131 (M-F, 8 am to 4:30 am EST) or (865) 576-1005 (after hours) to record the incident in the Radiation Accident Registry System.

After consultation, begin the following (as indicated):

- supportive care in a clean environment (if available, the use of a burn unit may be quite effective)
- prevention and treatment of infections
- stimulation of hematopoiesis by use of growth factors
- stem cell transfusions or platelet transfusions (if platelet count is too low)
- psychological support
- careful observation for erythema (document locations), hair loss, skin injury, mucositis, parotitis, weight loss, or fever
- confirmation of initial dose estimate using chromosome aberration cytogenetic bioassay when possible. Although resource intensive, this is the best method of dose assessment following acute exposures.
- consultation with experts in radiation accident management

### **For More Help**

Technical assistance can be obtained from the Radiation Emergency Assistance Center/Training Site (REAC/TS) at (865) 576-3131 (M-F, 8 am to 4:30 pm EST) or (865) 576-1005 (after hours), or on their web site at <http://www.orau.gov/reacts/>, and the Medical Radiobiology Advisory Team (MRAT) at (301) 295-0316.

Also, more information can be obtained from the CDC Health Alert Network at [emergency.cdc.gov](http://emergency.cdc.gov) or by calling (800) 311-3435.

### **References**

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1. The Gray (Gy) is a unit of absorbed dose and reflects an amount of energy deposited into a mass of tissue (1 Gy = 100 rads). In this document, the referenced absorbed dose is that dose inside the patient's body (i.e., the dose that is normally measured with personal dosimeters).
  2. The referenced absorbed dose levels in this document are assumed to be from beta, gamma, or x radiation. Neutron or proton radiation produces many of the health effects described herein at lower absorbed dose levels.
  3. The dose may not be uniform, but a large portion of the body must have received more than 0.7 Gy (70 rads).
  4. Note: although the dose ranges provided in this document apply to most healthy adult members of the public, a great deal of variability of radiosensitivity among individuals exists, depending upon the age and condition of health of the individual at the time of exposure. Children and infants are especially sensitive.
  5. Collect vomitus in the first few days for later analysis.