Sequelae of Chronic Radiation Exposure

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Abstract

Chronic radiation syndrome is based upon victims who were exposed to radiation for at least 3 years and who had received at least 100 rem or more to the marrow. The report reconfirms the International Commission on Radiological Protection (ICRP) recommendation that the maximum value of the dose constraint to be used in the optimization of radiological protection for a single source should be less than 1 mSv in a year, and that a value of no more than about 0.3 mSv in a year would be appropriate. Chronic exposure of radiation, who developed chronic radiation sickness, leukopenia, thrombocytopenia and inhibition of non-specific immunity factors, slight increase in nodule prevalence and thyroid antibody-positive subjects, increased frequency of chromosomal aberrations (both stable and unstable types) and CD3 – CD4+ mutant T-lymphocytes in the peripheral blood. Studies show that radioactivity from nuclear plants is getting into the environment and human body, and there is now strong evidence that it is hurting the health of Americans. There is now substantial evidence that exposure to radioactive releases from nuclear reactors is a significant causal factor of increasing childhood cancer rates and of other adverse health effects. *(Ann Disaster Med. 2003;2 Suppl 1:S27-S37)*

Key words: Chronic Exposure; Radiation; Disaster

Introduction

The signs and symptoms of chronic radiation poisoning, or chronic radiation syndrome, are based upon victims who were exposed to radiation for at least 3 years and who had received at least 100 rem or more to the marrow.[1] Chronic radiation syndrome is likely to be seen in people living within the radioactive fallout zone and who are continuously exposed to residual low dose radiation in their surroundings. Such victims may complain of headaches, vertigo, sleep disturbances, chills, epistaxis, poor appetite, generalized weakness with rapid fatigue, bone pain, hot flashes, increased excitability, loss of concentration, impaired memory, mood changes, ataxia, paresthesias, and syncopal episodes. Physical clinical findings may include tachycardia, mild hypotension, localized bone or muscle tenderness, intention tremor, ataxia, asthenia, and hyperreflexia, or sometimes hyporeflexia. Children who exposed in chronic radiation may be under developed secondary sexual characteristics and delayed menarche. Lab findings include mild to marked

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leukopenia, thrombocytopenia and bone dysplasia. Gastric hypoacidity and dystrophic changes may be present. If patient is removed from the radiation environment, the clinical symptoms and findings will be slowly resolve, and complete recovery has occurred from the lower doses.

Members of the public persistently and adventitiously result in prolonged exposures that are occasional to situations in which they may find themselves. The average annual dose associated with prolonged exposures is more or less constant or decreases slowly over the years. Typical prolonged exposures are those delivered by the so-called 'natural' sources such as cosmic radiation and original radio nuclide decay chains. Some 'artificial' sources may also deliver prolonged exposures; for example, long-lived radioactive residues from human activities are a common cause of prolonged exposure. It is to be noted that some radioactive residues may contain both natural and artificial radio nuclides. In situations of prolonged exposures, it may be difficult to separate the exposure attributed to the artificial component from that due to the natural component; likewise, protective measures against the artificial component can affect the exposure due to the natural component and vice versa.[1]

The report reconfirms the International Commission on Radiological Protection (ICRP) recommendation that the maximum value of the dose constraint to be used in the optimization of radiological protection for a single source should be less than 1 mSv in a year, and that a value of no more than about 0.3 mSv in a year would be appropriate.[2] It also stresses that consideration should be given to exposure situations where combinations of transient and prolonged exposures or a buildup over time of prolonged exposures from a source could occur. In these situations the report recommends verifying that appropriate dose assessment methods are used for ensuring compliance with the established dose constraint. The assessment should take account of any reasonably thinkable combination and buildup of exposures. In a special situation, such verification of compliance is not practical, the report considers it judicious to restrict the prolonged component of the individual dose from the source with a dose constraint of the order of 0.1 mSv in any given year during the operational lifetime of the source. Dose Limits: In relation to dose limits, the report also reconfirms the ICRP recommendation that the sum of the prolonged and transitory exposures from all regulated practices should be restricted to a dose limit of 1 mSv in a year. It also emphasizes that the national authorities concerned and, as appropriate, relevant international organizations should consider situations where there could be a buildup of the prolonged components of the exposures attributable to all regulated practices as a result of the accumulation of radioactive residues from continuing practices. The aim should be to prevent that the aggregated individual additional annual doses attributable to all current practices and to predictable future practices exceed the dose limit of 1 mSv in a year.

The recommendations in the ICRP report are based on objective assessments of the health risks associated with prolonged exposure levels and on radiological protection attributes of various exposure situations.[2] However, the radiation risks attributable to artificial sources of prolonged exposure in relation to those due to natural sources, the mem-

bers of the public may have personal and difference views on this. This depending on the origin of the exposure, and usually results in differently perceived needs for response and a different scale of protection. The reqiure for protection is generally stronger when the source of exposure is a technological by-product rather than when it is considered to be of natural origin. Society usually ignored that typically elevated prolonged exposures due to natural radiation sources, while relatively minor prolonged exposures to artificial long-lived radioactive residues are a cause of concern and sometimes prompt unnecessary actions. This actuality of social and political attributes, usually unrelated to radiological protection, mainly influences the final decision on the level of protection against prolonged exposure. Therefore, the ICRP report cautiously recognizes that it should be seen as a provider of decision-aiding recommendations usually based on scientific considerations on radiological protection, the outcome of its advice will be expected to serve as an input to a final decision-making process which may include other societal concerns and considerations. The decision-making process for the radiological protection of the public in situations of prolonged exposure may include the participation of relevant stakeholders rather than radiological protection specialists alone.

The Role of Strontium-90

In 1957 an explosion occurred at the depot of radioactive waste in the Southern Urals. An area of 23,000 km^2 was contaminated, with contamination density of over 1 Ci/m^2 for Strontium-90. The zone was named the East-Urals Radiation Trace (EURT). The population about 270,000 persons distribute in total 217 populated areas. The residents of 22 villages with contamination density of over 4 Ci/km^2 for Strontium-90 were evacuated. The times of evacuation differed from 7 to 670 days since the accident, depending on the level of contamination.

In 1988-1993 an individualized registry was created at the Urals Research Center for Radiation Medicine (URCRM), which included information on the residents of 22 evacuated villages and a proportion of unevacuated residents of the EURT area. Currently, the registry contains data on 30,000 residents. Of that number approximately 17,000 persons were born before, and 12,000 after the accident, it including about 9,000 offspring of exposed residents evacuated from the EURT, and about 3,000 persons who were born after the accident and have been living permanently in the EURT area.

According to the data first published by Romanov[8] the residents have received, over the 35-year period since the accident, mean effective doses ranging from 23 to 530 mSv. The mean effective doses received by permanent residents range from 5 to 60 mSv.

The first initiatory analysis of late radiation effects among the population exposed in the Southern Urals in 1957 was guided in 1989-1991 based on data from the individualized population registry. In accordance with the results obtained, no statistically significant increase in cancer mortality was registered in those dose groups, neither did the study trace any increase in congenital malformations and the proportion of childless marriages.[3-5] Those groups with mean effective doses for groups 1-4 being 40, 58, 120, 496 mSv . The analysis used mean-for-village doses calculated based on levels of contamination densities for Strontium-90 sug-

gested by Romanov.[6] Rural residents of the Chelyabinsk oblast included a control group. It is because of high suspicion of the results attributable to a wide variety of mortality values for certain years and different age groups, and the interpretation of the study results as hormesis by some authors,[7] there was a pressing need to continue collection of additional information and perform a repeat analysis of data at a next stage of the study. Over the period that had run out since the first publications the data underwent the following changes: doses received by the population were revised by G.N. Romanov[8] due to which accumulated dose estimates increased up to 950 mSv for some of the exposed people; more suitable control groups were sampled which allowed to take into account the ethnic identity; the information in the data base was updated and enhanced.

Mayak is the first nuclear weapons plutonium production enterprise built in Russia and includes nuclear reactors, a radiochemical plant for plutonium separation, and a plutonium production plant. Shilnikova's study is based on a registry containing medical and dosimetric data of the employees who began working at different plants of the Mayak nuclear complex who developed chronic radiation sickness.[9] Workers whose employment began between 1948 and 1958 exhibited a 6-28% incidence of chronic radiation sickness at the different facilities. There were no cases of chronic radiation sickness among those who began working after 1958. Data on doses of external whole-body gamma-irradiation and mortality in workers with chronic radiation sickness are presented.

A result of clinical observations and laboratory investigations performed for individuals exposed to chronic radiation due to discharges of about 3 million Ci of radioactive waste from the Mayak Industrial Association into the river Techa in 1949–1956 by Akleyev.[10] The population of the villages was exposed to a combined external gamma radiation and internal radiation, mainly due to Strontium-90. Under the nature of the exposure, critical organ for the exposed residents is there red bone marrow. During the first 2–4 years after the onset of chronic exposure, the peripheral blood were manifested changes by leukopenia, neutropenia, thrombocytopenia and inhibition of non-specific immunity factors, at equivalent dose rates to red bone marrow of 300–500 mSv per year, and higher. In the 1950s 940 residents with highest exposure doses were diagnosed with chronic radiation sickness. The status of hemopoiesis and immunity is normal among most of the exposed subjects after the beginning of exposure about 43–48 years later. However, the peripheral blood of the exposed persons are still show an increased frequency of chromosomal aberrations and CD3 – CD4+ mutant T-lymphocytes.

The Problem Concerning Strontium-90 and Human Health in Taiwan

In Taiwan, chronic radiation has been proved to be an effective immunity from cancers in an unusual "experiment" carried out by; 10000 inhabitants who lived in about 1700 houses unknowingly contaminated with 60Co for 10 to 15 yr. These houses were constructed from 1982 through 1984 and found contaminated since July 1992.[11] Based on the experience of the contaminated houses, the following conclusions can be deduced: 1. All chronic radiation received in nuclear power plants and all peaceful

uses of nuclear energy may also be beneficial to human beings. All the radiation protection policies, standards, and measures based on International Commission on Radiological Protection theory and recommendations should be properly modified. In addition, nuclear workers and the general public should be told to stop worrying about the risks of low-level radiation. 2. Chronic radiation from proper doses from proper sources should be considered to be an effective source of immunity from cancers. New knowledge about radiation effects might be this: Acute, high-dose radiation from nuclear explosions or accidents is harmful and the higher the dose, the higher the harmful effects; however, it has a threshold value of ~200 to 500 mSv and might be beneficial with doses below that threshold. Chronic radiation from nuclear power plants and other peaceful uses might be a constant benefit to human beings. Luckey's investigations of many cases with lower doses, at ~5 cSv, showed that cancer mortality was reduced to ~59.5%.[12] A threshold value for chronic radiation may be determined from the population with high doses in the Techa River area in Russia. It could be ten times higher than for acute radiation. It would be very unlikely for human beings to ever again receive such high doses.

Other Related Investigations

During 2001 and 2002, the Radiation and Public Health Project, Inc. (RPHP) carried out a South Florida baby teeth study and an initial study of radiation levels in the teeth of children without cancer ("healthy teeth") and of children diagnosed with cancer ("cancer teeth").[13] The major findings of this study are: 1. From 1986-89 to 1994-97, there was a 37% rise in the average levels of radioactive Strontium-90 in southeast Florida baby teeth. This rise reverses a long-term downward trend in Strontium-90 levels that has occurred since the mid-1960s, beginning after the atmospheric testing of nuclear weapons was banned. 2. This temporal trend of increasing levels of radioactive Strontium-90 was found in 485 Florida teeth tested, 95% of which came from six southeast Florida counties (Miami-Dade, Broward, Palm Beach, Martin, St. Lucie and Indian River). 3. When compared with baby teeth collected from other Florida counties, the highest levels of Strontium-90 were found in the counties closest to the Turkey Point and St. Lucie nuclear power plants. 4. The average levels of Strontium-90 found in the 17 cancer teeth were 85% higher than the radiation levels found in the 311 non-cancer teeth collected from children born in the same years and in the same counties. 5. Recent measurements of high energy beta activity, characteristic of Strontium-90 in southeast Florida water samples, indicate that the highest levels occur within 20 miles of the Turkey Point and St. Lucie nuclear power plants, ruling out the fallout from past nuclear tests as the principal source of radiation in Florida drinking water and baby teeth. The major conclusions of this study are: 1. Radiation emissions from nuclear power plants are the predominant cause of rising Strontium-90 levels in southeast Florida baby teeth. 2. Radiation levels are significantly higher in the teeth of children with cancer than in the teeth of children without cancer. 3. There is now substantial evidence that exposure to radioactive releases from nuclear reactors is a significant causal factor of increasing childhood cancer rates and of other adverse health effects in southeast Florida.

A study to determine the thyroidal consequences of the Chernobyl nuclear power station accident in a selected Turkish population.[14] This study was designed as a sectional, area study, between October 2000 and March 2001, in two different regions of Turkey. Although there was a slight increase in nodule prevalence and thyroid antibody-positive subjects in the study group, it is hard to conclude that Turkey was affected by the Chernobyl accident. These results, at least the significant differences with regard to the prevalence of goiters between groups, may reflect the different iodine status of the selected regions.

Strontium-90 is considered to be one of the most hazardous bone-seeking elements created in the fission of uranium or plutonium, because of its long half life of 28 years and because it resembles calcium so closely. By masquerading as calcium needed to form bone and teeth, it is readily taken up and concentrates in bone. In a pregnant woman, the Strontium-90 that has accumulated in the bone, together with that in her diet, is transported with calcium into the rapidly dividing cells of the embryo and fetus, where it can either kill or mutate them by the emission of high-energy electrons or beta particles. When Strontium-90 lodges near the bone marrow, where stem-cells form blood and immune system cells, there is an increased risk of leukemia, many other forms of cancer and autoimmune diseases, especially in newborn infants and elderly adults whose immune system functions are weak.

In early developmental stages of both humans, fish and other wildlife, when cells rapidly reproduce, damage to the genes is not efficiently repaired, so that if the cell survives and divides a defect is multiplied. Thus cellular damage can lead to a greater risk of leukemia or cancer in the newborn than in the mother, typically by anywhere from ten to a hundred times as great, depending on the stage of development. Moreover, many studies have shown that there is also an increased risk of premature birth, low birth weight and birth defects. The damage, which often does not become apparent until many years later, is known to involve the developing immune, hormonal and central nervous systems. In recent years, it has also been found that such conditions as obesity, diabetes, high blood pressure, heart disease and stroke can be the delayed result of the damage during development in the womb, leading to a higher death rate, particularly for individuals of abnormally low or abnormally high birth weight.

Especially serious is damage to different parts of the developing brain such as the prefrontal cortex, which can result in dyslexia, autism, and reduced cognitive ability. The reason is that neurons communicate by sending out calcium ions, so that Strontium-90 and Strontium-89 can be substituted for calcium, with devastating results due to the enormous energy with which electrons or beta rays are ejected from the nucleus in the course of the radioactive transformation from Strontium-90 to Yttrium-90, destroying neurons in the process.

Part of the reason why Strontium-90 is so damaging is that radioactive Yttrium-90, which has different chemical properties than Strontium-90, concentrates in the hormone producing soft-tissue glandular organs such as the pituitary gland, the pancreas, the thyroid, the male and female reproductive organs, and the female breasts. Thus, key hormones such as estrogen and testosterone can be affected both

during early development and later in life, when they play a major role in breast and prostate cancer, as well as in reduced fertility, premature births, sexual development and sexual orientation.

Another reason is that protracted exposures over periods of days, months or years were discovered to be much more damaging biologically than the same dose received in short diagnostic medical exposures or flashes from a nuclear bomb explosion by factors of hundreds to thousands of times. This is due to the greater efficiency of free-radical oxygen molecules in puncturing cell-membranes, when they are produced one-by one and do not become deactivated by colliding with each other in the dense cluster produced during short X-ray or gamma ray exposures. Thus, chronic exposures to Strontium-90 can produce cancer, immune system and respiratory damage such as asthma at very low doses. Moreover, it has been found in laboratory studies that Yttrium-90 also concentrates in the lung, so that the ingestion of Strontium-90 can cause lung cancer.

In addition to the Strontium-90 dose to the human body or organ, Strontium-90 is also an indicator of, or marker for, other radiation doses received from the many shorter-lived fission products that are produced together with Strontium-90 and released from nuclear reactors both in liquid and airborne effluents that do not rise high into the atmosphere. Elements such as Iodine-131, with an 8 day half-life and others with even shorter half-lives, can produce many times the radiation dose of Strontium-90, just as occurred during the early period of A-bomb testing in Nevada when the fallout came down in a matter of hours.

Minimizing adverse health effects of emissions from nuclear power reactors is an important element in any effective strategy to prevent disease and death. Studies show that radioactivity from nuclear plants is getting into the environment and human body, and there is now strong evidence that it is hurting the health of Americans, especially the health of the children on which the future of our nation depends.

Because of the need to minimize risk and prevent disease, Radiation and Public Health Project (RPHP) has initiated a national study of Strontium-90 in baby teeth, with the goal of collecting and testing several thousand teeth and correlating radioactivity levels found in these teeth with cancer risk. A study of in-body radioactivity levels in persons living near nuclear reactors is the most effective means of studying whether radioactivity emitted from nuclear reactors is affecting cancer levels in the U.S. To date, there have been no such studies by the U.S. government, state health departments, nuclear utilities, or other private researchers of the relationship between in-body levels of radiation and public health around nuclear reactors.

After reviewing the initial findings of the Baby Teeth Study in 1999, Dr. Sidel, past president of the American Public Health Association, and Dr. Geiger, past president of Physicians for Social Responsibility, stated: "If the levels of Strontium-90 in children's teeth and the variations in levels by geographic area reported in this study are validated by appropriate repetition, these findings would appear to justify intensive follow-up and continuing large-scale surveillance. Given the biological risk associated with body burdens of even small amounts of long-lived radioactive Strontium-90, it would be prudent to regard these findings as suggestive of a potential threat to human

health."

Southeast Florida typifies the recent rise of Strontium-90 levels in the nation, and has above average rates of childhood cancer, especially within thirty miles of its nuclear plants. There is now significant evidence that children diagnosed with cancer have higher Strontium-90 levels in their bodies than children without cancer. This is consistent with the discovery by Dr. Alice Stewart that very low doses from a few diagnostic X-rays of the mother during pregnancy lead to an excess risk of childhood leukemia and cancer.

It therefore appears that the combined data patterns of the highest beta activity in water samples near the Turkey Point and St. Lucie nuclear plants, of rising Strontium-90 in the deciduous teeth, and of increasing cancer incidence make an extremely strong case that the rising Strontium-90 found in the teeth of children born in the late 1980s and early 1990s cannot be due to the atmospheric tests that ended in 1980, or the venting of all underground bomb tests that ended in 1993.

Furthermore, it appears that recent rises in the childhood cancer incidence in Florida and the rest of the U.S. are causally related to internal exposures to radioactive fission products. The adverse health effects related to cancer and all diseases related to the human immune system and hormonal system have been underestimated by factors of hundreds to thousands of times, as recently concluded by the European Committee on Radiation Risk.[15]

Since the levels of Strontium-90 in the teeth have kept rising throughout the 1990s from their lowest values in the early 1980s long after the end of all atmospheric tests in 1980 and more than five years after the arrival of the Chernobyl fallout in 1986, it is no longer possible to regard Chernobyl or atmospheric bomb tests as significant sources of Strontium-90. Even the known venting from underground nuclear bomb testing in Nevada ended in 1992, and in China by 1993, making it impossible to regard the very high levels of Strontium-90 in both teeth with cancer and without cancer, found for children born in the late 1990s, as due to underground tests.

Taken together with the fact discussed in the present report that the highest levels of Strontium-90 beta activity in drinking water were found nearest to the location of the two nuclear plants in southeast Florida, there can no longer be any reasonable doubt that nuclear reactors are now the major source of fission products in the environment.

Thus, it appears that a significant cause, or contributing cause, of the two decade long rise in childhood cancer (including leukemia, brain cancer, and other cancers) since the early 1980s are the bone-seeking nuclear fission products such as Strontium-90, which are presently only released into the environment by commercial nuclear reactors in the United States, both in the course of accidents and during routine operations within presently permitted limits.

The finding that children diagnosed with cancer have higher Strontium-90 concentrations in their teeth at birth than children without cancer points to environmental radiation from nuclear reactors as the principal cause of the mysterious cluster of brain and other cancers diagnosed among infants and children in St. Lucie County. This cancer cluster was documented by the Florida Department of Health (FDOH) in 1997 and subsequently studied by both state and federal health researchers, who

eliminated chemical carcinogens as a possible cause of the increasing incidence of childhood cancers in St. Lucie County. During 1997-1999, the Department of Health conducted a comprehensive study of 561 chemicals known or suspected carcinogens and concluded that "based on comparisons to state and federal standards and toxicological publications, none of these chemicals represents a health threat or is associated with neuroblastoma or other childhood cancers."

But the FDOH study did not include a study of nuclear fission products in environmental samples or in the deciduous teeth of children, such as Strontium-90, that are chemically similar to calcium and seek out bone, irradiating the bone marrow where the red cells of the blood and the white cells of the immune system originate. Particularly serious is the damage to the immune and hormonal system as well as to the developing brain in the sensitive embryo, fetus and infant, often acting synergistically with other environmental toxins as Rachel Carson warned forty years ago in Silent Spring (1962).

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慢性暴露在輻射的後遺症

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摘要

受災者如果曝露在輻射的環境中超過三年，而骨髓接受大於一百 rem 單位的輻射時，會產生慢性輻射併發的症狀，國際輻射保護委員會(ICRP)認為安全的輻射曝露量是一年內不得超過0.3 mSv單位，或一年內單一件事中不得超過1 mSv單位。慢性輻射的曝露者會產生慢性輻射病，例如：白血球減少、血小板減少、抑制非特異性免疫因子、微量增加甲狀線的抗體物質、增加染色體突變和週邊血液T細胞CD3-CD4+的突變體等；在一些研究探討核能發電廠所產生的輻射對於四周環境和人類的影響，認為核能原子爐所釋放的輻射會增加兒童罹患癌症的機率和不良於健康的效應。(*Ann Disaster Med. 2003;2 Suppl 1:S27-S37*)

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