

This chapter is an excerpt from the Book, “Bio-Shield: Antioxidants against Radiological, Chemical and Biological Weapons”, By Kedar N. Prasad, PhD. This book can be purchased from (<http://www.strategicbookpublishing.com/Bio-Shield.html>).

Chapter 13

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Use of Antioxidant Bio-Shields for Radiation Workers, Patients Receiving Diagnostic X-Rays and Frequent Flyers

Introduction

People are exposed to low doses of radiation almost every day of their lives. The use of X-ray-based equipment for the early diagnosis of diseases is growing; therefore, patients require protection against the potential harmful effects of low doses of radiation. Individuals working with radiation equipment, such as radiation workers, also need to be protected from radiation damage. In addition, frequent fliers receive higher doses of radiation than infrequent fliers and therefore require protection. Airline pilots and crews who work eight hours a day are exposed to more radiation than the passengers and need to be protected. I recommend Bio-Shield-R1 and Bio-Shield-R2 for protecting these groups of individuals against the potential harmful effects of low doses of radiation.

Ionizing radiation, such as X-rays, has proved to be a double-edged sword since its discovery in 1895. Radiation is a potent mutagen (meaning it can alter genetic activity) and a carcinogen (a cancer-causing agent); however, it is also used in the diagnosis and treatment of human diseases. Background radiation, or radiation levels in the environment, consists of cosmic radiation and radiation emitted from radioactive substances present in the ground and commercial sources. Thus, all living organisms have been exposed to background radiation since their appearance on Earth.

It is believed that before the advent of atmospheric oxygen, anaerobic organisms, which require no oxygen for survival and growth, were the predominant life forms on Earth. These organisms

must have exhibited resistance to background radiation with respect to mutations, because as we now know, oxygen increases the radio-sensitivity of all organisms that require oxygen for survival and growth. A lack of oxygen may have reduced the level of radiation-induced mutation rate in anaerobic organisms and, thus, may have slowed down the rate of evolution. The appearance of oxygen some 4.5 billion years ago allowed for the appearance of aerobic organisms that used oxygen for their survival and growth. This usage of oxygen generated toxic chemical species and free radicals as byproducts. The interaction of radiation with oxygen may have caused an increase in the production of free radicals, and this biological phenomenon— together with direct ionization—probably accelerated the rate of mutations and functional abnormalities in aerobic organisms and became a driving force behind evolution. In order to cope with these adverse internal and external hostile conditions, the aerobic organisms that had developed antioxidant defense systems to quench excessive levels of free radicals and repair systems survived.

Although humans today are well-equipped with antioxidant systems from dietary and endogenous sources and efficient repair mechanisms, they are constantly exposed to varying levels of background radiation (1-2 mSv), depending on the altitudes where they live. We also receive medical radiation exposure of varying levels (up to 100 mSv)—generally about 20 mSv or less for diagnostic purposes. The use of radiation in medicine has always been rationalized on the basis of risk vs. benefit. Because of the growing use of nuclear energy in the world, especially in developed countries for civilian and military purposes, the concept of benefit vs. risk, which was previously applicable only to patients, was extended to other populations as well: those responsible for providing nuclear energy services for research and patient care, such as radiation workers, and those who are not (the general population). In order to further safeguard against potential radiation damage, the concept of Maximum Permissible Dose (MPD) was developed for these two separate population groups. The annual MPD value for the general population is 1 mSv, whereas it is 50 mSv for radiation workers. To address the growing health concerns of radiation-induced somatic and heritable mutations among radiation workers and patients who receive radiation for diagnostic purposes, the concept of ALARA (as low as

reasonably achievable) with respect to dose was recommended by state, federal and international radiation protection agencies.

At present, in addition to hospital-based standard diagnostic radiation equipment (such as X-ray machines, CT scans, PET scans and nuclear medicine procedures), new ionizing radiation-based diagnostic centers for heart scans, virtual colonoscopies and whole-body scans are opening across the U.S. Individuals at younger ages are exposed to very low doses of radiation for the early diagnosis of diseases, which may help to develop effective prevention and treatment strategies. However, if no strategy for biological protection against such damage is developed and implemented, low doses of ionizing radiation may also increase the levels of genetic defects in present and future generations. Radiation exposure during space voyages is also expected to increase health risks, including cancer, in astronauts after they return to earth. During space flight, astronauts are primarily exposed proton-radiation and heavy particles-radiation (HZE particles). Therefore, the success of long space voyages depends upon how well our astronauts are protected against radiation damage. Frequent fliers, flight crews on commercial jets and Air Force personnel flying at high altitudes are also exposed to low doses of ionizing radiation. Currently, there is no effective strategy for reducing the potential risk of low doses of radiation in humans.

Potential health risks of low doses of ionizing radiation in humans: Radiation scientists have been debating the health risks of low doses of radiation in humans for decades. This is evidenced by the fact that six BEIR (Biological Effects of Ionizing Radiation) reports have extensively analyzed in vitro (studies on cells growing in dishes), animal and human studies on somatic and heritable mutations, the incidence of cancer and birth defects following radiation exposure. Heritable mutations are of particular concern, especially among women, because the number of oocytes (eggs) is fixed at birth, and mutations, if not repaired, are cumulative and can increase the health risks of future generations. All radiation biologists and geneticists agree that no dose of ionizing radiation can be considered completely safe, and that the use of radiation must always be determined on the basis of risk vs. benefit. It has been reported that space radiation doses as little as 5cGy (50 mSv) enhances the level of oxidative stress in human cell lines and rats. Health risks include not only cancer, but also somatic mutations that may contribute to other illnesses (including birth defects and eye defects) and heritable mutations that may increase the risk of

diseases in future generations. Women who had diagnostic chest X-rays for tuberculosis or pneumonia had more than twice the normal risk of breast cancer.

Several studies on humans who were previously exposed to low doses of radiation have been published. These studies have so many confounding factors that it is not possible to determine cancer risk by radiation alone in humans. These confounding factors include environmental, dietary, and lifestyle-related factors that contain mutagens, carcinogens and tumor promoters as well as cancer-protective substances and cellular repair systems that may vary from one individual to another. Other confounding factors include: (a) the interaction of radiation with other physical (UV light), chemical and biological mutagens and carcinogens in a synergistic manner, and (b) the variation in sensitivity of individuals to radiation. It should be remembered that humans are simultaneously exposed to a variety of mutagens, carcinogens and tumor promoters, as well as cancer-protective agents, in addition to ionizing radiation. Therefore, low dose radiation-induced cancer risk in humans depends upon several variables, and most of these confounding factors cannot be corrected for in any studies that utilize individuals previously exposed to radiation. This may explain why the results of such human studies are not always consistent.

Effects of interaction of ionizing radiation with other environmental agents: Radiation-induced cancer in humans depends upon several factors. These include interaction with several chemical carcinogens and tumor promoters and anti-carcinogenic and anti-tumor-promoting agents. The efficacy of repair mechanisms also influences the risk of cancer. For example, X-radiation enhances chemical carcinogen-induced cancer by about 9-fold and UV-induced cancer by about 12-fold. X-irradiation also enhances the level of ozone- and viral-induced cancer by 2-fold to threefold in laboratory experiments. Radiation doses alone that do not induce cancer do so when combined with a tumor promoter such as estrogen. Ionizing radiation in combination with tobacco smoking increases the risk of lung cancer by about 50 percent. A low dose of radiation, such as 2 cGy (20 mSv), does not produce detectable levels of mutations as measured by chromosomal damage; however, in the presence of caffeine (which inhibits repair of DNA damage), mutations become detectable. It is important to point out that lower doses (about 1 mSv) of radiation do not activate some types of repair mechanisms. This lack of repair can lead to an accumulation of mutations that can increase the risk of chronic diseases. At the same time,

dietary and endogenously made antioxidants are known to protect tissues against radiation damage. These studies suggest that the health risks of low doses of radiation cannot be ignored.

Cancer risk in children of women exposed to low doses of radiation before and after conception: In recent debates, the issues of radiation damage to children of women who have been exposed to diagnostic doses of radiation before and after conception have been ignored. Since the number of oocytes, or eggs, is fixed at birth, radiation damage to eggs, some of the most radiosensitive cells, may be cumulative and therefore may be very crucial for inducing heritable genetic damage. It has been reported that an increase in cancer risk is directly proportional to the number of X-ray films or fetus doses received. It was estimated that 1 cGy (10 mSv) delivered to the fetus shortly before birth would cause an increase of 300-800 deaths per million before the age of 10 years due to cancer. A significant increase in malignancy has been found even after 2.0-2.5 mSv to human fetuses (relative incidence of cancer = 1.25). One of the most surprising results published showed an increased cancer risk by a factor of 1.6-2.0 among the children of women who received diagnostic doses of radiation before conception. Another study reported that diagnostic doses of 0.5-7 cGy (5-70 mSv) to the ovaries before conception induced 10 times more mentally retarded children in radiation-exposed women compared to unexposed women. Exposing reproductive organs with a dose of 5 cGy (50 mSv) increased eye defects, and 3 cGy (30 mSv) increased the mutation rate by 1 percent. While these studies have some problems with respect to the many variables humans are exposed to during their lifetime, they should not be ignored. In my opinion, the health risks of low doses of radiation exist in humans.

Radiation-induced noncancerous diseases: The incidence of noncancerous diseases was studied in children living in radiation-contaminated areas near the Chernobyl nuclear accident site. The incidence of thyroid gland enlargement and vision disorders, mostly dry eye syndrome, was closely related to the levels of radiation. These children have increased levels of markers of damage produced by free radicals.

Radiation protection by physical factors: Efforts to protect normal tissues were started soon after Dr. Hermann J. Muller of Columbia University observed in 1927 that radiation causes gene mutations in *Drosophila melanogaster* (the common fruit fly). The concept of radiation protection, the primary purpose of which was to reduce the dose of radiation to normal tissues as

much as possible, was developed. This concept involved three physical principles: 1) shielding (usually by lead) of unexposed areas, especially radiosensitive organs such as bone marrow, gonads and thyroid; 2) increased distance between the radiation source and radiation workers or patients; and 3) reduction of exposure time. Each of these factors has been very useful, but they do have limitations. For example, during diagnostic procedures such as fluoroscopy, it may not be possible to protect the gastrointestinal tract (one of the most radiosensitive organs) against radiation damage by lead shielding. Increasing the distance between the radiation source and recipients may not be practical for many radiation workers, patients, civilians, or military personnel. Reducing exposure time may also not be pertinent to all populations except those that are involved in taking care of patients who have received gamma-emitting radioisotopes for medical purposes or who are responsible for radioactive decontamination as a result of accidents or attack. Nevertheless, radiation protection based on physical factors has served a useful purpose and has been successful in reducing the level of unnecessary medical exposure to patients and to radiation workers. In order to protect normal tissues from potential radiation damage, it would be important to identify biological or chemical agents that, when given before radiation exposure, could protect all normal tissues. Such radioprotective agents would help to extend the concept of ALARA, which focuses on radiation dose reduction to reduce biological damage.

Radiation protection by Bio-Shields: The search for nontoxic radioprotective agents that can protect against radiation damage began soon after World War II. Extensive radiation protection studies yielded numerous agents that, when given before radiation exposure, protected animals (primarily rodents) against radiation injuries. From these studies it became clear that agents that scavenge free radicals and/or cause hypoxia (a reduced oxygen level) are of radioprotective value. Unfortunately, most of these compounds at radioprotective doses were toxic to humans. With the decreased risk of nuclear confrontation experienced during the Cold War and later, interest in the study of radioprotective agents markedly decreased. However, due to a rapid growth of X-ray-based diagnostic equipment and increased use of radiological procedures in the early diagnosis of disease, concerns are being raised about a potential increase in somatic and heritable mutations that can increase the risk of gene-linked diseases in present and future generations. Therefore, it has become imperative that tissues be protected against potential radiation damage no matter how small that damage might be.

Radiation protection studies have identified several radioprotective compounds that are nontoxic to humans. These include vitamins E, C and beta-carotene and mineral selenium, but very little attention has been given to these compounds with respect to their use in biological protection against radiation damage in humans. Compounds such as N-acetylcysteine (NAC) and alpha-lipoic acid, which are rapidly absorbed and that elevate glutathione levels within the cells, are of radioprotective value and are nontoxic to humans. Therefore, I have developed Bio-Shield-R1 and Bio-Shield-R2 containing multiple antioxidants that are nontoxic and cost-effective, and that can provide significant protection against low doses of radiation damage. Laboratory and human studies that support the validity of a bio-shield are discussed in Chapter 10.

Bio-Shield- R1 for patients receiving diagnostic x-rays and frequent flyers: Doses received by some commonly used diagnostic procedures, and dose limits for the public and radiation workers are listed in Tables 1 and 2. The number of people around the world—especially in the U.S.—undergoing CT (computed tomography) scans is increasing at a rapid rate, because of its potential value in the early diagnosis of various diseases such as cancer and heart disease. The number of CT scans performed in the U.S. has increased from 3 million in 1980 to at least 67 million in 2006, an increase of about 22 times. The early diagnosis of these diseases has led to early treatments that have saved or prolonged thousands of lives. Some radiation doctors, however, have expressed concerns about CT scans being overused and that radiation received from these exposures may induce an increased risk of cancer in the population. Others have argued that the benefits of CT scans clearly outweigh the risks of radiation damage. For example, exploratory surgery that was common 10 to 15 years ago is no longer done; all the risks associated with the surgery have disappeared because of the CT scan. Consequently, the average level of medical radiation exposure has increased 600-fold since 1980. At present, about half of the medical radiation exposure to the U.S. population is from CT scans. It has been estimated that CT scans may induce about 6,000-24,000 extra incidences of cancer in the U.S. population.

Some scientists suggest that X-ray screening for breast cancer is being overused, especially in younger women, and that it can increase the risk of breast cancer in that population. Others argue that the benefits outweigh the risks.

When debating the pros and cons of using CT scans, breast screenings, or any other diagnostic procedure involving X-rays, both sides admit the potential long-term health risks of low doses of

radiation. It is unfortunate, however, that they do not discuss how to protect against radiation damage no matter how small that might be. Most radiologists believe that telling patients about the risk of radiation may alarm them, causing some to shy away from the diagnostic procedures. Some also fear lawsuits and financial loss. Knowing, however, that about two-thirds of radiation damage is caused by free radicals, it's easy to devise a nontoxic strategy that would remove free radicals generated during and after radiation exposure. Bio-Shield-R1, which contains multiple dietary and endogenous antioxidants, fulfills this need. I recommend the use of Bio-Shield-R1 as described below.

One dose orally 30 to 60 minutes before chest X-rays, dental X-rays, abdominal X-rays, CT scans, breast cancer screening, fluoroscopy and other diagnostic procedures or a commercial flight, and one dose one to two hours later.

Nuclear medicine procedures involve the use of radioactive substances that can remain in the body for a few hours to a few days. Therefore, one dose should be used orally 30-60 minutes before these procedures, followed by one dose one to two hours after the procedure. After that, it should be taken twice a day (one dose in the morning and one dose in the evening) for five to seven days.

Air craft pilots and crews and frequent flyers: Pilots, air crews and frequent flyers on aircrafts flying at high altitudes are exposed to cosmic radiation at higher levels than those individuals residing on the ground level. Cosmic radiation is also a form of ionizing radiation and it consists primary particles (protons, electrons, alpha particles and other heavy ions) and secondary particles (neutrons). Cosmic radiation contributes to about 13 percent of natural background radiation level which about 1 mSv per year. In contrast to radiation workers in nuclear industry or patients receiving diagnostic procedures who primarily receive x-rays or gamma-rays, the air crews, pilots, and frequent flyers receive radiation doses in which about 50 percent is from neutron radiation. Neutron radiation is more damaging than x-rays or gamma-rays.

The dose rate in the aircraft flying at high altitude is about 0.005 mSv/ hour. A frequent flyer travelling around 100 hours per year would receive an addition dose of 0.5mSv, whereas the pilots and air crews flying 1000 hours per year can receive 5 mSV. Flying at 37,000 feet for 4.1 hours can deliver a radiation dose of about 1 chest x-rays.

The health risks for pilots, air crews, and frequent flyers are being debated. A Canadian study with 2,2740 Air Canada Pilots showed an increased risk of prostate cancer, acute myeloid leukemia, and a slight increased risk of melanoma, brain cancer as well as all types of leukemia. British Airways survey of 411 pilots revealed a slight increase in the risk of melanoma, brain tumor and colon cancer. Another study with Danish crews revealed increased risk of cancer. Among female crews working for more than 15 years, an increase risk of breast cancer was reported.

American regulators believe that any harmful effect of cosmic radiation would be minor. The European Commission has issued directives that require all European airlines to start measuring radiation doses on each flight.

At present there are no biological protection strategies to reduce the risk of potential harmful effects of cosmic radiation in pilots, air crews, or frequent flyers. An oral consumption of Bio-Shield-R2 daily would reduce the potential harmful effects of cosmic radiation in pilots and air crews. An oral consumption of Bio-Shield-R1 30-60 min before departure and a few hours after arrival would reduce the potential harmful effects of cosmic radiation in frequent flyers.

Bio-Shield- R2 for radiation workers: Radiation workers who work eight hours a day, five days a week are exposed to higher levels of radiation than those who do not work with radiation equipment. These individuals should take one dose in the morning and another in the evening for their entire lifetime.

The use of high-tech X-ray-based machines is very important for the early diagnosis of diseases, although overuse should be avoided. In my opinion, instead of arguing about the pros and cons of using X-ray-based equipment for early diagnosis, radiologists should consider providing patients with Bio-Shield-R1 pills in order to reduce the damage no matter how small that might be. I am sure patients would appreciate the fact that their doctors are so concerned about their well-being. It is not comforting for patients to hear from their doctors that although there may be a very small risk of radiation damage, they should not worry about it.

Radiation workers are also aware of the risk of radiation damage, but they are told by the radiologists that they shouldn't worry about it. Therefore, they take no steps that can offer biological protection from low doses of radiation except for lead shielding.

Main conclusions

1. An oral administration of Bio-Shield-R1 30-60 minutes before and after diagnostic x-rays or nuclear medicine procedures may reduce the long-term potential adverse health effects of low doses of radiation in patients.
2. An oral administration of Bio-Shield-R2 daily twice a day may reduce the long-term potential adverse health effects of low doses of radiation in radiation workers.
3. An oral administration of Bio-Shield-R1 30-60 minutes before and after flight may reduce the long-term potential adverse health effects of low doses of radiation in frequent flyers.

Table 1

Estimated doses of ionizing radiation delivered once during various diagnostic procedures

| Procedure type | Effective dose (mSv) |
|---------------------------------------|----------------------|
| Chest or dental X-ray | 0.01 |
| Electron-beam CT (cardiac) | 1.0-1.3 |
| Electron-beam CT coronary angiography | 1.5-2.0 |
| Catheter coronary angiography | 2.1-2.5 |
| Electron-beam CT whole body | 5.2 |
| CT (head) | 2.0 |
| CT (abdomen) | 10.0 |
| Barium enema | 7.0 |
| Upper G.I. exam. | 3.0 |
| I.V. urogram | 2.5 |
| Lumbar spine | 1.3 |
| Mammogram | 7.0 |
| Passenger from Athens to New York | 0.06 |
| Occupational annual dose limit | 50.0 |
| General public annual dose limit | 1.0 |
| Background annual dose at sea level | 1.0 |

Occupational and general public radiation dose limits do not include background radiation.

Table 2

Estimated doses of radiation from radioactive nuclides administered once during nuclear medicine procedures

| Procedure type | Effective dose (mSv) |
|--------------------------------|----------------------|
| 18F-Fluorodeoxyglucose, 10 mCi | 4.8 |
| 99mTc-MAA lung scan, 5 mCi | 0.60 |
| 99mTc-HDP bone scan, 20 mCi | 4.0 |
| 201Tl Thallium scan, 3 mCi | 0.60 |
