Ionizing Radiation & Pregnancy

Possible Health Risks to Children of Women Who Are Exposed to Radiation During Pregnancy

Pregnancy is a time to be aware of hazards in your surrounding environment and in your life that could affect your unborn child. For those of you who work in or visit areas designated for the use of radioactive materials, it is desirable that you understand the biological risks of radiation to your unborn child.

Everyone is exposed daily to various kinds of radiation; heat, light, ultraviolet, microwave, ionizing, etc. For the purpose of this guide, only ionizing radiation such as x and gamma rays, neutrons, alpha particles, and beta particles (electrons) are considered.

<table>
<thead>
<tr>
<th>Source</th>
<th>Source Description</th>
<th>Type of Exposure; Tissue Exposed</th>
<th>Effective Dose Rate mrem/year*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrestrial</td>
<td>Inhaled Radionuclides (primarily radon-222 and daughter products)</td>
<td>Internal; bronchial epithelium</td>
<td>200</td>
</tr>
<tr>
<td>Cosmic</td>
<td>Ingested Radionuclides (primarily K-40)</td>
<td>Internal; whole body</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exposure from external terrestrial radionuclides</td>
<td>External; (Cosmic Rays) whole body</td>
<td>40</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>Approximately 300</td>
</tr>
</tbody>
</table>

* Adapted from the National Council Radiological Protection (NCRP) Report No. 94.

In addition to exposure from normal background radiation, certain medical procedures may contribute to the dose an individual receives. The following table lists the average doses received by the bone marrow (blood forming cells) from different medical applications involving x-rays:

<table>
<thead>
<tr>
<th>X-ray Procedure</th>
<th>Average Radiation Dose Per View*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal chest examination</td>
<td>20 millirem (0.2 mSv)</td>
</tr>
<tr>
<td>Normal dental examination</td>
<td>20 millirem (0.2 mSv)</td>
</tr>
<tr>
<td>Rib cage examination</td>
<td>140 millirem (1.4 mSv)</td>
</tr>
<tr>
<td>Gall bladder examination</td>
<td>170 millirem (1.7 mSv)</td>
</tr>
<tr>
<td>Barium enema examination</td>
<td>500 millirem (5.0 mSv)</td>
</tr>
<tr>
<td>Pelvic examination</td>
<td>600 millirem (6.0 mSv)</td>
</tr>
</tbody>
</table>

*Variations by a factor of 2 either above or below are not unusual.

Nuclear Regulatory Commission Position (NRC)

NRC regulations and guidance are based on the conservative assumption that any amount of radiation, no
matter how small, can have harmful effect on an adult, child, or unborn child. These conservative guidelines and regulations are used even though there is no data showing ill effects from small radiation doses. The National Academy of Sciences has expressed "uncertainty as to whether a dose of, say, 1000 millirem (10 mSv) would have any effect at all." Although it is known that the unborn child is more sensitive to radiation than adults, particularly during certain stages of development, the NRC has established a special fetal dose limit of 500 millirem during the gestation period (50 mrem per month) for declared pregnant (radiation) workers. Additionally, the NRC has taken the position that special protection of the unborn child should be based on decisions made by the workers and employers who are well informed about the risks involved.

For the NRC position to be effective, it is important that both the employee and employer understand the risk to the unborn child from radiation received as a result of the occupational exposure of the mother. This document tries to explain the risk and to compare it with other, more familiar, risks to the unborn child during pregnancy. Hopefully, this will help pregnant employees evaluate the risk to the unborn child against the benefits of employment. This document also discusses methods of keeping the radiation dose, and therefore the risk to the unborn child As Low As Reasonably Achievable (ALARA).

**Radiation Exposure Limits**

The NRC and State of California limit on the occupational radiation exposure that can be received is 5000 millirem (50 mSv) per year. The UC Davis Radiation Dose Guideline is one-half of the federal and state limit.

Since 1906, it has been known that rapidly dividing, undifferentiated cells are more sensitive to radiation. The embryo/fetus is composed of cells that meet these criteria and are more sensitive to radiation.

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1. In conformity with 10 CFR, Part 20, the term "embryo/fetus" is used throughout this document to represent all stages of pregnancy. The definitions are taken from Stedmans Medical Dictionary, 21st Edition, The Williams and Wilkins Company, Baltimore MD and reads as follows:

- **Embryo**: An organism in the early stages of development; in man, from conception until approximately the end of the second month. Developmental stages from this time to birth are commonly designated as fetal.
- **Fetus**: The unborn young of a viviparous animal after it has taken form in the uterus; in man, the product of conception from the end of the eighth week to the moment of birth.
- **Undifferentiated Cells**: Those cells in early development that have no progressed to a mature and specialized state, such as muscle or nerve cells

**Advice for Employee and Supervisor**

Although the risks to the unborn child are small under normal working conditions, the employee and supervisor should work together to decide the best method for minimizing exposure. Some methods include reducing the time spent in the radiation areas, providing personal (abdominal) shielding, and maximizing the distance from radiation sources. **The decision of when to declare pregnancy in the workplace is up to the employee. When the decision is made to declare, the employee should inform their supervisor and the campus/medical center Radiation Safety Officer.** The supervisor may be able to estimate the probable exposure to the unborn child during the normal nine-month pregnancy period and inform the employee of the amount. The campus/medical center Radiation Safety Officer will provide a workplace exposure estimate and may provide radiation dosimetry in order to measure and document (medical record) any radiation exposure that may occur during the pregnancy.
Internal Hazards

This document has been directed primarily toward a discussion of radiation exposures received from external sources. Workers must also be aware of the risk of radioactive material entering the body. General precautions used in the laboratories to reduce the probability of absorption, ingestion and inhalation are as follows:

1. Do not smoke, eat, drink, or apply skin care products in the laboratories.
2. Do not pipette solutions by mouth.
3. Use disposable gloves when handling radioactive materials.
4. Wash hands after working around radioactive materials.
5. Wear lab coats and other protective clothing whenever working with radioactive materials.

Remember that the P.I. is required to have an approved safety protocol for each experiment. Workers are urged to follow established procedures and consult the radiation safety officer whenever problems or questions arise.

X-rays and Pregnancy (Pregnant X-ray Technologists)

When a technologist becomes aware of the pregnancy, she should declare her pregnancy to her supervisor and the campus/medical center Radiation Safety Officer as soon as possible. Both the supervisor and the radiation safety officer will review her previous radiation exposure history, in order to decide what additional protective actions may be necessary. Upon declaration of the pregnancy, the pregnant x-ray technologist becomes known as a "declared pregnant worker" and the federal and state radiation dose limit of 500 millirem during the gestation period (50 millirem per month) becomes effective. The declared pregnant worker can "undeclare" pregnancy at any time, thus, returning to the annual radiation dose limit of 5000 millirem (whole body).

Although some technologists may exceed 1000 millirem per year (10 mSv/year), most receive less than 500 millirem (5 mSv) per year, as indicated with the personnel monitoring device (dosimeter) positioned at the collar above the protective lead apron. The exposure at the waist under the protective apron will not normally exceed 10% of these radiation doses.

There are several ways to protect the fetus with minimum interference to clinical activity. In a large clinical setting where many technologists are assigned, a declared pregnant worker might be removed from fluoroscopy, special procedures, and portable work; activities that have been shown to result in the bulk of the radiation exposure that a technologist receives.

In a small clinical setting, a reassignment of the declared pregnant technologist may not be possible. In this case, efforts should be made to provide adequate protective apparel. Currently, all lead aprons at UC Davis are required to be at least 0.5 mm lead equivalent. These provide approximately 88% attenuation at 75 kVp and that is sufficient. One millimeter (1 mm) lead equivalent protective aprons are available, but such thickness is not necessary, particularly in view of the additional weight that must be burdened. Back problems during pregnancy constitute a greater hazard than the radiation exposure. The length of the apron need not extend to the knees or below. If necessary, a special effort should be made to provide an apron of proper size because of its weight.
After these protective measures have been instituted, it is reasonable to **provide the declared pregnant worker with a second personnel monitoring device (dosimeter)** at waist level and under the protective apron when such an apron is worn. Both the inside and outside of the apron dosimeters will be used to calculate the whole body dose to the declared pregnant worker and the radiation dose to the fetus.

Use of an additional dosimeter has consistently shown that exposures to the fetus are insignificant. Suppose, for instance, that the declared pregnant worker wearing a single radiation dosimeter at collar level outside of the lead apron receives 1000 millirem during the nine month pregnancy. The dose at waist level under a protective apron would be approximately 5% of the collar radiation dose, or 50 millirem. Because of attenuation by the maternal tissues overlying the fetus, the dose to the fetus would be approximately 30% of the abdominal skin dose, or 15 millirem. Consequently, when adequate protective measures are taken, it is nearly impossible for the declared pregnant worker to even approach the fetal exposure limit of 500 millirem.

When pregnancy is declared, regardless of the nature of the x-ray facility or the technologist’s work experience, the supervisor should review acceptable practices of radiation protection. This review should emphasize the cardinal principles of radiation protection; minimize time, maximize distance, and use available shielding.

**Effects on the Embryo/Fetus Due to Radiation Exposure and Other Environmental Hazards**

In order to decide whether to continue working with ionizing radiation during pregnancy, a woman should understand and compare the potential effects on an embryo/fetus from other environmental risks such as smoking and drinking. The results of exposure of the embryo/fetus to the risk factors and the dependence on the amount of the exposure are explained below and summarized in Table 1.

The following section discusses the studies that information in Table 1 was derived. The results of exposure of the embryo/fetus to the risk factors and the dependence on the amount of the exposure are explained:

**RADIATION RISKS**

1. **Childhood Cancer**

   Numerous studies of childhood cancer have been performed but a number of them are controversial. The National Academy of Sciences, Biological Effects of Ionizing Radiation (NAS BEIR V) report reevaluated the data from these studies and reanalyzed the results. Some of the strongest support for a causal relationship is provided by twin data from the Oxford survey. For maternal radiation exposures of 1,000 millirems (10 mSv), the excess number of deaths (above those occurring from natural causes) was found to be 0.2 deaths per million children.

2. **Mental Retardation and Abnormal Smallness of the Head (Microcephaly)**

   Studies of Japanese children who were exposed while in the womb to the atomic bomb radiation at Hiroshima and Nagasaki have shown evidence of both small head size and mental retardation. Most of the children were exposed to radiation doses in the range of 1,000 to 50,000 millirems. The importance of the most recent study lies in the fact that investigators were able to show that the gestational age (i.e., age of the embryo/fetus after conception) at the time the children were exposed was a critical factor. The highest risk of small head size as a function of age is shown in Table 1. Similarly, the highest risk of mental retardation occurred during the 8-15 week period after conception. For a radiation dose of 1000 millirems (10 mSv) at 4-7 weeks after conception, the excess cases of small head...
size was 5 per thousand; at 8-11 weeks, it was 9 per thousand.

A EPA study\textsuperscript{6} calculated that the number of excess cases of mental retardation per live birth ranges between 0.5 and 4 per thousand per 1000 millirem.

Radiation induce genetic effects have not been seen to date in humans. The largest source of material for genetic studies involves the survivors of Hiroshima and Nagasaki but the 77,000 births that occurred among the survivors provided no evidence of genetic effects.\textsuperscript{7} For radiation doses received by the pregnant worker in the course of employment considered in this guide, the dose received by the embryo/fetus would have a small effect on its descendants.\textsuperscript{7}

3. Genetic Effects

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NON-RADIATION RISKS

1. Occupation

A study\textsuperscript{8} involving the birth records of 130,000 children in the State of Washington indicates that the risk of death to the unborn child is related to the occupation of the mother. Workers in the metal industry, chemical industry, medical technology, wood industry, textile industry, and farm workers exhibited stillbirths or spontaneous abortions at a rate of 90 per thousand above that of workers in the control group that consisted of workers in several other industries.

2. Alcohol

It has been recognized that alcohol consumption has an effect on the unborn child. Carthaginian law forbade the consumption of wine on the wedding night so that a defective child might not be conceived. Recent studies have indicated that small amounts of alcohol consumption have only the minor effect of reducing the birth weight slightly, but when consumption increases to 2-4 drinks per day, a pattern of abnormalities called the Fetal-Alcohol-Syndrome (FAS) begins to show\textsuperscript{9}. The syndrome consists of: reduced growth in the unborn child, faulty brain functions, and abnormal facial features. The natural occurrence of full FAS in the U.S. is about 1-2 cases per thousand, but for mothers who consume 2-4 drinks per day, the excess occurrences number about 100 per thousand. For those who consume more than 4 drinks per day, excess occurrences number 200 per thousand. The most sensitive period for this effect appears to be the first few weeks of conception, before the mother-to-be realizes she is pregnant\textsuperscript{10,11,12}. Also, 17% or 170 per thousand of the embryo/fetuses of chronic alcoholics develop FAS and die before birth.

3. Smoking

Smoking during pregnancy causes reduced birth weights in babies amounting to 5 to 9 ounces on the average. In addition, there is an increased risk of 5 infant deaths per thousand for mothers who smoke less than one pack per day and 10 infant deaths per thousand for mothers who smoke one or more packs per day\textsuperscript{13,14}.

4. Miscellaneous

Numerous other risks affect the embryo/fetus, only a few of which are touched upon here. Most people are familiar with the drug thalidomide (a sedative given to some pregnant women) that causes children to be born with missing limbs, and the more recent use of the drug diethylstilbestrol (DES), a synthetic estrogen given to some women to treat menstrual disorders that produce vaginal cancers in the daughters born to women who took the drug. Living at high altitudes also gives rise to an increase in
the number of low birth weight children born, while an increase in Down's Syndrome (mongolism) occurs in children born to mothers who are over 35 years of age and the rapid growth in the use of ultrasound in recent years has sparked an ongoing investigation into the risks of high frequency sound waves for diagnostic procedures.

Table 1 provides information on the potential effects resulting from exposure of an embryo/fetus to radiation and non-radiation risks. The third column gives the rate that the effect is produced by natural causes in terms of the number per thousand births. The fourth column gives the number of additional effects per thousand births believed to be produced by exposure to the specified amount of the risk factor.

Table 1. Effects of Risk Factors on Pregnancy Outcome

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Effect (reference)</th>
<th>Number Occurring Excess from Natural Cause</th>
<th>Occupations Due to Risk Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I. RADIATION RISK</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Childhood Cancer</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Radiation dose of 1000 millirem (10 mSv) received before birth</td>
<td>Cancer death</td>
<td>200 per thousand</td>
<td>0.2 per thousand</td>
</tr>
<tr>
<td>Abnormalities</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Radiation dose of 1000 millirem (10 mSv) received during the specific periods after conception</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>4-7 weeks</td>
<td>Small head size</td>
<td>40 per thousand</td>
<td>5 per thousand</td>
</tr>
<tr>
<td>8-11 weeks</td>
<td>Small head size</td>
<td>40 per thousand</td>
<td>9 per thousand</td>
</tr>
<tr>
<td>Radiation dose of 1000 millirem (10 mSv) received during the following period after conception</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>8-15 weeks</td>
<td>Mental Retardation</td>
<td>4 per thousand</td>
<td>4 per thousand</td>
</tr>
<tr>
<td><strong>II. NON-RADIATION RISK</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupation</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Work in high risk occupations (see text)</td>
<td>Stillbirth or spontaneous abortion</td>
<td>200 per thousand</td>
<td>90 per thousand</td>
</tr>
<tr>
<td>Alcohol Consumption</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Radiation dose of 1000 millirem (10 mSv) received during the specific periods after conception</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>2-4 drinks per day</td>
<td>Fetal Alcohol Syndrome</td>
<td>1-2 per thousand</td>
<td>100 per thousand</td>
</tr>
<tr>
<td>More than 4 drinks per day</td>
<td>Fetal Alcohol Syndrome</td>
<td>1-2 per thousand</td>
<td>200 per thousand</td>
</tr>
<tr>
<td>More than 10 drinks per day</td>
<td>Fetal Alcohol Syndrome</td>
<td>1-2 per thousand</td>
<td>350 per thousand</td>
</tr>
<tr>
<td>More than 10 drinks per day</td>
<td>Perinatal Infant Death</td>
<td>1-2 per thousand</td>
<td>170 per thousand</td>
</tr>
<tr>
<td>Smoking</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Less than 1 pack a day</td>
<td>Perinatal Infant Death</td>
<td>23 per thousand</td>
<td>5 per thousand</td>
</tr>
<tr>
<td>More than 1 pack a day</td>
<td>Perinatal Infant Death</td>
<td>23 per thousand</td>
<td>10 per thousand</td>
</tr>
</tbody>
</table>

References


Contact

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