



FACT SHEET

Prenatal Radiation Exposure: A Fact Sheet for Physicians

Most radiation exposure events will not expose the fetus to levels likely to cause health effects. This is true for radiation exposure from most diagnostic medical exams as well as from occupational radiation exposures that fall within regulatory limits. However, instances may arise where an expectant mother and her physician should have some concern. This brochure provides physicians with background information about prenatal radiation exposure as an aid in counseling these patients.

Because the human embryo or fetus is protected in the uterus, a radiation dose to a fetus tends to be lower than the dose to its mother for most radiation exposure events. However, the human embryo and fetus are particularly sensitive to ionizing radiation, and the health consequences of exposure can be severe, even at radiation doses too low to immediately affect the mother. Such consequences can include growth retardation, malformations, impaired brain function, and cancer.

Estimating the Radiation Dose to the Embryo or Fetus

Because fetal sensitivity to radiation exposure depends largely on the radiation dose to the fetus, the dose needs to be estimated before potential health effects can be assessed.

Estimating the radiation dose to the fetus requires consideration of all sources external and internal to the mother's body. For this document, the fetal radiation dose from sources external to the mother's body can be estimated by determining the dose to the mother's abdomen. Estimating the dose from sources internal to the mother's body is more complex.

If a pregnant woman ingests or inhales a radioactive substance that subsequently is absorbed in her bloodstream (or enters her bloodstream through a contaminated wound), the radioactive substance may pass through the placenta to the fetus. Even though for some substances the placenta acts as a barrier to the fetal blood, most substances that reach the mother's blood can be detected in the fetus' blood, with concentrations that depend on the specific substance and the stage of fetal development. A few substances needed for fetal growth and development (such as iodine) can concentrate more in the fetus than in corresponding maternal tissue. In addition, radioactive substances that may concentrate in the maternal tissues surrounding the uterus including the mother's urinary bladder can irradiate the fetus. For substances that can localize in specific organs and tissues in the fetus, such as iodine-131 or iodine-123 in the thyroid, iron-59 in the liver, gallium-67 in the spleen, and strontium-90 and yttrium-90 in the skeleton, consideration of the dose to specific fetal organs may be prudent.

Physicians should consult with experts in radiation dosimetry about fetal dose estimation.

Hospital medical physicists and health physicists are good resources for expertise in radiation dose estimation. The National Council on Radiation Protection and Measurements (NCRP) Report No. 128, "Radionuclide Exposure of the Embryo/Fetus," provides detailed information for assessing fetal doses from internal uptakes. Fetal dose estimations from medical exposures to pregnant women can be found in "Publication 84: Pregnancy and Medical Radiation" from the International Commission on Radiological Protection (ICRP). In addition, the Conference of Radiation Control Program Directors, Inc. (CRCPD) maintains a list of state Radiation Control/Radiation Protection contact information at www.crcpd.org/map/map.asp and the Health Physics Society (HPS) maintains a list of active certified

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Health Physicists at www.hps1.org/aahp/members/members.htm. Physicians should contact these organizations for assistance in estimating fetal radiation dose.

Once the fetal radiation dose is estimated, the potential health effects can be assessed. The possible effects associated with prenatal radiation exposure include immediate effects (such as fetal death or malformations) or increased risk for cancer later in life.

Potential Health Effects of Prenatal Radiation Exposure (Other Than Cancer)

The potential noncancer health risks of concern are summarized in [Table 1](#). This table is intended only to help physicians advise pregnant women who may have been exposed to radiation, not as a definitive recommendation. The indicated doses and times post conception, or gestational age, are approximations.

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Table 1: Potential Health Effects (Other Than Cancer) of Prenatal Radiation Exposure

Acute Radiation Dose* to the Embryo/Fetus	Time Post Conception				
	Blastogenesis (up to 2 wks)	Organogenesis (2–7 wks)	Fetogenesis		
			(8–15 wks)	(16–25 wks)	(26–38 wks)
< 0.05 Gy (5 rads) †	Noncancer health effects NOT detectable				
0.05–0.50 Gy (5–50 rads)	Incidence of failure to implant may increase slightly, but surviving embryos will probably have no significant (noncancer) health effects	<ul style="list-style-type: none"> Incidence of major malformations may increase slightly Growth retardation possible 	<ul style="list-style-type: none"> Growth retardation possible Reduction in IQ possible (up to 15 points, depending on dose) Incidence of severe mental retardation up to 20%, depending on dose 	Noncancer health effects unlikely	
<p>> 0.50 Gy (50 rads)</p> <p><i>The expectant mother may be experiencing acute radiation syndrome in this range, depending on her whole-body dose.</i></p>	Incidence of failure to implant will likely be large ‡, depending on dose, but surviving embryos will probably have no significant (noncancer) health effects	<ul style="list-style-type: none"> Incidence of miscarriage may increase, depending on dose Substantial risk of major malformations such as neurological and motor deficiencies Growth retardation likely 	<ul style="list-style-type: none"> Incidence of miscarriage probably will increase, depending on dose Growth retardation likely Reduction in IQ possible (> 15 points, depending on dose) Incidence of severe mental retardation > 20%, depending on dose Incidence of major malformations will probably increase 	<ul style="list-style-type: none"> Incidence of miscarriage may increase, depending on dose Growth retardation possible, depending on dose Reduction in IQ possible, depending on dose Severe mental retardation possible, depending on dose Incidence of major malformations may increase 	Incidence of miscarriage and neonatal death will probably increase depending on dose §

Note: This table is intended only as a guide. The indicated doses and times post conception are approximations.

*Acute dose: dose delivered in a short time (usually minutes). Fractionated or chronic doses: doses delivered over time. For fractionated or chronic doses the health effects to the fetus may differ from what is depicted here.

†Both the gray (Gy) and the rad are units of absorbed dose and reflect the amount of energy deposited into a mass of tissue (1 Gy = 100 rads). In this document, the absorbed dose is that dose received by the entire fetus (whole-body fetal dose). 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.

‡A fetal dose of 1 Gy (100 rads) will likely kill 50% of the embryos. The dose necessary to kill 100% of human embryos or fetuses before 18 weeks' gestation is about 5 Gy (500 rads).

§For adults, the LD50/60 (the dose necessary to kill 50% of the exposed population in 60 days) is about 3-5 Gy (300-500 rads) and the LD100 (the dose necessary to kill 100% of the exposed population) is around 10 Gy (1000 rads).

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Gestational age and radiation dose are important determinants of potential noncancer health effects. The following points are of particular note:

- **Before about 2 weeks gestation (i.e., the time after conception), the health effect of concern from an exposure of > 0.1 gray (Gy) or 10 rads¹ is the death of the embryo. If the embryo survives, however, radiation-induced noncancer health effects are unlikely, no matter what the radiation dose.** Because the embryo is made up of only a few cells, damage to one cell, the progenitor of many other cells, can cause the death of the embryo, and the blastocyst will fail to implant in the uterus. Embryos that survive, however, will exhibit few congenital abnormalities.
- **In all stages of gestation, radiation-induced noncancer health effects are not detectable for fetal doses below about 0.05 Gy (5 rads).** Most researchers agree that a dose of < 0.05 Gy (5 rads) represents no measurable noncancer risk to the embryo or fetus at any stage of gestation. Research on rodents suggests a small risk may exist for malformations, as well as effects on the central nervous system in the 0.05–0.10 Gy (5–10 rads) range for some stages of gestation. However, a practical threshold for congenital effects in the human embryo or fetus is most likely between 0.10–0.20 Gy (10–20 rads).
- **From about 16 weeks' gestation to birth, radiation-induced noncancer health effects are unlikely below about 0.50 Gy (50 rads).** Although some researchers suggest that a small possibility exists for impaired brain function above 0.10 Gy (10 rads) in the 16- to 25-week stage of gestation, most researchers agree that after about 16 weeks' gestation, the threshold for congenital effects in the human embryo or fetus is approximately 0.50–0.70 Gy (50–70 rads).

The normal rate of failure of a blastocyst to implant in the uterine wall is high, perhaps 30%–50%. After the embryo implants there, however, the miscarriage rate decreases to about 15% for the rest of the pregnancy, and the cells begin differentiating into various stem cells that eventually form all of the organs in the body.

Ionizing radiation can impair the developmental events that occur at exposure. Also, atomic bomb survivor data show a permanent retardation of physical growth with increasing dose, particularly above 1 Gy (100 rads). This retardation of growth is most pronounced when the exposure occurs in the first 13 weeks of gestation. Atomic bomb survivor data suggest about a 3%–4% reduction of height at age 18 when the dose is greater than 1 Gy (100 rads).

Radiation may significantly affect brain development among persons exposed at 8–15 weeks' gestation. Atomic bomb survivor data indicate that, in this stage, the average IQ loss is approximately 25–31 points per Gy (per 100 rads) above 0.1 Gy (10 rads), and the risk for severe mental retardation² is approximately 40% per Gy (per 100 rads), above 0.1 Gy (10 rads).

¹ Both the gray (Gy) and the rad are units of absorbed dose and reflect the amount of energy deposited into a mass of tissue (1 Gy = 100 rads). In this document, the absorbed dose is that dose received by the entire fetus (whole-body fetal dose). 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.

² For studies of the atomic bomb victims, severe mental retardation was related not to IQ, but to clinical observation: "unable to perform simple calculations, to make simple conversation, to care for himself or herself, or if he or she was completely unmanageable or had been institutionalized" (Schull, 1995). This corresponds to an IQ less than 50 (0.4% prevalence in the unexposed population).

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The central nervous system is less sensitive in the 16- to 25-week stage of gestation. However, the same effects seen in the 8- to 15-week stage also may occur at this time at higher doses. In the 16- to 25-week stage the average IQ loss is approximately 13–21 points per Gy (per 100 rads) at doses above 0.7 Gy (70 rads), and the risk for severe mental retardation is approximately 9% per Gy (per 100 rads) above 0.7 Gy (70 rads). Also, if internal uptake of radioactive iodine occurs in this stage, the long-term health consequences to the thyroid of the offspring should be considered. The fetal thyroid is very active in this stage, and if the mother ingests or inhales radioactive iodine, it will concentrate in the fetal thyroid as well as in the mother's thyroid.

Beyond about 26 weeks, the fetus is less sensitive to the noncancer health effects of radiation exposure than in any other stage of gestation. However, at doses above 1 Gy (100 rads) the risks for miscarriage and neonatal death (i.e., infant death within 28 days after birth, including stillbirth) increases.

Potential Carcinogenic Effects of Prenatal Radiation Exposure

Cancer risk for a specific time of life (such as childhood) often is separately assessed from cancer risk over a person's entire life. The risk for **childhood cancer** from prenatal radiation exposure is shown in Table 2. For estimation purposes, the lifetime cancer incidence risk for exposure at age 10 years also is shown in Table 2.

Table 2: Estimated Risk for Cancer from Prenatal Radiation Exposure

Radiation Dose	Estimated Childhood Cancer Incidence ^{*, †}	Estimated Lifetime [‡] Cancer Incidence [§] (exposure at age 10)
No radiation exposure above background	0.3%	38%
0.00–0.05 Gy (0–5 rads)	0.3%–1%	38%–40%
0.05–0.50 Gy (5–50 rads)	1%–6%	40%–55%
> 0.50 Gy (50 rads)	> 6%	> 55%

* Data published by the International Commission on Radiation Protection.
† Childhood cancer mortality is roughly half of childhood cancer incidence.
‡ The **lifetime cancer** risks from prenatal radiation exposure are not yet known. The lifetime risk estimates given are for Japanese males exposed at age 10 years from models published by the United Nations Scientific Committee on the Effects of Atomic Radiation.
§ Lifetime cancer mortality is roughly one third of lifetime cancer incidence.

In addition,

Whether the carcinogenic effects for a given dose vary on the basis of gestation period has not been determined. At this time, the carcinogenic risks are assumed to be constant throughout the pregnancy. However, analysis of animal data suggest that while there is a strong sensitivity to carcinogenic effects in late fetal development, the stages of blastogenesis and organogenesis are not found to be susceptible.

The radiation risk for childhood cancer from prenatal radiation exposure has been estimated, but the lifetime cancer risk is not yet known. Studies are under way to determine the lifetime cancer risk from prenatal radiation exposure. However, early indications are that cancer risk from prenatal radiation exposure is similar to, or slightly higher than, cancer risk from exposure in childhood. Therefore, lifetime cancer risk from childhood radiation exposure can provide a good approximation of the prenatal risk.

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Conclusion

Fetal sensitivity to radiation-induced health effects is highly dependent on fetal dose, and the mother's abdomen provides some protection from external sources of ionizing radiation. In addition, noncancer health effects depend on gestational age. This document should provide helpful information about the complex issue of prenatal radiation exposure to physicians counseling expectant mothers who may have been exposed to ionizing radiation.

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For more information, visit www.bt.cdc.gov/radiation,
or call CDC at 800-CDC-INFO (English and Spanish) or 888-232-6348 (TTY).

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