



Beyond Nuclear

Reference Girl: Necessary, but not the endpoint for radiation protection

Current radiation exposure standards are based on an outdated model known as [Reference Man](#): "... a nuclear industry worker 20-30 years of age, [who] weighs 70 kg (154 pounds), is 170 cm (67 inches) tall...is a Caucasian and is a Western European or North American in habitat and custom." But with current global exposures to ionizing radiation increasing, Reference Man no longer represents the most protective model, leaving out women, children and pregnancy, which are less resistant to radiation exposure.

We need a new model: Reference Girl. Today is her day. As a health protection model, she will afford more protection to our entire population fairly easily under the current regulatory regime. However, she cannot represent the totality of the exposure damage to our entire *lifecycle*. For that, we would need a Reference Fetus, a more complicated standard. Nonetheless, Reference Girl¹ is needed and can be deployed in the rapid fashion our health requires.

Early on in the nuclear weapons' age, researchers suspected that children and pregnancy might be more susceptible to radiation exposure than the adult males who were the focus of radiation protection in the 1940s and 50s. Yet weaponeers (a person who designs, uses or maintains weapons, especially nuclear weapons) pushed regulators to set exposure levels for Standard Man (later changed to Reference Man) anyway. They were ignoring the ubiquitous radioactive pollution being released to our environment from nuclear bombs, power, mining, and other facilities.

But Reference Man is more resistant to radiation than women, children or pregnancy. As of today, little has changed since even the most protective standards in the U.S. average adult males with those less resistant to radioactivity when calculating cancer risk. Non-cancer and pregnancy impacts are mostly not considered.²

There had been hope that regulators would account for at least some disproportionate impacts, with the recognition of the need for a "*Standard Child*", briefly considered in 1960 (and never mentioned officially again) for use in radiation exposure regulations. So the concept of "*Reference Girl*" is certainly novel — at the time *Standard Child* was mentioned, there was no stated recognition that *female* children may be more sensitive than male children to radiation exposure — a fact we now know.³

At the same time, the need for Reference Girl should be no surprise considering children have, for decades, been known to be more damaged by radiation than adults. The presence of already widespread, and unceasing, radioactive contamination — from a combination of atomic test fallout, nuclear power, uranium mining, reprocessing plant accidents and routine releases, etc. — has only exposed more people and will continue to do so. For instance, even decades later, we are still exposed to cesium 137 from the atomic bomb tests and additionally from civilian nuclear routine releases and catastrophes, with EPA recognizing that it is "impossible to

avoid⁴”; and radiostrontium⁵ and plutonium⁶ still appear in children’s teeth. So, in fact, even if we establish Reference Girl, she is arriving much later than she was needed.

We have a general risk model for children and we have research that begins to quantify the increased sensitivity of females. But current risk models don’t account for certain physiological aspects or cultural and economic resource differences of females, children, pregnancy and black, Indigenous and people of color (BIPOC). These parameters would need to be accounted for in order for Reference Girl to deliver the best protection that any model can provide to those that would be most impacted, accepting that models are never perfect.

But Reference Girl is better than Reference Man, and while not as protective as a “Reference Fetus” concept, risk formulas can be more easily adjusted to accommodate her. Considering current worldwide nuclear contamination, and the threat of even more, the need for the correction that Reference Girl will provide is well overdue.

Still, Reference Girl can’t be the ultimate endpoint. She is inadequate over the longer term because fetal development is more impacted by radioactivity due to complicated fetal development processes and the quality of radiation damage to them, especially damage from radiation inhaled or ingested.

Not all damage from radiation, particularly to pregnancy development, can be represented by current models. Random, or stochastic health impacts (which can include cancer and other genetic damage) are difficult to predict and to protect against, in part, because the severity of the impact is ostensibly independent of dose and without threshold.⁷ Recommendations for regulations may try to have reasonable protection against such impacts⁸, but as exposures increase through our continued use of nuclear technology, the number of people affected will increase.

Pregnancy—where one hit from radiation could damage or destroy cells meant to become organs—presents a particularly sensitive time for radiation damage; and a particularly difficult challenge to model. Therefore, pregnancy is mostly ignored in exposure standards.

Even when the dangers to pregnancy are known, exposure recommendations fail to account for several significant processes, although these shortcomings are recognized by those issuing the recommendations. The International Commission on Radiological Protection (ICRP) is a self-selected body that puts out recommendations for radiation exposure, which are followed by many governments and global bodies.

These recommendations fall short in many ways when determining pregnancy damage. ICRP claims *in utero* risk is similar to early childhood exposure risk, despite the very different stages of organ formation for each. ICRP uses uterine dose to determine embryo dose and uses postnatal exposures to calculate prenatal damage, claiming this is more convenient for comparisons during different lifestages.⁹ ICRP fails to account fully for damage to the placenta, which is essentially a functioning organ¹⁰ for the fetus, to which any damage can surface as negative health impacts later in adult life.¹¹ ICRP fails to fully account for damage to highly sensitive sites and stem cells responsible for blood formation.¹² ICRP rejects study data for damage that is too complex or uncertain to integrate into their models and recommendations.¹³ ICRP will often mention they are aware of the shortcomings of these approaches.

Fetuses and reproductive tissues collect some nuclides to greater concentrations, making doses from inhaled or ingested radionuclides a particular concern. And some nuclides that pose less risk outside the body can pose the greatest risk inside. Fetal tissue can collect radiocarbon and tritium (radioactive hydrogen) at nearly twice the concentration of maternal tissue.¹⁴ Fetal and childhood bone development collects radiostrontium in foundational bone material, meaning that

the bones can carry this nuclide into later childhood and into adulthood, receiving a dose of radiation the entire time.¹⁵ Females collect more radiostrontium in their bodies than men; and research shows that younger women can collect a higher level of radiostrontium in their gonads compared to women who are older — age 40 and greater.¹⁶ Radioactive polonium also collects in reproductive tissue, threatening the health of the next generation.

While fetal damage is more uncertain and more complex, research points to [health outcomes](#) among pregnancy and children that should provide warnings against exposing our biology to radiation during either of these life phases. In areas with higher background radiation (both natural and man-made), or in areas around nuclear facilities (including uranium sites and facilities), we see increases in childhood cancers, including thyroid, leukemia, reproductive, and central nervous system cancer. We see increases in perinatal mortality and birth defects. We also see impaired neural development leading to other impacts such as lower IQ. Some of these impacts are diagnosable; others may be considered subclinical, but they still impact an individual's life. Finally, among those exposed *in utero* during the atomic bombings, nine cancer deaths were noted among females, while one was noted among males, indicating a need to consider not just fetal life phase sensitivity, but how gender of the fetus may impact future health outcomes.¹⁷

Then there are the genetic implications of exposing humans to radiation during the fetal life phase. A female fetus creates all of the eggs she will ever have while her mother is pregnant with her. In essence, the foundation for the pregnant woman's *grandchildren* is being set. Yet, ICRP does not believe it has enough information to calculate cumulative heritable radiation damage past the second generation.¹⁸ Nor does ICRP account for cumulative biological damage from continually eating or drinking small amounts of radioactive contamination.¹⁹

Add to this the less resistant nature of females to radiation exposure in general, and it is clear that extra protection should be afforded not just to postnatal females, but *prenatal* as well. This is why, in the long term, protection afforded Reference Girl should be extended to account for the prenatal part of our lifecycle. Further, during the first weeks of pregnancy a woman may not know she is pregnant nor will the gender of the child be clear. So the fetal protection standard should be extended to all adult females of childbearing years.

We are all participants in a lifecycle, the present stage of which is not always clear to us. What is clear, is that this process has now come full circle. Female fetuses should really be the standard²⁰, not least because of the implication for human eggs and third generation. Decades of studies indicate that radiation poses a risk and that radiation damage may be carried across generations with increasing sensitivity to radiation among the descendants of those exposed, in addition to accelerated mutation rates.^{21, 22, 23}

Reference Girl is a more rapidly doable, necessary first step while we research, and attempt to account for, heritable impact, which truly represents the exposure of the entire *lifecycle of the population* to radiation, not just the most sensitive *individual*. Ultimately, characterizing the complicated damage and health implications of fetal exposure may be too great a challenge. It may necessitate a precautionary, truly minimal, exposure approach that accounts for not only current exposure and damage, but historical exposure and damage suffered to date.

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