Radiation Basics Made Simple

Segment 4: Biological Effects of Radiation

Radiation is one of the best-understood health hazards. We've been studying the effects of radiation for over 100 years. So, we know quite a bit about how ionizing radiation interacts with living tissue. We know that at high doses radiation can be lethal. We know that it can cause cancer. We know that it can cause harm to the fetus at various stages of pregnancy. And although we haven't seen it in humans, we know that radiation can cause hereditary effect in laboratory animals.

But as with other toxins, it's the dose that makes the poison. You recall from a previous segment that we're exposed constantly to a certain amount of radiation from our natural environment. So, every exposure is not expected to result in harm. It's the amount of exposure, it's how much radiation we're exposed to, it’s the dose that determines potential health outcomes.

So how does radiation damage living tissue? Ionizing radiation can break bonds in molecules, any molecule. Inside the cell it does the same thing. And as with other toxins, our genetic material, DNA, is the primary target, and radiation can damage DNA directly by interacting with the molecule or indirectly. And that means we have plenty of water molecules in our cells, so radiation will interact with water, break down the water molecules, produce free radicals, and then the free radicals would damage our DNA. That's an indirect method.

But that's how ionizing radiation can damage our cells. So, what happens once a cell is irradiated, and the DNA is damaged? Well, it can repair itself faithfully to how it was before the damage, so the cell is repaired and there's normal function, and the cell would go on.

Another thing that could happen is it could misrepair, repair it incorrectly. So, the cell becomes an altered cell, and then that cell has potential eventually to perhaps turn into a cancerous cell. There's that potential.

Alternatively, after the cell is damaged, the cell can die. So, cell death is the outcome. And actually, that's not a bad thing because if only a few cells die, then the function of that tissue is not impaired, and we don't have a potential for a misrepaired cell to later on cause harm to us. But if there's a lot of damage, if the dose is high and there's a large number of cells that die, then that impairs the function of that organ, and that's not good. We get organ failure at that point. So those are the three outcomes.

In addition to dose that we discussed –radiation dose– health effects of radiation also depend on dose rate; how fast is that dose delivered to the body. So, if the same dose is delivered over an extended period of time, the effect would not be as severe as if the same dose were delivered all at once. It also depends what part of the body is irradiated. If a dose is delivered only to a portion of the body, the health effect is not as severe as if our whole body, the entire body, is exposed.

There is also individual sensitivity. Children and young adults are more sensitive to late effects of radiation. They have growing tissue, dividing cells, and they have so many years ahead of them, lifespan ahead of them, it's long enough to allow for any potential cancer to develop later in life. So, children and young adults are more sensitive to that. Also, among individuals of the same age there's variation in individual sensitivity to radiation.

Now, to get the general feel for the range of health effects that we might observe from a very high dose of radiation to a very low dose of radiation, let's consider three situations. If the dose of radiation is high, it's delivered to the whole body, and is given in a short amount of time, the potential likely outcome is death. The individual will die. That death can occur within a few days; if the dose is really high, it could happen within a few hours, even. And it could take several weeks after a period of severe illness that includes internal bleeding and infections.

Now, if the dose is moderate, the individual would develop radiation sickness. The symptoms would appear. But that individual has a good chance to survive, and the chance of survival is better if prompt medical care is provided to that individual. For those who survive this moderate dose of radiation, there will be a higher-than-expected risk of cancer later in life. So, their risk of cancer would be higher than what we would expect from the average person.

If the dose of radiation is low, there will be no radiation sickness. There will be no immediate health effects, no symptoms, and likely there will be no observable health effect later in life either. But statistically there will be a higher-than-average risk of developing cancer later in life. So, they would carry that small risk of cancer throughout their life.

If the dose is really, really low, then that small increase in risk of cancer is so low that we can't measure it. We can't even estimate it. So, for all practical purposes, that risk is non-existent at that point. So, regarding potential health effects of radiation, remember, it's all about dose, which needs to be evaluated in context.

On this chart you will see typical doses from common exposures, including air travel, chest X-ray or CT scan, compared to what we get from our natural background on an annual basis. You also see the 50 percent survival dose. That's the dose that would give a 50 percent chance of survival. The person would have a 50 percent chance of surviving radiation sickness.

And that dose is 4,000 millisieverts. That's equivalent to getting 400 CT scans back-to-back, or 1,300 years of natural background radiation in one sitting. Now, I know these dose numbers can still be a little abstract. So let me show you in a different way what these doses would look like.

Instead of millisieverts, let's use pinto beans as a unit of radiation. Just for those of you who like radiation units – I do too, but for this lecture I'm going to equate one pinto bean to 10 microsieverts, or one millirem. So, a pinto bean is 10 microsieverts or one millirem. I'm not going to talk about dose anymore, I'm going to talk about pinto beans.

Remember from previous segments, we get exposed to a certain amount of radiation from our natural background every year, and so on. That equals to 300 pinto beans. I'll put it in this jar. So, it’s one-third full. This is the amount of radiation we receive from our natural environment on average every year. And remember that this dose is – we get it on a daily basis. So, the rate is equal to one pinto bean a day is what we get just from our natural environment.

So, on one of these days, you need to get a CT scan. And when you do, what you're going to receive is about this many pinto beans. Like 1,000 pinto beans in a CT – abdominal CT let's say. So, this is about three times this. So, it's three years' worth of getting natural background radiation in one CT. And remember, now, you're getting the benefit from this– so don't forget that you receive a benefit from this dose. So, let's not overlook that part.

If you have to get a second test, of course you get a second one, and so on. But this is part of our daily lives. This is what we do, and what we get over time. So, at what point are we going to see any effect that we can observe clinically in a person that receives radiation, or pinto beans? Okay, so this is the amount here.

This is how many pinto beans we need to start seeing something in a person. The person who receives this many pinto beans still would not show radiation sickness, would not have any symptoms, would not feel any different. But if you took a blood sample from this person, you're going to see decreased levels of lymphocytes and platelets in this person, and it will be temporary. The person would recover on their own without any medication and would not know the difference. There would be a temporary drop in blood counts.

Now, this person will have a higher risk of cancer developing later in life. So, he carries that risk with him. There will be a slight increase in cancer risk for this person, but there will be no clinical manifestation that can be observed. So, at what point are we going to see clinical? At what point are we going to see the effects of radiation exposure? That would be about two of these jugs– we're going to start getting to the territory of developing radiation sickness. About two of these jugs, but it is still not lethal.

To get to the 50 percent survival dose, we need ten of these jugs. So, ten of these jugs, if a person received ten of these, would have a 50 percent chance of survival. The reason I wanted to show you this is to illustrate the difference between doses in our daily lives that we're exposed to and the type of doses that can actually do us harm.

Because we can measure radiation, and because we can understand its health effects, we can work safely around it. And also, we can take practical measures to limit our radiation exposure. And I'm going to talk about those in a different segment.