Radiation and Aircrew

As pilots fly ever higher in the atmosphere, and overcrowding leads to increased use of currently in frequently used routes, such as trans-bowler, the issue of radiation and aviation becomes more important. In my aviation medicine practice I field frequent questions concerning radiation, particularly from female flight crew members who are pregnant. In order to examine this question some basic science is in order.

Firstly, what do we mean by radiation? Radiation refers to high energy particles generated by nuclear processes. These occur from the chemical reactions of surrounding stars, most importantly being our Sun, but also background galactic radiation from cosmic sources. The high-energy particles which are received on Earth from space consist of 79% protons, 20% helium nuclei which are also referred to as alpha particles and 1% heavy atomic nuclei. Fortunately, for us, we are protected by the Van Allen belts. Given Earth’s metallic core, there is a strong magnetic field around Earth, which protects us from this cosmic bombard. The inner Van Allen belt occurs at a distance from Earth of approximately 150 to 600 miles, and the outer belt occurs anywhere from 5000 to 27,000 miles. As stated, the source of cosmic radiation comes from our Sun, where it is called solar cosmic radiation and from the stars where it is called Galactic cosmic radiation. This produces both primary radiation and secondary radiation (which results from collisions in the upper atmosphere.)

When we measure radiation, we need to know the effect it has on human tissue, therefore we use specific measurements designed to express this. One gray (Gy) refers to one joule of energy being absorbed in 1 kg of tissue (j/kg). Since this is a lot of radiation we need a unit which expresses smaller amounts. For that we use the rad. 1 rad is .01 Gy. A Sievert is the dose equivalent in joules per kilogram. A rem refers to “roentgen equivalent, man”. One rem equals .01 Sv.

Radiation, experienced on or near the surface of the Earth, is not equal over the entire globe. Because Earth is a massive bar magnet, and the Van Allen belts duck in at either pole, radiation exposure is far greater flying trans-polar, at either extreme of the globe. In addition there is something called the "South Atlantic anomaly" in which radiation, coming from the inner Van Allen belt, is higher here than in any other place on earth. Obviously, flying either trans-polar, or over the South Atlantic, exposes crew members to greater doses of radiation. Radiation is all around us, and is striking the Earth constantly. On the ground, an average radiation dose in North America is .006 rem/hr. at 35,000 feet, the dose is .6 mrem/hr. so it can immediately be seen that traveling at higher altitudes entails increasing doses of radiation. What often gets missed in such comparisons is the fact that we are still talking about extremely low overall doses. This is a little like saying would you rather your body be hit by six feathers or six hundred feathers? 600 feathers is still a very light amount of weight and would not hurt you. These radiation figures are averages, and they vary depending on latitude. Roughly, they are two times the amount at the poles as they are at the equator. In addition, depending where we are at in the 11 year solar cycle, the Sun can produce more or less solar radiation. For instance, the normal dose at the pole at 41,000 feet is 1.2 m/rem per hour. Between 1956 and 1972 there were four solar events sufficient to increase this dose on polar routes at 41,000 feet to 10 mrem/hr.

In an effort to provide actual data for flight crews, a researcher named Friedberg and his team studied 32 flights. The dose varied from .2 to 2 mrem for Continental flights and 5
to 9 mrem for transoceanic (New York to Tokyo) flights. Using these data, and extrapolating a yearly exposure estimated to be 950 block hours, this gave annual doses for flight crew members ranging from 20 to 910 mrem, (.2-9.1 mSv). In the nuclear industry, the recommended maximum occupational exposure for an adult is 50 mSv/year. Thus, even using these numbers, somebody flying the maximum block hours, receiving the maximum measured radiation, would still only accumulate 20% of the acceptable maximum occupational exposure for an adult.

In the days when the supersonic transport was in active service, and cruising at between 60 and 68,000 feet, the estimated radiation received by the crew was 50-130 mSv/yr. thus, obviously, as newer generations of aircraft cruise ever higher, by the time we reach altitudes above 60,000 feet, it is entirely possible that, especially with crews flying trans-Atlantic or transpolar routes, the acceptable maximum safe dose of radiation per year will be exceeded. In addition, these numbers do not take into account the possibility of pregnancy in female crewmembers.

The acceptable maximum for a pregnant female is .5 mSv./mo, or 50 mrem. Since the Athens to New York route has been measured at 83 mrem/mo, it is possible, in routine airline flying, to exceed the recommended maximum dose. In this case the dose would be exceeded by 1 1/2 times normal. In terms of other risk factors, obviously cancer is the thing we are most concerned about with high-energy radiation. The Environmental Protection Agency has published a risk coefficient of 2.5/100,000 per mSv/year. Another way to look at this is one's risk of cancer rises 2.5 per hundred thousand every milli-Sievert of radiation exposure if we look at somebody flying in continental North America, they are receiving approximately 5 mSv of radiation per year. This is calculated on 19 one-way flights every two weeks for 11 months. This would give them a risk of 5 x 2.5 = 12.5/100,000 per year. If they flew this amount for 20 years their lifetime risk would be 250/100,000 or roughly 3/1,000. In plain english this is best expressed by stating "if 1,000 crew members flew this route for 20 years, three would die of occupational exposure to radiation".

Another simple way to look at aviation and radiation is that transcontinental aircrew are receiving .2-5.0 mSv/year, while people on the ground receive 1.1 mSv/year. So flying gives one, at worst, five times the amount of radiation on the ground. So what does all this science mean? What flight crew really care about is what is their risk of cancer. The following, sometimes conflicting research studies, shed some more light on this risk:

1. Finish flight attendant cohort followed 1967-1992 had 1.9x h in breast ca and 15x h in bone ca in BMJ article by Pukkala, Sep 9, 1993, yet calculated doses were only 2-3 mSv/yr
2. Concorde pilots annual est dose 11-37 mSv/yr (1100 – 3700 mrem) were found to have 8-fold increase in lymphocyte chromosome aberration (Heimers A, Mutat Res May 2000; 8:467(2) 169-76)
3. Cancer Incidence and Mortality Among Flight Personnel: A Meta Analysis Ballard T et al, ASEM Mar 2000, 71:3, 216-24: Found increased relative risk for melanoma 1.97; brain ca 1.49; prostate 1.65; (Flt Att breast 1.35 and melanoma 1.54)
4. Cancer Incidence Among 10,211 Airline Pilots: A Nordic Study; Pukkala E et al; ASEM Jul 2003; 74:7 699-706: found increase only in skin ca (melanoma 2.3; squamous 2.1; basal 2.5)
5. AML and Melanoma Increased in Danish Crew; Gundestrup 1999: in this study Danish cockpit crew members known to an aviation medicine clinic from 1946 to almost 2000 were surveyed and found to have a relative risk of 1.9 for leukemia, 5.1 for acute myelogenous leukemia, 1.3 for chronic lymphocytic leukemia, 2.8 for melanoma and 3.0 for other skin cancers.

In terms of pregnant flight crew, this is also a controversial area. Clearly, the best advice to give is to state that pregnant flight crew should be afforded the option of flying, or not flying as they wish, in that radiation exposure will be higher at altitude than on the ground. Whether this minimal increase in radiation exposure has any significant effect, is open to debate. Current research would suggest that it does not. In research done by Asphom et al, fetal wastage (12.1%) was found to be slightly higher than non working controls (9.2%), but the same as ground based working controls. (Asphom R et al; J Occup Environ Med, June, 1999; Cone et al; J Occup Environ Med, Mar 1998, 40(3):210-6). If radiation had a significant effect on either birth defects or fetal death, we would see a much greater effect in flight crew than ground-based controls. In fact, we do not.

So, based on the foregoing, what is a prudent crewmember to do? Firstly, at altitudes below 60,000 feet, flying in southern latitudes, there does not appear to be a significant problem. Flight crew should be aware that, the more they fly, the higher their risk of malignancy becomes, particularly in the area of skin cancer. No crewmember should ignore any abnormal skin lesion, and should promptly have all of these checked by a physician who is aware of their occupational history. If in doubt, a biopsy should be performed. Secondly, pregnant crew members may wish, at their discretion, to stop flying, although current research would not support such a decision. Lastly, there is at least one organization that is monitoring for radiation. Further information can be obtained at www.healthycrew.org. The wearing of radiation dosimeter badges will likely become a fixture in the future, as advanced aircraft climb ever higher and economics dictate longer working hours. Taking the lead from both the medical radiology world, and the commercial nuclear energy industry, radiation exposure to humans can be managed, without undue risk to them, or their offspring.

References

1. Galactic Cosmic Radiation Exposure and Associated Health Risks for Air Carrier Crewmembers; Friedberg W et al; ASEM Nov 1989, 60:1104-8
2. Galactic Cosmic Radiation Exposure of Pregnant Crew Members; Nicholas JS et al; ASEM Jun 2000; 71:6, 647-8