A PERSPECTIVE ON DOSE LIMITS AND BIOLOGICAL EFFECTS OF RADIATION ON THE FOETUS

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ABSTRACT

Current regulations governing employment of atomic radiation workers in Canada indicate that the radiation dose to the abdomen of a pregnant worker after the employer is informed of the pregnancy of that worker shall not exceed a total of 10 mSv accumulated at a rate of not more than 0.6 mSv per two weeks. This regulation was adopted in 1985 after consultation with medical and scientific advisory groups and eliminated previous regulatory discrimination between male and non-pregnant female workers. The ICRP has recently recommended that once the female worker knows that she is pregnant, radiation doses to the pregnant woman should be restricted to a maximum of 2 mSv of external radiation to the surface of the abdomen and that intakes of radionuclides should be restricted to one-twentieth of the new annual limits on intake for non-pregnant workers. Many radiation workers in Canada currently receive much higher occupational doses.

The potential biological effects of these doses to the embryo and foetus are reviewed; these hazards are in general very small compared to the normal biological hazards associated with human development. Potential carcinogenic effects may well be the major biological problem associated with foetal exposures. Radiation hazards to the embryo are essentially zero for exposures occurring during the first four weeks after conception.

The new ICRP recommendations on exposures of pregnant women suggest a number of problems to be solved in the near future. The list of problems includes (a) improvements in current methods of measuring both external radiation doses and intakes of certain radionuclides in Canada, (b) further research on the metabolism of radionuclides in pregnant women, including concentrations of certain radionuclides in foetal/embryonic tissues and also in adjacent tissues of the mother, and (c) the difficult socio-economic problems that may be involved in implementation of the new ICRP recommendations on exposures of pregnant workers, particularly in small facilities such as nuclear medicine departments in hospitals.

1. Canadian Regulations and New ICRP Recommendations on Dose Limits.

Protection of the foetus against the possible harmful effects of radiation exposure has a long history in the Canadian nuclear industry. In the early days of the development of the Canadian Atomic Energy Project, it was recommended that women should not be employed in areas where there was any serious possibility of irradiation hazard (Mitchell 1945, see also ACRP-11 1990). The Atomic Energy Control Regulations of 1960 prohibited employment of pregnant women as atomic radiation workers (ARWs). Following considerable discussion among Canadian authorities (Letourneau 1983), the 1964 ICRP recommendations were interpreted in 1969 in Canadian regulations governing ARWs to mean that the maximum permissible dose to the abdomen of a female ARW of reproductive capacity shall be 1 mSv per week or 2 mSv per 2 weeks, and that after a female ARW is known to be pregnant, the maximum permissible dose to the abdomen during the remainder of pregnancy shall be 10 mSv. In order to assure themselves that women of reproductive capacity did not exceed the legal limit of 2 mSv per 2 weeks, major nuclear employers set their administrative dose control level at 1 mSv per 2 weeks. This made the routine employment of female ARWs in the reactor environment impractical at that time, and thus excluded young women from interesting and rewarding work in the nuclear industry (Letourneau 1983, ACRP-6 1984).

Following queries from the Canadian Human Rights Commission, the Atomic Energy Control Board (AECB) of Canada in turn consulted its medical and scientific advisory panel. After consideration of the risk of harm to the offspring of women of childbearing age (Letourneau 1983, ACRP-6 1984), the medical advisors indicated that the regulation governing radiation exposure of non-pregnant female ARWs was unduly restrictive. The Canadian regulations were modified in 1985 to eliminate discrimination between male and female ARWs until such time as the woman advised her employer of pregnancy. The employer is then required to ensure that the pregnant worker is assigned to a job where the total occupational dose to the abdomen during the remainder of pregnancy cannot exceed 10 mSv, accumulated at a rate of not more than 0.6 mSv per 2 weeks. A dose of 0.6 mSv is 3 times the limit of detection in the current federal TLD service. These regulations seem to be working smoothly and have not interfered with employment of women in major nuclear facilities.

The new ICRP recommendations (ICRP-60 1991) have introduced a number of changes in recommended dose limits for all radiation workers. Most important is the recommendation to reduce occupational dose limits from 50 mSv to 20 mSv per year, the latter being averaged over five year periods. The major practical problems in this case are likely to be encountered in underground uranium mines and not in other facilities. In line with the 1985 Canadian regulations, ICRP-60 recommends that "the basis for the control of the occupational exposure of women who are not pregnant is the same as that for men" (para.176). However, "once pregnancy has been declared the conceptus should be protected by applying a supplementary equivalent-dose limit to the surface of the woman's abdomen (lower trunk) of 2 mSv for the remainder of pregnancy and by limiting intakes of radionuclides to about 1/20 of the ALI" (para.178). The ALIs in question will of course be the new values recommended in ICRP Publication 61, which are based on the new dose limit of 20 mSv per year and new values for tissue weighting factors. There does not seem to be any specific intent to recommend that radiation doses from external sources and from internal radionuclides must be added in order to determine effective dose to the conceptus; this contrasts with the situation for non-pregnant radiation workers and for members of the general public (ICRP-60 1991). Reasons for this difference may include current uncertainties concerning radiation doses to the foetus from radionuclides which are inhaled or ingested by the mother and other practical difficulties.

We will not consider potential doses to the foetus under the new recommendations in detail; these will presumably be considered by other authors. However, it might be noted that foetal doses from high energy gamma-ray photons are likely to be in the region of 1.5 mSv, while foetal doses from X-ray photons in the region of 30 keV average are likely to be less than 1 mSv, when the doses to the surface of the abdomen are 2 mSv. Doses to the foetus from 1/20 ALI could tentatively be taken to be about 1 mSv on average, though it is known that effective doses from certain radionuclides such as inhaled radon progeny, uranium and probably radioiodine are appreciably smaller for the foetus than for the mother. As a rough approximation, it might be assumed for the time being that exposure of the foetus would not normally exceed 2 mSv when the pregnant mother is exposed both to 2 mSv external radiation to the surface of the abdomen and to 1/20 ALI of radionuclides. The new ICRP recommendations are currently being considered in detail by the AECB.

2. Biological Effects of Radiation on the Conceptus.

There are many uncertainties in the estimation of risks of radiation to the conceptus. A summary of approximate values is given in Table 1.

Estimation of lethal effects depends entirely on extrapolation from the results of studies on experimental animals, primarily mice. The most sensitive period in humans is assumed to be the first 8 days after fertilization, when the fertilized egg cell is dividing and preparing for implantation in the uterus. The 50% lethal dose is probably close to 1 Sv but effects have been observed in animals with doses as low as 0.1 Sv at high dose rate. Irradiation with doses up to 20 mSv during this brief stage might result in a small non-detectable risk of failure to implant, but surviving embryos develop normally when implantation does occur (ACRP-13 1991, ICRP-60 1991). As the embryo and foetus develop, the lethal dose of radiation at high dose rate increases to approach that for adults; foetal deaths at low doses of radiation at low dose rate should be zero, as they are for adults.

Irradiation of pregnant mice at high dose rate during the time of major organogenesis, corresponding to about 3 or 4 to 8 weeks after conception in humans, can produce a variety of congenital malformations in the offspring. The dose response curves are usually curvilinear and dose thresholds probably apply (UNSCEAR 1986, ACRP-13, ICRP-60 1991).

Severe mental retardation, mostly combined with small head size, has been observed in 21 out of 514 children who were exposed at high dose rate in utero at Hiroshima and Nagasaki in 1945 (UNSCEAR 1986). No excess cases were observed in children conceived 0-7 weeks or later than 25 weeks before irradiation. The most vulnerable period was 8-15 weeks after conception, where the incidence of mental retardation was about 40% after exposure to 1 Sv at high dose rate; this is a risk 50 times greater than that in the unexposed comparison group (ACRP-6 1984, UNSCEAR 1986, ACRP-13 1991, ICRP-60 1991). Analysis of the dose response curve using the new DS86 dosimetry suggested that a threshold or quasi-threshold was likely (ICRP-60 1991). The normal incidence of mental retardation in the general population has been found by various investigators to vary from about 0.2% to 8% depending on the methods and criteria used to define mental retardation (Richardson 1985). The value of 0.8% given in Table 1 is that observed in the control population at Hiroshima and Nagasaki (UNSCEAR 1986).

The increased incidence of mental retardation in these children has been linked with a general decrease in IQ for all children exposed in utero to high doses of radiation at high dose rate at Hiroshima and Nagasaki (ACRP-13, ICRP-60 1991). Schull and co-workers discovered that the average IQ of the children exposed to 1 Sv at high dose rate at 8-15 weeks after conception was reduced by about

Table 1. Approximate estimates of effects of low doses of radiation on the human embryo and foetus

Effect	Most radiosensitive stage of gestation after conception	Potential risk x 100 for foetal exposures over the last 8 months of pregnancy		Spontaneous incidence per 100 children born
		2 mSv	10 mSv	
Death and spontaneous abortion	Early, especially first 2 weeks	Zero	Zero	30-50 (per 100 conceptions)
Viable congenital malformation	3-8 weeks	Zero	Zero	6-8
Mental retardation	8-15 weeks	Close to Zero		0.8
Decrease in IQ	8-15 weeks	Not detectable		0
All childhood cancers	Unknown	0.01	0.05	0.2
Lifetime fatal cancers	3 weeks to birth	0.03	0.15	25
Serious heritable changes in all subsequent progeny	Last 6-7 months	0.004	0.02	20-30

30 IQ points. The spectrum of intelligence levels in any population is known to be very broad and to follow approximately a normal distribution. A general decrease of 30 IQ points on average would increase the fraction of mentally retarded children with an IQ of less than 67 from about 1% to 40%. It has been concluded that the observed shift of 30 IQ points at 1 Sv is best suited to describe the risk of mental retardation (ICRP-60 1991). Even if the dose response curve for IQ shift were linear, the dose response curve for induction of the effects of radiation at low dose rate are available. As noted in ICRP-60 (para.93), "all the observations on IQ and severe mental retardation relate to high dose and high dose rate, and their direct use probably over-estimates the risks" of exposure to low doses at low dose rate.

ICRP-60 (1991) is rather ambiguous about the classification of the shift in IQ caused by irradiation of the foetus during the period 8-15 weeks after conception. On the one hand, it assumes that "the shift is proportional to dose" (para.92); on the other hand, "the effect is presumed to be deterministic with a threshold related to the minimum shift in IQ that can be recognized" (para.S-7). The logic is unclear, but perhaps this will be clarified by Dr. Schull.

The stochastic effects of radiation on the foetus are assumed to include cancer induction. However, estimates of the probability of cancer induction after irradiation of the foetus are again highly uncertain (ICRP-60 1991). Studies of very large numbers of children in the U.S. and the U.K. who were exposed to low doses of medical diagnostic X-rays in utero suggest a significant excess of childhood cancers before age 15. The risk estimates derived from these studies have been interpreted as being in the region of 3 fatal cancers (BEIR 1990) or 4-6 total cancers (NRPB 1988, Mole 1990) per 100 person-Sv to the foetus (ACRP-13 1991). No increase in fatal childhood cancers was observed in the much smaller number of children exposed to high radiation doses at Hiroshima and Nagasaki. However, it is considered prudent to assume that irradiation of the foetus will increase the risk of childhood cancer (UNSCEAR 1986, 1988). Constancy of risk during most of pregnancy may be assumed in the absence of convincing evidence to the contrary (UNSCEAR 1986, 1988). Data on the normal incidence of childhood cancers in Canada can be derived from NCIC (1990).

A 40 year followup of 1630 Japanese bomb survivors irradiated in utero shows some indications that excess fatal cancers may appear after age 15, although the followup is far from complete and the magnitude of the risk is uncertain. ICRP-60 (1991) "assumes that the nominal fatality probability coefficient is, at most, a few times that for the population as a whole" (para.91). The results of calculations given in BEIR (1990) and ICRP-60 (1991) agree that the predicted lifetime risk of fatal cancers after irradiation of children is about 2 times greater than after irradiation of the

whole population. For simplicity, we have assumed in Table 1 that the lifetime risk of fatal cancers after irradiation of the foetus is at most 3 times the ICRP estimate for the general population, i.e. is about 15 per 100 person-Sv. Animal studies have failed to demonstrate unusual sensitivity of the foetus to induction of cancer by radiation (UNSCEAR 1986). The ICRP (1991) (para.91) has assumed that cancers can be induced in humans by exposure to radiation throughout the period from 3 weeks after conception until the end of pregnancy.

The stochastic risk of induced heritable changes in the germ cells after irradiation of the foetus was not specifically considered in ICRP-60 (1991) although this possibility was noted in ACRP-6 (1984). Induced frequencies of specific-locus mutations in mice are slightly lower after irradiation of foetal or of newborn males than of adult males (UNSCEAR 1977). A conservative approach would be to assume the same genetic risk coefficient for human adults and for the human foetus in the later stages of development after the gonadal tissues have been formed. Assuming then a conservative total of 2.5 per 100 children per person-Sv of parental radiation for serious heritable changes summed over all subsequent generations (ICRP-60 1991), a small risk of heritable changes could exist following exposure of the foetus to low doses of radiation (Table 1). This radiation risk is particularly small when compared to the normal incidence of serious genetic diseases; following the lead of ICRP-60 (1991), we have taken this normal incidence to be 20-30%, i.e., one third of the total incidence of 60-100% for all diseases with a genetic or partially genetic component (UNSCEAR 1986, BEIR 1990). It should also be noted, first, that the stochastic risk of serious genetic changes in the immediate children of the irradiated person is thought to be about 5 times lower than the sum over all subsequent generations (UNSCEAR 1988, BEIR 1990, ICRP-60 1991) and, second, that the potential genetic risk is considerably smaller than the assumed potential lifetime risk of induced fatal cancer following irradiation of the foetus (Table 1).

Another major conclusion can be drawn from recent scientific reviews of the relevant scientific literature: The biological effects of low doses of radiation to the foetus are essentially zero when radiation exposures occur during the first four weeks after conception, i.e., during the first six weeks after the last maternal menses. The critical issue for protection of the foetus is thus the radiation doses received after the first 6 weeks following the last menses of the mother. It might be assumed that female ARWs will currently have been able to ascertain the probability of pregnancy within six weeks after their last menses, whether or not they choose to do so.

3. Recorded Occupational Radiation Exposures

The National Dose Registry provides statistics on annual occupational radiation doses in Canada (Ashmore 1990). External radiation doses are normally measured by TLDs which are worn at waist height and are read every 2 weeks or 3 months, depending on the circumstances and category of worker. Various correction factors are used to convert these readings to absorbed doses; however, the values do provide a reasonable estimate of external radiation dose to the surface of the abdomen. Table 2 indicates the categories of radiation workers for which the average recorded doses exceeded 1 mSv per year in 1989 (Ashmore 1990). These represent some of the areas in which it would be difficult to employ pregnant women if the new ICRP-60 recommendations became the law in Canada.

Other problems will be encountered in some occupations due to the additional ICRP-60 recommendation to restrict the intake of radionuclides during pregnancy to one-twentieth of the ALI. The majority of workers involved in underground uranium mining and milling in Ontario receive much more than 1/20 of the ALI for inhaled radon progeny (ACRP-12 1990, see also Ashmore 1990), the average exposures being in the region of 1/5 to 1/4 of the ALI for radon progeny that is currently recommended by the ICRP. However, doses to the foetus from inhaled radon progeny would be extremely low.

Radiation doses to Canadian radiation technologists in medicine are of particular interest, since about 81% of these technologists are female and the majority are women age 20 to 45 (Huda 1991). Data on the distribution of recorded occupational doses from external radiation to three categories of Canadian radiation technologists (Huda 1991) are given in Table 3. Although the occupational doses are generally low, there would appear to be an appreciable number of women, particularly in the category of nuclear medicine, who normally receive more than 2 mSv per year. At these low doses, the sensitivity of the measurement of dose becomes important. Even if the TLDs are worn for a three month period, cumulative doses in the region of 0.5 mSv per year could be read as zero when the threshold reading is 0.2 mSv per TLD.

Table 2. Categories of workers for which average occupational doses from external radiation exceeded 1 mSv per year in 1989 (Ashmore 1990)

Category	Average dose in mSv	Number of workers (and % of total in category) with doses of 5 mSv or more
Medical:		
nuclear medicine	2.1	140 (12.3%)
Industry:		
fuel processor	4.0	20 (35.7%)
industrial radiographer	4.8	389 (25.1%)
well logger	1.3	59 (5.6%)
Power stations (tritium exposures included):		
chem. & rad'n control	1.3	20 (8.2%)
elect. maintenance	1.2	68 (8.2%)
fuel handling	4.9	17 (45.9%)
mech. maintenance	3.1	247 (23.6%)
operations	2.0	212 (14.9%)
Mining:		
uranium mining	1.8	374 (8.3%)

Table 3. Distribution of annual occupational doses from external radiation for three categories of Canadian radiation technologists during the 5-year period 1983-87 (Huda 1991)

Recorded annual doses in mSv	Number of annual records (and % of total in category)		
	Diagnostic radiology	Radiotherapy	Nuclear medicine
0-1	40,854 (97.1%)	1,702 (67.1%)	2,268 (49.5%)
1-2	736 (1.7%)	422 (16.6%)	691 (15.1%)
2-5	375 (0.9%)	333 (13.1%)	1,149 (25.1%)
5-30	115 (0.3%)	78 (3.1%)	469 (10.2%)
30-50	0 (0 %)	0 (0 %)	1 (0.02%)
Average	0.14 mSv	1.01 mSv	1.89 mSv

4. Some Problems in Implementation of the ICRP-60 Recommendations

The new ICRP recommendations on protection of the foetus suggest a number of problems which need to be solved as soon as possible, in order to be able to implement these recommendations in Canada. One problem is the ability to measure external radiation doses and potential intakes of radionuclides to the required degree of sensitivity. An external exposure of 2 mSv to the surface of the mother's abdomen over about 8 months is equivalent to 0.12 mSv per two weeks. This dose is below the sensitivity of the current TLD service operated by Health and Welfare Canada. This problem could be approached with a system of double TLD badges for pregnant personnel, one of these badges being read every 2 months for example and the other being read at a 2 week interval. However, in order to determine occupational doses at the time of exposure rather than some months after the fact, greater reliance will have to be placed on commercially-available personal digital dosimeters rather than the conventional TLD service.

Intake of certain radionuclides cannot currently be measured to the required degree of sensitivity. The problem could be particularly difficult with pure alpha-emitters and with the purified uranium which is used in nuclear fuel fabrication facilities. Other problems will be encountered with short-lived nuclides such as technetium-99m which are commonly used in nuclear medicine. Because of the short half-life, the application of conventional bioassay methods is difficult and would be very expensive (Linauskas 1991). Workplace controls will of course minimize potential exposures and can help identify whether any intakes could have occurred, but it will be difficult to be certain whether intakes have been restricted to less than 1/20 ALI over an 8 month period. Possible future improvements in engineered controls such as remote handling devices in nuclear medicine facilities, and innovative technological methods for the administration of radionuclides, should of course not be excluded from consideration (Linauskas 1991).

Although not essential in order to comply with the ICRP-60 recommendations, it would be extremely useful to have a better idea of actual doses to the foetus after intake of various radionuclides and of labelled compounds by the pregnant mother. Tritium in the form of water or of hydrogen gas is perhaps the best understood of the radionuclides (see for example ACRP-10 1991) and does not appear to present any major problems with respect to foetal doses. However, tritiated organic compounds, especially tritiated DNA precursors, may deserve more attention. Similarly the variety of materials labelled with technetium-99m that are used in nuclear medicine may well deserve more attention, particularly with respect to the fraction of material that is liable to migrate across the placenta and to reach the foetal tissues. In general, further research on the metabolism of radionuclides in the pregnant mother is highly desirable. As noted in UNSCEAR (1986), we need better estimates of the actual doses absorbed by the foetus at various representative pre-natal ages following exposure of the mother to radionuclides, especially those having practical importance. Estimation of foetal doses should of course include the possible concentrations of gamma-emitters in adjacent tissues (e.g. the bladder) of the mother. A preliminary review of the relevant literature has already been sponsored by AECB (Lamothe 1989). In general, radiation doses to the foetus at 1/20 ALI are likely to vary widely from one radionuclide to another.

There may be some difficult socio-economic problems involved in the implementation of the ICRP recommendations on exposures of pregnant workers. For administrative ease and to add a measure of conservatism, it is a common health physics practice in many institutions to establish investigation or action levels well below the legal dose limits. The simplest solution is the immediate

removal of pregnant workers from work involving occupational exposure to radiation or radionuclides. This solution is already in place at major nuclear facilities (e.g., Ontario Hydro) in Canada who employ large numbers of trained workers. However, this solution is not as simple in small facilities, for example nuclear medicine departments, where the operation of the facility depends upon a small number of highly skilled specialists who may themselves wish to continue employment during pregnancy. Implementation of the new ICRP-60 recommendations may be controversial and costly in this case.

The costs to the individual (and to her child or family) who would be forced in most Canadian provinces to leave her job without pay for several months would be large, if the woman in question chose to declare pregnancy at an early stage and to carry the pregnancy through to term. As with the abortion issue, the rights of the mother versus those of the unborn child could turn out to be a serious human rights issue. One cannot ignore the additional possibility that employers, in order to protect themselves from considerable inconvenience and expense related to potential pregnancies, might tend to discriminate against young women in the hiring process. It is to be hoped that these problems will be considered by AECB in its analysis of the socio-economic impact of implementing the new ICRP recommendations.

In considering the new ICRP-60 recommendations on protection of the foetus, it would also be useful to reflect on para. 124 of ICRP-60 (1991) which reads in part as follows: "In practice, several misconceptions have arisen about the definition and function of dose limits. In the first place, the dose limit is widely, but erroneously, regarded as a line of demarcation between 'safe' and 'dangerous'. Secondly, it is also widely, and also erroneously, seen as the most simple and effective way of keeping exposures low and forcing improvements. Thirdly, it is commonly seen as the sole measure of the stringency of a system of protection. These misconceptions are, to some extent, strengthened by the incorporation of dose limits into regulatory instruments. Causing a dose limit to be exceeded then becomes an infraction of the rules and sometimes a statutory offence." The paragraph goes on to stress the importance of the optimization of radiation protection.

Table 1 suggests that the largest percentage increase in stochastic radiation risks to the foetus, compared to the normal incidence of the same risks, might be attributed to potential induction of childhood cancer. Roughly one-third of all childhood cancers are currently fatal in developed countries (NCIC 1990). Deaths due to childhood cancers represent a little less than 10% of total childhood deaths in Canada, the major causes of death prior to age 15 being various perinatal causes, congenital anomalies and motor vehicle accidents (NCIC 1990). When considering the optimization of radiation protection, ICRP-55 (1989) noted: "As a general

guide, the amount of resources devoted to reducing radiation exposures has to be compared with resources devoted to other needs of society. The overall objective is optimum resource allocation for safety and protection. Good practice generally in relation to health and safety must surely have the same overall objective." Before imposing more stringent legal dose limits on external and internal radiation exposures during pregnancy, the AECB should carefully study and weigh the benefit of such action (reduced potential risk to the foetus) versus the detriment, which includes high socio-economic costs to pregnant workers and the institutions that employ them, and possible widespread gender discrimination (because of potential pregnancies) in hiring practices. It may well be more productive to retain the existing dose limit for pregnant workers, and at the same time emphasize the optimization principle during pregnancy. Equally important, young women who are employed as radiation workers should be provided with accurate scientific information on radiation risks to the foetus as compared to the normal risks of childhood development.

It would of course also be interesting to know if low doses of radiation to the foetus really do cause childhood cancer, which is likely to be the most sensitive indicator of potential radiation effects (Table 1). The available data are not consistent and considerable uncertainty exists (ICRP-60 1991). A feasibility study could be recommended to determine whether or not any useful data could be obtained from a study of cancer incidence in the children of pregnant workers whose annual dose records are on file at the National Dose Registry in Ottawa. The possibility of obtaining additional data on incidence of childhood cancers in the high background radiation areas of China could also be explored.

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Question and Answer Period for Myers

Question: Mr. G. Cowper
Has anything been done approaching nuclear medicine facilities; i.e., that there be changes in the training programs such that nuclear technicians can do other things, for example ultrasounds?

Answer: What they do, according to my co-author, and this is in order to stay below the existing limit, to ensure that they are staying actually below half of the existing limits, they send a notice out saying this woman can still work in the nuclear medicine department but is not to do certain jobs. Knowing that the chances of exposure are a bit higher in certain jobs than in others, they rotate them within the department.

That is an excellent suggestion to try and get them into some other area of medicine.

Comment: Mr. G. Cowper
You show that one stage, the quote from ICRP 60 that said that the dose of the abdomen should be less than 2 mSv. It is an ambiguous statement and I wish that I had not made it because, first of all, even with ^{60}Co, the surface does not get the maximum dose. That is why we use ^{60}Co to get a depth dose. If you have an opened and unsealed source, the surface of the abdomen is going to get another beta dose.

Why on earth can't ICRP and ICRU get together and work out a new quantity and specify what the 10 mm dose should be delivered to? They haven't been quite clear if it covers exposure to ^{16}N, which is 6 MeV and all other kinds of doses in different situations. But to blither on about dose to the surface of the abdomen!

Answer: I believe I quoted that correctly. It is the surface of the abdomen, yes. It doesn't say where on the surface. Normally, I think, the convention in nuclear medicine, as it is here at Chalk River and in most other places, is that the TLD is to be worn at waist height. I think that is what they are referring to.

Comment: Dr. S. Yaniv
But that measures depth dose, not surface dose.

Answer: Well we have various measurements on the TLD's at Chalk River. You can measure all kinds of different things.

Comment: Dr. R.G.C. McElroy
What it does say is surface dose and not dose at the surface. Therefore, I take that as the badge at that location. The thick chip then would serve as a sufficient check.

Comment: Mr. G. Cowper
And in fact, what we are simulating is the dose of the 10 mm depth.

Answer: We have some people here that understand this full system very well. The problem is that most of the people in the National Dose Registry would rely upon the Federal TLD Service, which is not run the same way. But I think you know that. The cut-off limit on measuring a dose is 20 mrem, I believe.

Question: Mr. M. Lupien
For fetal dosimetry, I would like to know if we can use the weighting factors as specified in ICRP60, or would you recommend a different set of weighting factors?

Answer: For the later stages of fetal development, I would think that this would be very appropriate. As for the early stages, I have no idea.

Comment: Dr. S. Yaniv
If you are talking about childhood cancers rather than adult cancers, the weighting factors are totally inappropriate. Does a child get lung cancer or childhood breast cancer?

Answer: No. Most childhood cancer, I have forgotten the exact numbers, somewhere around 50%, are leukemias. Let's say that another 40% major contributor is brain cancer. Then there are various other things. Am I correct in that Dr. Mole?

Comment: Dr. R. Mole
There is a distinction, because you are not talking about childhood cancer as such, but rather a cancer anytime afterwards.

Answer: No. We have given two different types of risk coefficients. One is from the Childhood Cancer Study, which is cancer developing before age 15. The other is for fatal cancers that may develop at any time during life after that.

Comment: Dr. R. Mole
Yes, but if you are serious about thinking about exposures of the fetus for lifetime cancers thereafter, you have not got any direct inspiration about the appropriate weighting factors, as of yet.

Answer: I agree.

Comment: Dr. R. Mole
Another thing, you had asked the genuine question of where this had come from in ICRP. I think that is the real question to be asked.

They specify the restriction in terms of dose and not risk. That leaves the question entirely open for serious discussion. They just called the fetus a member of the general public and apply the same dose restriction to the fetus as that to an adult. That does not necessarily give the fetus the same risk.

If we look at the slide where activity is taken into the mother, and where the fetus is treated as a compartment of the pregnant woman and showing physical transfer from the blood, the fetus has neither an inhalation pathway nor an oral pathway. You can't immerse it in a noble gas. The normal connection of doses taken into account for an adult simply does not occur in the fetus. With perhaps the exception of radon, there is no possibility of exposure from these routes.

The basic question is whether to restrict the absolute increase in cancer following fetal exposure, or a proportional increase, because, as it is here, the embryo or fetus is much more protected than a member of the general public. The fetus or embryo is an especially protected member of the general public. The concept that the embryo and fetus is a member of the general public is obviously a social reason, the same thing for radiation protection reasons.

Answer: I must say that I am impressed with the quality of the work trying to determine fetal doses that we have heard of in the past two days. It is my impression that we need a great deal more work on many of the radionuclides. That is probably the reason for the ICRP recommendations, i.e., just work on the 1/20th limit on intake to the mother even though fetal doses from one radionuclide to the other may vary greatly.

Comment: Dr. R. Mole
I don't think that ICRP got it right at all.

Answer: Yes. But one doesn't have to agree with it.

Comment: Dr. A. Marko
I am very much concerned about these restriction limits for pregnant women. I don't believe this is very practical.

In one of the publications they said that dose restrictions would take care of many problems. That is a lot of nonsense. As you had pointed out for nuclear medicine departments, they can't enforce restraints to multiple sources.

What worries me even more is that in Canada they may just adopt ICRP limits into the regulations. You had mentioned a lot of possibilities to get around this, but I don't think that the option will be given to the Canadian people to have any input into this. It will simply appear in the regulations.

A lot of us keep talking about these social and economic factors. One almost visualizes a pot of money given for high risk, one for radiation and one for airplane safety. It simply is not true. The pot is not divided rationally. I think you are going to have a lot of problems on radiation protection of pregnant women.

Answer: I agree with you totally. This is what I am trying to say. I think that Karin Gordon would agree in the same way.

Comment: Mr. F. Horvath
Speaking for the regulatory body, I won't mention which one, I would like to state that the proposed regulations will be going out for comments. I encourage you strongly to make your concerns known.

Comment: Dr. R. McFadden
Can you suggest that, before this goes to the public, all the regulatory agencies get together and work on this first?

As an example, I find myself in the situation where the employment standards branch of Labour Canada tell me I can not do exactly the same things that the Control Board [ed. note Atomic Energy Control Board] says I must do.

Answer: I am fairly certain that if we are to go through without any modification or further consideration, the Control Board will consider all the comments that they receive. However, I think that if provincial legislation that covers compensation happens to have enquiries, then this will go through the Human Rights Commission again. I am almost certain of it.

Comment: Mr. E. Rabin
The AECB has undertaken an impact assessment statement. A detailed questionnaire will be circulated to a cross-section of the Radiation Licensees, asking for comments on the proposed amendments and on each of the individual statements that have been prepared. These should be going out in a week or so. It is being translated at the moment. We should get good feedback from that particular project. We could then present this feedback to the board.

Comment: Dr. M. Sikov
Just a comment here. At least in the States, it has gone beyond the Radiation Protection question. None of the agencies speak to each other and the rules do not agree with one another. This applies equally to fire safety or anything else.
The punishment of violating a single safety regulation is much more severe than what the Equal Opportunity equivalent might inflict. Therefore, except for companies that will move pregnant women to office positions, and have the resources to do so, companies will discriminate in order to protect themselves against very costly liability suits.

Comment: Dr. S. Yaniv
There was, this past summer, a United States Supreme Court decision in a case that excluded women of childbearing age or who could not provide substantial evidence that they are sterile, from high-paying work involving LET. The Supreme Court decision sided with the women, and put the onus of the risk acceptance and avoidance on the women.

The woman here has the option of not declaring the pregnancy. Even if it is obvious that she is nine months pregnant, if she did not declare her pregnancy in writing, she is not pregnant. This is now the law of the land in the United States.

Comment: Dr. M. Sikov
The other factor from the case that we can't do anything about is that they are now trying to sell that part of the company and move it out of the United States. There is a dichotomy between the different regulatory options, and they have to be dealt with one way or the other.

Question: Dr. R. Mole
I can only hope that you get this sorted out right, because anybody in Europe is now advised and directed by the European

community in Brussels that the ICRP is to be accepted as such. It's modernization, so they say.

Question: Dr. D.K. Myers
Is there any form of compensation for these women who would then be unable to work because they had declared their pregnancy?

Comment: Dr. R. Mole
Not that I know of, but of course pregnancy is private.

Comment: Dr. D.K. Myers
You can't compel them to declare. I think there is a form that women sign when they join Chalk River [AECL Research] suggesting rather strongly that they should notify as soon as possible when they become pregnant.

Comment: Dr. R. Mole
There are very fine notices in Canada. A very polite directive that I read on the aeroplane states that you must close your shutter and tie your seat belt. And then they said this is not an instruction.