EVALUATION OF INTERNAL CONTAMINATION DOSE TO EMBRYO AND FETUS

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ABSTRACT

In its Publication n. 60 the ICRP recommends that the methods of protection at work of women which may be pregnant should provide a standard of protection for any conceptus broadly comparable with that provided by the System of Protection for members of the general public. The Commission's policy could not be satisfied following maternal internal contamination before the declaration of pregnancy by some radionuclides homogeneously diffused into the body as ^{137}Cs and ^{3}H.

Antenatal exposure to ionising radiation seems to be likely to cause (1) an undetectable death of the conceptus before the beginning of organogenesis, deterministic effects (malformations), with an estimated threshod to be about 0.1 Gy, during the period of major organogenesis and an increased probability of cancer in the live-born. To limit to a tolerable level the health effects affecting the conceptus following the mother's occupational exposure the Commission recommends that the methods of protection at work of women which may be pregnant should provide a standard of protection for any conceptus broadly comparable with that provided by the System of Protection for members of the general public. The Commission states that its policy seems to be adequately applied if the mother is exposed, prior to a declaration of pregnancy, according to the recommended protection system, including the respect of the occupational dose limits and of the source-related dose constraints, if any. The exposure of women which may be pregnant is thus not believed by the Commission to require specific arrangements and no special occupational dose limits for women are in general recommended, owing to the substantial reduction (by a factor 2/5) in the dose limits for workers. Once the pregnancy has been declared the conceptus should be protected by applying a supplementary equivalent dose limit to the surface of the woman's abdomen of 2 mSv for the remaining of the pregnancy and by limiting intakes of radionuclides to about 1/20 of the ALI. Exclusion should be considered from jobs carrying a significant probability of high accidental doses and intakes.

The application of these recommendations seems to be straightforward in the case of external exposure, but a deeper analysis could be required in the case of internal exposure. Some computations (2) of the fetus equivalent dose received following the continuous internal exposure of the mother under the annual limit recommended for the members of the public

(roughly 1/20 of the Annual Limit on Intake for workers) confirm that the resulting dose can be very small and satisfying the general Commission's policy regarding the occupational exposure ofwomen. Some doubts could however arise in the case of occupational exposure of women which could be pregnant, owing to the flexibility in averaging the intakes over five years allowed by the Commission's Recommendations. This is because keeping the exposure of women which may be pregnant at an approximately regular rate, is no longer recommended. Some exposure scenarios should be investigated to verify that a significative dose to the conceptus can be excluded following the occupational exposure of the mother before the beginning of the pregnancy, even if the recommended exposure conditions are satisfied.

The equivalent dose to the different organs or tissues following the intake of a radionuclide into the body depends on the type and energy of emitted radiations, on the distribution of the radionuclide in the source organs, and on the mean residence time in the different organs and tissue, determined by the physical half-life and by the biological retention period. There are not general methods for calculating equivalent dose to the developing embryo and fetus following intake of radionuclides by the mother before the declaration of pregnancy (2). Two different aspects should be considered for the irradiation of the conceptus: a) by penetrating radiation emitted from radioactive materials deposited in the mother's organs; b) by non penetrating radiation emitted from material deposited in the fetal organs and tissues. In the first case, owing to the lack of of more complete information, it can be generally assumed that the dose to the embryo up to the end of the second month of gestation is equal to the dose to the uterus. For the second case the selectivity of the placenta will be very often the most important factor. Following the entry into fetal and mother's body fluids, information is ideally required on the initial uptake of radioctivity by the fetal tissue during the very early stages of gestation, on the activity distribution and retention in developing fetal organs and tissues and also on the extent in which activity is translocated to the fetus from the the maternal tissue, which could behave as a reservoir after the end of the direct intake by the mother. In the different exposure scenarios discussed in the following reference is made to the radioactive materials which are mostly present in the work-place, by selecting from the different groups characterized by a particular metabolic behaviour the radionuclide which can produce a not negligible exposure of the embryo and fetus.

A continuous exposure to 1 ALI per year of ^{239}Pu (i.e an intake of 300 Bq for class W (3)) has been assumed as critical with reference to bone seekers radionuclides. The largest fraction of bone seekers taken-up into the body-fluids is deposited in the mother's bone and only a minor fraction is available for the fetus, even without taking into account the placental discrimination factor. Literature data (4) relative to ^{90}Sr, for wich the placental discrimination factor seems to

be very small, show that the concentration in fetal bone at time of birth is equal or lower than in mother's bone. According to other results (5) we can thus expect for actinides a low concentration in fetal bone, causing to it a dose lower than that received by the mother's bone. The actinide concentration in soft tissue can also be assumed to be equal to the concentration in maternal uterus. Considering a biological half-life of 500 days and a dose-factor of 1 μSv/Bq (6) we obtain for a continuous constant intake at the level of 1 ALI/year, stopped after the first month of gestation, a total fetal dose of about 0.34 mSv. According to the flexibility allowed by the System of protection in averaging the intakes over 5 years we can also consider a further acute intake of 1 ALI just before the beginning of the pregnancy, because the requirement of an aproximately regular exposure no longer holds. The fetus could so receive an additional dose of 0.24 mSv during the following gestation time, with a total dose amounting up to 0.58 mSv. For bone-seeker radionuclides, in particular actinides, the occupational exposure of the mother under the exposure conditions recommended in 1990 ICRP Recommendations seems to bear no problems for the exposure of the conceptus.

Owing to its importance in industry, in research places and in nuclear medicine ^{131}I has been selected among the radionuclides characterized by a selective affinity for an organ or tissue. Human data on which a dosimetric model cab be based are also available for this radionuclide (7). Owing to short physical half-life the acute exposure to 1 ALI (800 kBq) can be assumed as critical. Fetal and maternal tissues other than the thyroid will receive an equal dose around 0.032 mSv, assuming a committed dose of 40 pSv/Bq (6). No significative thyroid irradiation could reasonably be assumed before the declaration of the pregnancy, owing to the short half-life of ^{131}I. A larger, but always small thyroid dose could be evaluated for ^{125}I. Exposure during the pregnancy at the recommended value of 1/20 of the ALI could cause, between the third and the sixth fetal months, the dose to the thyroid of the fetus to exceed the maternal thyroid dose by a factor no larger than two. Maternal exposure to radioiodine under the conditions suggested by the Commission would cause no deleterious deterministic effects to the fetus, but only a small overcome of the risk of stochastic effects allowed for the members of the public.

For radionuclides which diffuse homogeneously within the human body (i.e. ^{137}Cs and ^{3}H) an homogeneous diffusion into the fetal tissues is assumed, with a dose rate equal to that delivered to maternal soft tissues. Assuming a continuous constant inhalation of 1 ALI/year (2 MBq/y) of ^{137}Cs an equivalent dose of about 1.7 mSv will be received by the embryo during the first month after the beginning of the pregnancy (i.e. up to the time of the diagnosis). Moreover, considering for cesium in the pregnant woman a biological half-life of 50 days, an additional dose of 3.8 mSv will be received over the next months, up to the exhaustion of the maternal cesium

burden, leading to a total fetal dose of 5.5 mSv. In the case of a single intake of 1 ALI just before the beginning of the pregnancy, taking into account the different biological half-life during the pregnancy, the embryo will receive a dose of 12 mSv during the first two months, and a dose of 8 mSv during the following seven months. For internal contamination by tritium the total dose will be received in short time after a single acute intake, namely 99% in the first 60 days. The whole committed dose to the soft tissues of the embryo (about 20 mSv) can therefore be received soon after the intake. As a conclusion, when the exposure conditions recommended in ICRP Publication 60 are satisfied, maternal exposure from radionuclides homogeneously diffused within the body could cause the fetus to receive a dose significatively larger than that allowed for the members of the public, even if the value of the dose seems not to be large to cause deterministic effects. The Commission's policy aimed to protect the conceptus by protecting the mother seems to be not completely satisfied.

For trace radionuclides like zinc, nickel, cobalt, technetium, etc. literature data (4) show in some fetal organs values of concentration larger than in maternal organs. Since the kinetics of these radioelements in fetal organs is not known, it is not possible to calculate the fetal dose due to the maternal contamination. It seems proper therefore to recommend a particular caution in the exposure of women of reproductive capacity to this group of radioelements.

REFERENCES

1. Recommendations of the International Commission on Radiological Protection. ICRP publ. 60. Pergamon Press, Oxford, 1991.
2. Phipps A.W. et al.: Committed Equivalent Organ Doses and Committed Effective Doses from Intakes of Radionuclides. NRPB - R 245, Didcot 1991.
3. Annual Limits of Intake of Radionuclides by Workers Based on the 1990 Recommendations. ICRP Publ. 61. Pergamon Press, Oxford, 1991
4. Gerber G.B., Metivier H., Smith H., Editors : Age-related Factors in Radionuclides Metabolism and Dosimetry. Martinus Nijhoff publ. Dordrecth 1987.
5. Weiss J.F. et al.: Placental Transfer of Americium and Plutonium in mice. Health Physics, 39,903,1980.
6. Age-dependent Dose to Members of the Public from Intake of Radionuclides. Part. 1. ICRP Publ. 56. Pergamon Press, Oxford, 1990.
7. Johnson J.R.: Fetal Thyroid Dose from Intakes of Radioiodine by the Mother. Health Physics, 43,573,1982