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FETAL DOSE AND RISKS FROM OCCUPATIONAL EXPOSURE IN INTERVENTIONAL RADIOLOGY PROCEDURES

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ABSTRACT

The protection of the unborn children of pregnant women from ionizing radiations is very important because the fetus is particularly vulnerable to the effects of ionizing radiation. The determination of the equivalent dose to the unborn child in diagnostic radiology is of interest as a basis for risk estimates from occupational exposures of the pregnant worker. Routine individual monitoring is necessary to ensure that occupational exposures are being kept as low as reasonably achievable (ALARA) and also that authorized limits are not exceeded [1]. In the present work, typical fetal equivalent doses to the staff occupationally exposed to ionizing radiation in interventional radiology have been quantified by using personal monitoring doses from an Approved Dosimetry Service (ADS) database. Monthly average whole body doses from 453 staffs involved in high dose procedures were collected from the ADS and were analyzed in order to estimate fetal equivalent dose to pregnant staff. These whole body doses were used to represent the dose received from all procedures performed by the technologist (occupational dose). Assuming that all technologists wore 0.25 mm lead equivalent apron during every procedure, the fetal equivalent dose per month was estimated using the methodology suggest by Osei et al. [2] where coefficients for converting TLD readings to equivalent dose to the fetus have been calculated by using Monte Carlo simulation.

1. INTRODUCTION

Radiation doses to occupationally exposed staff working with radiological equipments are generally low and it is unlikely that the equivalent dose limit recommended by the National Commission of Nuclear Energy [3], CNEN, and as adopted in the Publication 453 of National Health Surveillance Agency [1], ANVISA, will be exceeded. However, for some fluoroscopy procedures there is a potential for higher radiation doses to staff. Consequently, the implications of the Publication 453 recommendations on the radiation exposure of the fetus of staff performing interventional radiology procedures should be assessed. The motivations of the present work are to evaluate the fetal dose from occupational exposure in interventional radiology procedures, considering that the staff member can be pregnant, to compare the result with the authorized limit, and to estimate the associated radiation risks like induction of cancer and leukemia, decline in IQ score, hereditary effects, and severe mental retardation.

2. METHODOLOGY

2.1. Fetal Dose

The fetal equivalent dose can be estimated by using the methodology suggest by Osei et al. [2] where coefficients for converting TLD readings to equivalent dose to the fetus have been calculated by using Monte Carlo simulation. These coefficients are called NUD (Normalized Uterine Dose) and may be used depending on the position (i.e. over or under the lead apron if it is worn) of the dosimeter or if no lead apron is worn.

In the present work, typical fetal equivalent doses to the staff occupationally exposed to ionizing radiation in interventional radiology have been quantified by using personal monitoring doses from an Approved Dosimetry Service (ADS) database. Monthly average whole body doses from 453 staffs involved in high dose procedures were collected from the ADS and were analyzed in order to estimate fetal equivalent dose to pregnant staff. These whole body doses were used to represent the dose received from all procedures performed by the technologist (occupational dose). The Fetal Dose, F_{eq}, may therefore be estimated as

$$F_{eq} = \overline{L_m} \cdot \overline{NUD_{oc}} \tag{1}$$

Where $\overline{NUD_{oc}}$ is the occupational normalized uterine dose, and $\overline{L_m}$ is the average whole body dose by staff. Assuming that the pregnant staff wore 0.25 mm lead equivalent apron during every procedure, the occupational normalized uterine dose is equal to 0.05 mSv/mGy.

2.2. Monthly Fetal Dose Reference

According to Publication 453 [1], the fetus of a radiation worker should be protected by the application of a supplementary equivalent dose limit of 1 mSv to the surface of the woman's abdomen (lower trunk) for the remainder of the pregnancy, once it has been declared. With this value, and assuming a total of 40 weeks of a declared pregnant worker in an early pregnancy, the Monthly Fetal Dose Reference, F_r, was introduced in this work and is equal to 0.1 mSv/month.

2.3. Radiation Risk

For purposes of estimating the risks following in utero exposure, a no-threshold concept is assumed. The risk is calculated from Equation 2

$$p_R = R_e \cdot F_{eq} \tag{2}$$

Where p_R is the risk associated with the dose F_{eq}, and R_e is the risk coefficient. Risks coefficients published in the literature [4-6] are shown in the Table 1.

Table 1. Risks coefficients published in the literature [4-6].

Deleterious Effect	R_e (mSv^{-1})
Decline in IQ score	2.90×10^{-2}
Severe mental retardation	4.30×10^{-4}
Hereditary effects	2.49×10^{-5}
Fatal childhood cancer	1.75×10^{-5}
Fatal leukemia	1.25×10^{-5}

3. RESULTS

The F_{eq} frequency distribution for all the 453 staffs involved in high dose procedures is shown in the Figure 1. The results showed that 426 staffs, 94% from the sample, presented the F_{eq} less than the reference adopted for this work, F_r. The equivalent average dose obtained for this work was 0.040(30) mSv/month, with a fetal dose range of 0.081 - 0.363 mSv/month.

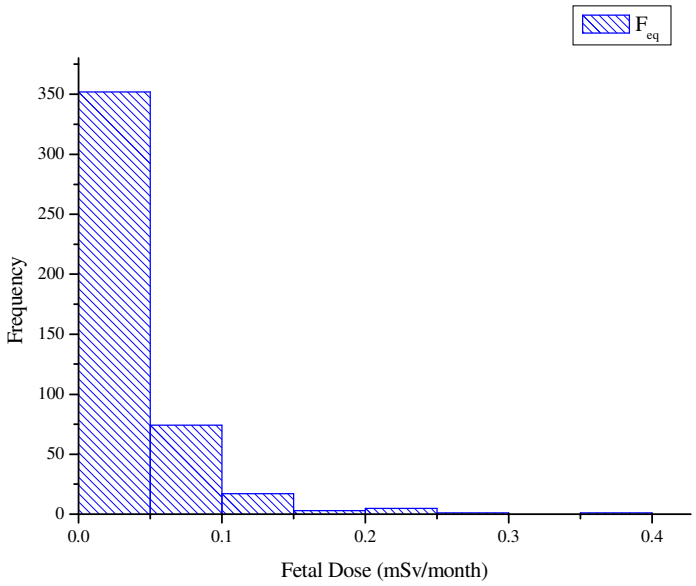

Figure 1. Histogram obtained from observations of the fetal dose, F_{eq}, for all the staffs involved in high dose procedures. The graph represents the distribution of 453 workers.

The results showed that only 27 staffs, 6% from the sample, presented the fetal dose higher than the reference adopted for this work, F_r. The F_{eq} frequency distribution in this case is shown in the Figure 2.

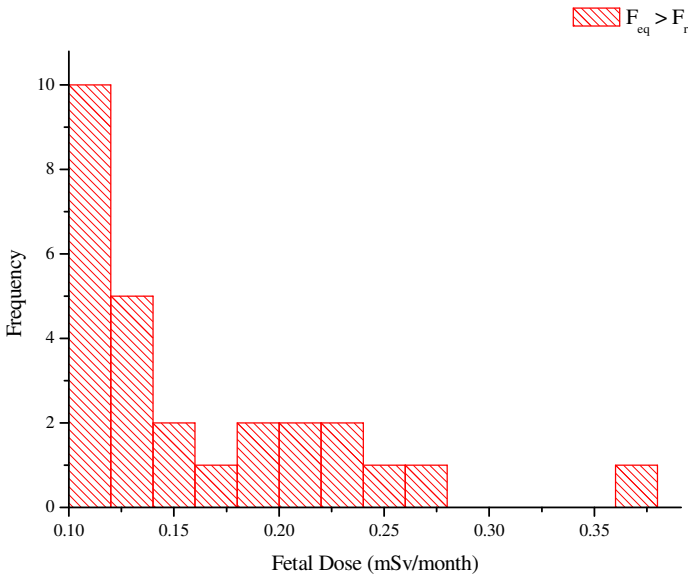

Figure 2. Histogram obtained from observations of the fetal dose, F_{eq}, whose found values were above the reference value adopted for this work, F_r. The graph represents the distribution of 27 cases of workers that presented $F_{eq} > F_r$.

The radiation risks of induction of decline in IQ score, severe mental retardation, hereditary effects, fatal cancer and leukemia, were obtained for the 27 cases of workers that presented $F_{eq} > F_r$. The results, and the error bars obtained with the error propagation method, are shown in the Figures 3, 4, and 5.

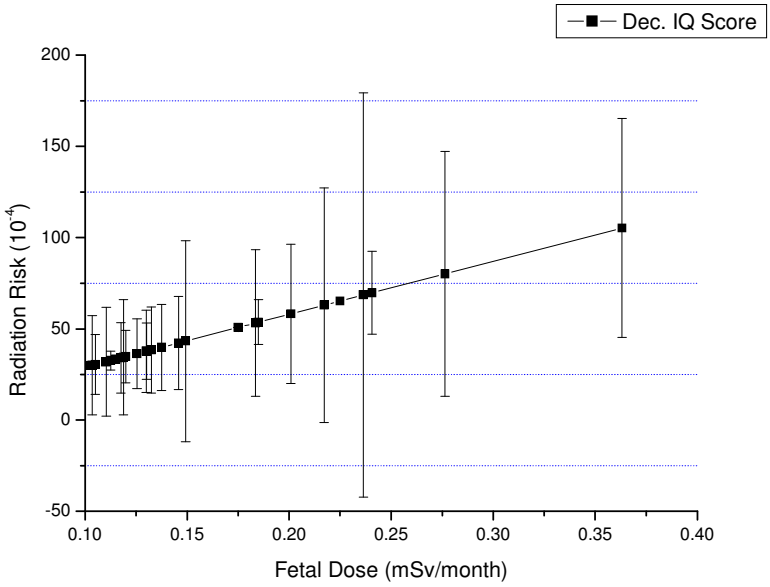

Figure 3. The radiation risks, with error bars, of decline in IQ score for the 27 cases of workers that presented $F_{eq} > F_r$.

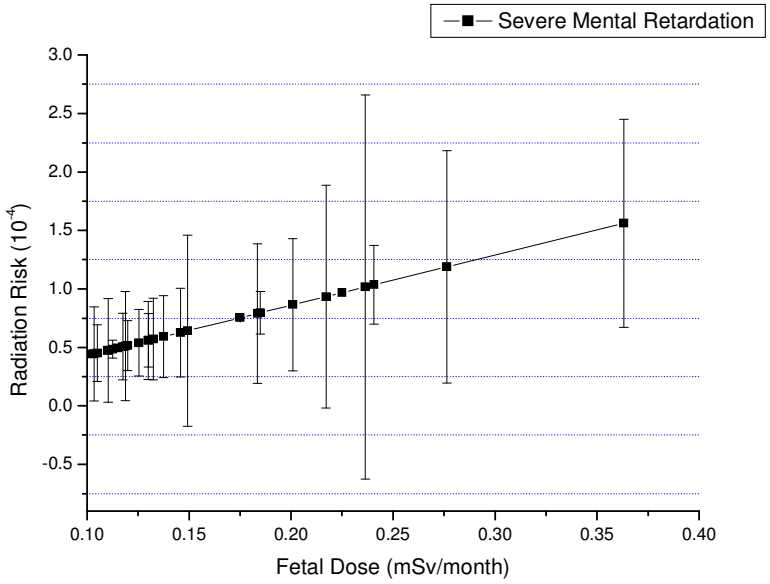

Figure 4. The radiation risks, with error bars, of induction of severe mental retardation for the 27 cases of workers that presented $F_{eq} > F_r$.

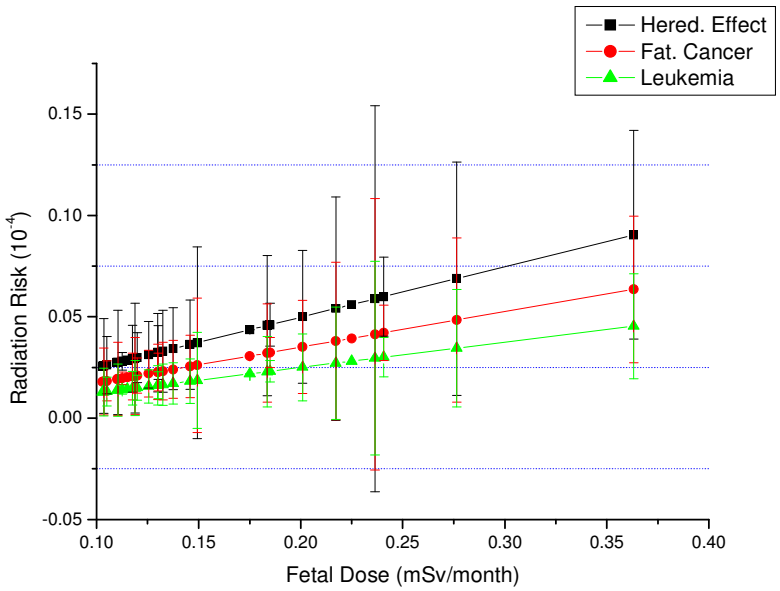

Figure 5. The radiation risks, with error bars, of induction of hereditary effects, fatal caner and leukemia, for the 27 cases of workers that presented $F_{eq} > F_r$.

3. CONCLUSIONS

The result suggest that during the first two months of pregnancy (when the female staff member and/or physician may not be aware of a pregnancy) a female radiation staff working under similar conditions which give whole body dose shown in the used database will subject the fetus to an equivalent average dose of 0.040(30) mSv/month during that period (fetal dose range 0.081 - 0.363 mSv/month). It may be deduced that the equivalent dose limit to the fetus will not be exceeded even if she continues to work under similar conditions for the rest of the pregnancy. The radiation risks of induction of related diseases per mean exposure were also obtained for the most critical case. The results obtained were 105.3 x 10^{-4} (1.053 %) and 1.6 x 10^{-4} (0.016 %) to the induction of decline in IQ score and mental retardation per mean fetal dose, and 0.09 x 10^{-4} (0.0009 %), 0.06 x 10^{-4} (0.0006 %) and 0.05 x 10^{-4} (0.0005 %) to the induction of hereditary effects, fatal leukemia and fatal cancer, per mean fetal dose, respectively.

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