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RADIATION-INDUCED EFFECTS IN HUMANS AFTER IN UTERO EXPOSURE: CONCLUSIONS FROM FINDINGS AFTER THE CHERNOBYL ACCIDENT

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Abstract. A threshold dose of 100 mSv is assumed for radiation-induced teratogenic effects in publication No. 90 of the ICRP (2003) which is based on the findings in the Japanese A-bomb survivors. A variety of observations about congenital malformations, fetal loss, stillbirths, and infant deaths, as well as Down´s syndrome after the Chernobyl release demand to point out the incompleteness of the Japanese data. Radiation-induced developmental effects by Chernobyl, especially in great distances, are usually denied because of the low values of the estimated human exposures. Biological dosimetry in contaminated regions, however, shows that physical dose estimations lead to considerable underestimations of the true exposure. The assumptions about teratogenic effects by incorporated radionuclides have to be revised.

Keywords: radiation-induced malformations, perinatal mortality; Chernobyl effects in children; dosimetry of incorporated radioactivity, biological dosimetry

Introduction

The evaluation of radiaton risks by international radiation protection committees is based on the findings in the Japanese A-bomb survivors. The effects observed there after prenatal exposure were mental retardation and reduced head size while no other significant detriment was detected. The time between the 8^{th} and 15^{th} week of gestation is thought to be the period of risk.

As was pointed out by different researchers the Japanese data suffer, however, from several restrictions which limit their suitability as a general base for deriving radiation risks. One point is a probable and proven severe selection bias because of the catastrophic situation after the bombing. Another objection which must be stressed especially considering perinatal effects is the fact that the investigations of the Radiation Effects Research Foundation (RERF) in Hiroshima did not begin earlier than 5 years after the catastrophe when the RERF research institute was established there. The completeness of the data must therefore be doubted.

The reduced selection of assumed effects and the assertion of a threshold dose as high as 100 mSv by the ICRP contradicts former findings in experimental research (Table 1) and several observations in humans already before the Chernobyl accident. Tables 2-5 list the results of studies in regions affected by fallout from the latter.

TABLE 1. Minimum dose below 100 mSv which showed significant effects after in utero x-ray exposure in experimental studies (data taken from Fritz-Niggli, 1997)

	Dose mSv	Days after conception	Effects	Reference
Mice	10	8	Cumulated developmental defects	Michel, Fritz-Niggli 1977
	50	0.5	Death of the embryo	Rugh, Grupp 1959
	50	0.5; 1.5	Death of the embryo, polydactyly	Ohzu 1965
	50	7.5	Death of the embryo, skeletal malformations	Jacobsen 1966
Rats	10	18	Reflex distortions	UNSCEAR 1986
	50	0.4; 0.7	Fetal death	Roux et al. 1983

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TABLE 2. Observed increase of congenital malformations after in utero exposure by the Chernobyl accident

Country	Effects	References
Belarus National Genetic Monitoring Registry	Anencephaly, spina bifida, cleft lip and/or palate, polydactyly, limb reduction defects, esophageal atresia, anorectal atresia, multiple malformations	Lazjuk et al. 1997
Belarus Highly exposed region of Gomel	Congenital malformations	Bogdanovich 1997; Savchenko 1995
Chechersky district of the Gomel region	Congenital malformations	Kulakov et al. 1993
Mogilev region	Congenital malformations	Petrova et al. 1997
Brest region	Congenital malformations	Shidlovskii 1992
Ukraine Polessky district of the Kiev region	Congenital malformations	Kulakov et al. 1993
Lygyny region		Godlevsky, Nasvit 1998
Turkey	Anencephaly, spina bifida	Akar et al.1988/89; Caglayan et al. 1990; Güvenc et al. 1993; Mocan et al. 1990
Bulgaria, region of Pleven	Malformations of heart and central nervous system, multiple malformations	Moumdjiev et al. 1992
Croatia	Malformations by autopsy of stillborns and cases of early death	Kruslin et al. 1998
Germany German Democratic Republic, Central registry	Cleft lip and/or palate	Zieglowski, Hemprich 1999
Bavaria	Cleft lip and/or palate Congenital malformations	Scherb, Weigelt 2004 Korblein 2003a, 2004; Scherb, Weigelt 2003
Annual Health Report of West Berlin 1987	Malformations in stillborns	Strahlentelex 1989
City of Jena (Registry of congenital malformations)	Isolated malformations	Lotz et al. 1996

TABLE 3. Observed increase of stillbirths, infant deaths, spontaneous abortions, and low birth weight after in utero exposure by the Chernobyl accident

Country	Effects	References
Belarus Selected regions	Perinatal deaths*)	Petrova et al. 1997
Chechersky District near Gomel	Perinatal deaths	Kulakov et al. 1993
Gomel region	Perinatal deaths	Korblein 2003a,b
Ukraine Polessky District near Kiev	Perinatal deaths, reduced birth rate**), premature births	Kulakov et al. 1993
Lygny region	Early neonatal deaths	Godlevsky, Nasvit 1998
Zhitomir oblast, Kiev region, Kiev City	Perinatal deaths, reduced birth rate	Korblein 2003a,b
Europe: Greece, Hungary, Poland, Sweden	Stillbirths	Scherb et al. 1999b, 2000b, 2003
Poland	Infant mortality	Korblein 2003a
Norway	Spontaneous abortions	Ulstein et al. 1990
Hungary	Low birth weight	Czeisel 1988
Finland	Premature births among malformed children Reduced birth rate Stillbirths	Harjulehto et al. 1989 Harjulehto et al. 1991 Scherb, Weigelt 2003
Germany Total (FRG + GDR)	Perinatal deaths	Korblein, Kuchenhoff 1997; Scherb et al. 2000a,2003
Southern Germany	Early neonatal deaths	Lüning et al. 1989
Bavaria	Perinatal deaths, stillbirths Reduced birth rate	Grosche et al. 1997; Scherb et al. 1999a, 2000a, 2003 Korblein 2003a

*) Perinatal deaths summarize stillbirths and deaths in the first 7 days from birth
**) Reduced birth rate is considered as a measure for spontaneous abortions

TABLE 4. Increase of Down´s syndrome after in utero exposure by the Chernobyl accident

Region	Results	References
Belarus National Genetic Monitoring Registry	Excess 1987-1994 ca. 17 % Excess peak in January 1987	Lazjuk et al. 1997 Zatsepin et al. 2004
Western Europe	Beginning 1 y after the accident, reaching 22% within 3 years	Dolk et al. 1999
Sweden	„Slight“ excess in most exposed areas (30 %)	Ericson, Kallen 1994
Scotland, Lothian region (0.74 million inhabitants)	Excess peak in January 1987 (2-fold significant)	Ramsay et al. 1991
South Germany	Elevation found by investigations of amniotic fluid	Sperling et al. 1991
Berlin West	Excess peak in January 1987	Sperling et al. 1991, 1994

TABLE 5. Observed health defects in children after in utero exposure by the Chernobyl accident except malformations and Downs´s syndrome

Belarus Selected regions	Mental disorders Speech-language disorders, mental retardation	Kondrashenko et al. 1996 Kolominsky et al. 1999
Chechersky District near Gomel	Diseases of respiratory organs, blood, circulation etc.	Kulakov et al. 1993
Stolin District in Brest region	Diseases of respiratory organs, glands, blood, circulation, digestive organs	Sychik, Stozharov 1999a,b
Belarus, Ukraine, Russia	Mental retardation and other mental disorders	Kozlova et al. 1999
Ukraine Polessky District near Kiev	Diseases of respiratory organs, blood, circulation etc.	Kulakov et al. 1993
Rovno Province	Childhood morbidity	Ponomarenko et al. 1993
Immigrants to Israel from contaminated areas	Asthma	Kordysh et al. 1995

Estimated exposures from the Chernobyl accident

Inspite of the overwhelming evidence of effects observed also in countries far away from the Chernobyl event they are ignored by international radiation protection committees. They assume that the exposures of the population are much too low to generate teratogenic effects. Indeed, the physical dose estimates resulted in mean effective life-time exposures in large regions of Europe and in Turkey below 1.2 mSv (UNSCEAR 1988). The highest average dose for a subregion in the first year after the accident is derived to 2 mSv in Belarus.

These estimates show, however, large discrepancies in comparison with biological dosimetry. Investigations of unstable and stable chromosome aberrations in the lymphocytes of persons in the contaminated regions have been done by a variety of research groups in rather large collectives directly after the accident or some years later. Dicentric chromosomes can be considered as radiation-specific and most sensitive because of their very low and nearly constant rate in unexposed persons (Hoffmann and Schmitz-Feuerhake, 1999).

It is a general experience that the observed rates of dicentric chromosomes after Chernobyl are considerably higher – by 1 or 2 orders of magnitude – than would be expected from physically derived dose estimates. This evaluation is possible although the dose-effect relationships in cases of incorporated radioactivity are not known. For low dose homogenous exposure by low LET irradiation the rate of dicentrics can be considered as dose-proportional which follows from studies in the range of background exposure. In European countries far from the Chernobyl site the exposure of the tissues except the thyroid is assumed to be mainly generated by ^{137}Cs and ^{134}Cs which distribute homogenously inside the body. The whole body doubling dose for dicentrics by homogenous low LET radiation is about 10 mSv (Hoffmann and Schmitz-Feuerhake, 1999). Elevations of dicentrics in persons which are higher than 2-fold would therefore mean that the whole body dose exceeds 10 mSv. Such elevations have been found manifold after Chernobyl. Findings for Austria, Germany and Norway are shown in Table 6.

A remarkable finding in many of the chromosome studies is that they report an overdispersion of the dicentrics and the occurrence of multiaberrant cells (Bochkov and Katosova 1994; Hille et al. 1995; Salomaa et al. 1997; Scheid et al. 1993, Sevan`kaev et al. 1993; Stephan and Oestreicher 1989; Verschaeve et al. 1993). This is an indication for a relevant contribution of incorporated α-activity which is not considered adequately in the physical dose estimates.

TABLE 6. Chromosome aberrations in lymphocytes of persons living in West European regions contaminated by Chernobyl releases; dics dicentric chromosomes, cring centric rings

Region	Sample	Date of study	Method	Results mean elevation	Reference	Remarks
Salzburg, Austria	17 adults	1987	dics+crings	circ 4-fold	Pohl-Rüling et al. 1991	
Germany, southern regions	29 children + adults	1987-1991	dics+crings	circ 2.6-fold	Stephan, Oestreicher 1993	physical dose estimate <0.5 mSv
Norway, selected regions	44 reindeer sames 12 sheep farmers	1991	dics+crings	10-fold	Brogger et al. 1996	physical dose estimate 5.5 mSv

Conclusions

The data in tables 2-6 show that neither the exposure of populations affected by the Chernobyl accident nor the effects have been evaluated correctly up to now. It must be discussed, however, that some of the authors interprete their somatic findings as geneticly induced. In cases of continual exposure by radioactivity it is, indeed, not always to decide whether the damage occured in utero or by preconceptional mutation. Intrauterine deaths and infant deaths as well as malformations are also inducable by irradiation of the germ-cells in fathers or mothers. Rugh (1962) has already stated that the appearance of certain malformations of the brain is quite similar after preconceptional and in utero irradiation.

The studies in the A-bomb survivors did not show significant genetic effects. Investigations in the offspring of a large cohort of Sellafield workers, however, which were initiated after the leukaemia findings in the proximity of this British nuclear reprocessing plant, confirm a rise of stillbirths and congenital anomalies caused by preconceptional exposure of the fathers (Parker et al. 1999). The cited Chernobyl studies may therefore include some overlap of transgenerational and teratogenic effects. Although this conclusion demands further scientific effort for differentiation the fetus must be considered as most vulnerable by low dose exposures as was assumed in the early times of radiation research.

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