Mental risk among *in utero* exposed children following the Chernobyl accident

S. Igumnov and V. Drozdovitch[1]

Belarussian Medical Academy of Postgraduate Training, P. Brovki Str. 3, Minsk 220013, Belarus
[1] *Institute of Power Engineering Problems, National Academy of Sciences of Belarus, Sosny, Minsk 220109, Belarus*

Abstract. The study examined psychological development in 250 children at the age of 6–7 and 10–12, who had exposed in the prenatal period at the time of the Chernobyl accident in 1986. These children were compared to a control group of 250 children of the same age from non- and slightly contaminated areas of Belarus. The examination included psychiatric examination and intellectual assessment as well as the estimation of thyroid exposure *in utero*. The children of the exposed group had a lower mean full-scale IQ compared to the control group. Average IQ for subgroup of high exposed children (thyroid doses more than 1 Gy) was lower in comparison with average IQ for whole exposed group. The relative risk of mental and behavioural disorders has been estimated for emotional disorders OR=2.67, P<0.001. We conclude that probably a significant role in the genesis of borderline intellectual functioning and emotional disorders in the exposed group of children was played by unfavorable social-psychological and social-cultural factors, the break of microsocial contacts and adaptation difficulties, which appear following the evacuation and relocation from the contaminated areas.

INTRODUCTION

The accident at the nuclear power plant in Chernobyl in northwestern Ukraine, on April 26, 1986, released large amounts of radioactive materials. Of particular concern were the releases of 1.3 to 1.8 exabecquerels (35–50 million curies) of ^{131}I plus other shorter-lived radioiodines [1]. The radioactive cloud from the destroyed reactor, which reached the territory of Belarus within a few hours after the accident, resulted in population exposure, in particular rather high internal doses to the thyroids.

The factors that might cause mental and behavioural disorders were prenatal external exposure and internal exposure of the thyroid gland to radioiodines. In particular, the absorbed doses are 2–3 times higher in the developing thyroid gland of embryo and fetus than in the thyroid gland of the mother [2]. Radiation affecting the thyroid gland leads to involvement of other endocrine glands in the pathological process through the thyroid gland-hypophysis-hypothalamus system. This may cause psychological retardation, retardation of the central nervous system maturation, low psychological and emotional development and other mental disorders [3]. There are scanty data in the literature concerning the neurological and psychological status of persons exposed from this source during the prenatal and neonatal period. According to the [4], the possible negative effect of radiation on the psychological development of *in utero* exposed persons can be intensified by unfavourable psychosocial factors such as forced relocation or adaptation to new conditions of living in the contaminated area. These factors lea to psychoemotional stress in parents, and affected family relations. The educational process can also lead to "psychosocial isolation" of relocated persons. Thus, in estimating the influence of the Chernobyl accident and its effects on the psychological development of persons, it is necessary to take into account both pre- and postnatal exposure and other exogenic factors, and psychosocial factors.

Article published by EDP Sciences and available at http://www.radioprotection.org or http://dx.doi.org/10.1051/radiopro/2002171

1. MATERIALS AND METHODS

The exposed group was 250 children, born during the period from May 1986 to February 1987. During the Chernobyl accident their mothers in different periods of pregnancy lived in the settlements with ^{137}Cs soil deposition densities ranged from 100 to 15400 $kBq \cdot m^{-2}$. Among them mothers of 14 children lived in town Pripyat (Ukraine) and were evacuated in Belarus shortly after the accident. In 1991–1993 the families of the children were evacuated from the contaminated settlements to Minsk region and Minsk-city. The control group was formed by means of random selection and consisted of 250 children who were born in the period from May 1986 to February 1987. Their mothers had constantly lived in non- and slightly contaminated areas of Belarus in the settlements with ^{137}Cs soil deposition densities ranged from 0.2 to 200 $kBq \cdot m^{-2}$. The distribution of children according to sex and the period of gestation at the time of the Chernobyl accident given in Table 1 shows that there are nor statistically significant differences in age and sex structure between exposed and control groups. Also there were no relevant distinctions in education levels as well as in social status of parents of the children belonging to the exposed and control group (the most of them were farmers, workers and employers). It should be noted that parents of children from the control group had had no professional contact with sources of ionizing radiation.

Table 1. Age and sex distributions of children of exposed and control groups

Gestation period, weeks	Number of children in						Comparison between groups, *P*	
	exposed group			control group				
	M	F	Total	M	F	Total	in sex	total
0-7	35	24	59	38	32	70	0.57	0.26
8-15	29	24	53	28	24	52	0.93	0.91
16-25	29	27	56	30	28	58	0.99	0.83
> 25	33	49	82	32	38	70	0.50	0.24
Total	126	124	250	128	122	250	0.86	–

The psychiatric examination of the children of both groups was performed by means of semi-structured clinical interview based on the diagnostical criteria of ICD-10, chapter V (Mental and behavioural disorders). The intellectual development of the above children was examined by means of psychological testing using the Wechsler Intelligence Scale for Children - WISC-III UK [5]. We also used clinical-psychological and social-psychological methods: studying of microsocial surrounding of children; analyzing of situational and personal anxiety of parents (a modified variant of the test "The State-Trait Anxiety Inventory" (STAI) [6]; and comparing the level of education obtained by parents (incomplete secondary, secondary, special secondary, higher educational).

Thyroid exposure to inhabitants of Belarus has been formed due to different pathways and radionuclides. The major contribution to the thyroid dose was the ingestion of ^{131}I with contaminated milk with minor contribution from ingestion of ^{131}I with contaminated leafy vegetables. Inhalation can be considered as important pathway only for persons shortly evacuated after the accident and for those who radically reduced their consumption of locally produced foodstuffs. Thyroid doses were estimated for children exposed *in utero* based on the results of individual thyroid dose estimates for the mother and a transfer coefficient from mother's to the foetus that takes into account the period of gestation at the time of exposure [7]. For mothers evacuated shortly after the accident from town Pripyat thyroid dose estimates based on results of [8]. For other persons only thyroid doses due to ^{131}I ingestion have been considered in our paper. Thyroid doses from iodine ingestion have been reconstructed on the basis of results of ^{131}I thyroid activity measurement (if such data were available for mother of child included in the study) and applying of an ^{131}I environmental transfer model adapted to Belarusian conditions [9].

To estimate the individual thyroid doses the following information about the life-style of the mother during the iodine period was obtained by personal interview: (a) consumption rates of most important for

iodine intake foodstuffs: fresh milk and milk products; (b) origination of consumed foodstuffs; (c) interruption of consumption of local produced foodstuffs; (d) residence at the time of accident; (e) migration during April-May 1986; (f) iodine prophylaxis, etc.

The uncertainties factors attached to the reconstructed individual thyroid doses were estimated [10] to be in range from 1.7 to 2.8 depending on used methodology (direct thyroid activity measurements or model calculations). Because of these large uncertainties children from both groups were assigned to one of the three dose intervals: less than 0.3, 0.3–1.0 and more than 1.0 Gy. These three dose intervals were used for the most clinical and dosimetry analysis rather than individual thyroid doses.

2. RESULTS AND DISCUSSION

2.1. Anthropometric parameters

For retrospective analysis of the peculiarities of the prenatal period the mass of body, length and head size have been taken from birth records. The data characterizing of these parameters appeared to be identical in both groups of children (see Table 2). On the following stages of the development of the children no differences in the temps of growth and increase of the head size were noticed either.

Table 2. Anthropometric parameters of newborn children of exposed and control groups

Parameter	Exposed group	Control group	*P*
Weigh, g	3440±390	3420±330	<0.001
Length, cm	52.0±1.9	51.9±1.6	<0.001
Head size, cm	34.4±1.6	34.4±1.6	<0.001

2.2. Thyroid doses

For 64 children from exposed group and for 72 children from control group thyroid dose was estimated to be zero. It is due to the fact that gestation age of the foetus at the time of the accident was less than 10 weeks and there was not of uptake of ^{131}I by undeveloped thyroid [11]. Means and medians for those distributions are: exposed group, 0.39 and 0.23 Gy; control group, 0.04 and 0.01 Gy. Means of thyroid doses for the control group is significantly lower that for exposed children ($P<0.001$). Among the children of exposed group the maximal individual dose of prenatal exposure to the thyroid gland is estimated to be 4.1 Gy.

Table 3 compares the children from exposed and control groups in the terms of the three specified above dose intervals. As in the comparison of mean thyroid dose those two groups differ significantly, the odds ratio for the lowest dose interval compared to the two highest dose intervals ($OR=41.7$) shows strong relationship between prenatal thyroid doses and exposed/control status of children.

Table 3. Comparison of thyroid doses of children of exposed and controls groups

	Thyroid dose interval, Gy			Total	χ^2	*P*
	< 0.3	0.3–1.0	> 1.0			
Exposed group	135	95	20	250		
Control group	245	5	–	250		
Total	380	100	20	500	132.7	<0.001

2.3. IQ test results

At the age 6–7 the children of the exposed group had a lower mean full-scale IQ compared to the control group (89.6±10.2 vs 92.1±10.5, P=0.007). We found that the children of the exposed group had a relatively more cases of a low average range of full-scale IQ (IQ=80–89) as compared to the control group (see Table 4). Clinically low average range was characterized by moderate disorders of gnostic processes, poor motivation and the lack of intellectual prerequisites (active attention, short-term memory, constructional functions, etc.). By the age 10–12 years there were no statistically significant distinctions between mean IQs of the exposed and control groups (94.3±10.4 vs 95.8±10.9, P=0.117) and between IQs of the exposed and control groups (see Table 4).

Table 4. Distribution of IQ in the exposed and control groups of children

Full Scale Intelligence Quotient (IQ)	Exposed group		Control group		χ^2	P
	N	%	N	%		
at the age of 6–7						
≥ 90 (average and high average range)	125	50.0	158	63.2	8.866	0.003
80-89 (low average range)	92	36.8	66	26.4	6.255	0.012
70-79 (borderline intellectual functioning)	27	10.8	22	8.8	0.566	0.452
≤ 69 (exceptionally low range)	6	2.4	4	1.6	0.408	0.523
at the age of 10–12						
≥ 90 (average and high average range)	177	70.8	193	77.2	2.661	0.103
80-89 (low average range)	56	22.4	42	16.8	2.488	0.115
70-79 (borderline intellectual functioning)	11	4.4	10	4.0	0.049	0.825
≤ 69 (exceptionally low range)	6	2.4	5	2.0	0.093	0.760

2.4. ICD Diagnoses

The data for children who were exposed to the influence of radionuclides prenatally at different period of gestation showed a relative increase in psychological disorders compared to the control group. This was mainly due to the increased prevalence of cases of specific developmental disorders of speech and language, specific developmental disorders of motor function, emotional disorders with onset specific to childhood and disorders of social functioning. The prevalence rates of mental and behavioural disorders among the children of exposed and control groups are shown at Table 5.

The borderline intellectual functioning was accompanied in some cases by specific developmental disorders of speech and language, nocturnal enuresis, tic disorders and subtle nonfocal neurological signs. At the elementary school age the specific developmental disorders of speech and language, as a rule, lead to the specific disorders of scholastic skills such as dyslexia, dyscalculia and other kinds of learning disability (r=0.68, P<0.01). Clinically marked mental retardation was found in 5 cases in the both groups. In two cases of mental retardation in the exposed group vs one case in the control group microcephaly was diagnosed.

The relative risk of mental and behavioural disorders has been estimated as the ratio of chances (odds ratio) according to the [12]. As can be seen from Table 5 the relative risk of the development of emotional disorders is estimated to be OR=2.67 (P<0.001). The frequency of the formation of mental retardation, learning disorders, hyperkinetic disorders and other mental and behavioural disorders in children from both groups was approximately the same.

Table 5. Prevalence rates of mental and behavioral disorders among children

Mental and behavioral disorders	ICD-10 code	Exposed group		Control group		χ^2	P	Odds ratio (OR)
		N	%	N	%			
Mild mental retardation	F70.9	5	2.0	5	2.0	0	1.0	1.00 (0.57–6.93)[1]
Specific developmental disorders of speech and language	F80	20	8.0	21	8.4	0.027	0.87	0.95 (0.84–3.75)
Specific developmental disorders of scholastic skills	F81	18	7.2	13	5.2	0.86	0.35	1.41 (0.95–4.13)
Specific developmental disorders of motor function	F82	11	4.4	6	2.4	1.52	0.22	1.86 (0.72–5.44)
Disturbance of activity and attention	F90.0	12	4.8	11	4.4	0.05	0.83	1.10 (0.86–4.58)
Emotional disorders with onset specific to childhood	F93	45	18.0	19	7.6	12.11	<0.001	2.67 (1.12–3.50)
Disorders of social functioning	F94.0	12	4.8	9	3.6	0.45	0.50	1.35 (0.82–4.79)
Transient tic disorder	F95.0	16	6.4	12	4.8	0.61	0.44	1.36 (0.91–4.28)
Others	F98	23	9.2	17	6.8	0.98	0.32	1.39 (1.03–3.80)
One or more diagnoses		101	40.4	62	24.8	13.85	<0.001	2.06 (1.35–2.90)

[1] 95 % confidence interval

2.5. Family study

In the course of family examination, we examined mothers and fathers of all children in the exposed and control groups using the test "The State-Trait Anxiety Inventory". According to the data obtained, the mothers of children in the exposed group were characterized by an increased prevalence of high personal anxiety compared to the control group. High personal anxiety was marked by excessive emotional lability, dread of expected difficulties, decrease of self-esteem. High degree of personal anxiety was also seen in fathers of children of the exposed group compared to the control group. There was a moderate correlation between high personal anxiety in parents and emotional disorders in children: for mothers r=0.38, $P<0.05$; for fathers r=0.43, $P<0.01$.

In the exposed group we found a positive moderate correlation between the intellectual level (IQ) of children and the educational level of their parents – mothers (r=0.50, $P<0.01$) and fathers (r=0.52, $P<0.01$). The correlation between the intellectual level of the children of the control group and the educational level of their parents was relatively lower – mothers (r=0.41, $P<0.05$) and fathers (r=0.42, $P<0.05$). This fact can be explained by a significant disintegration of the social infrastructure of the territories of strict radiation control, the outflow of qualified specialists in the area of education from these settlements. As the result, the formation of the conception about the outer world, the motivations to learning were determined mainly by the influence of their parents. In cases of psychological deprivation of children, determined by unfavorable family conditions, no information deficiency was made up.

Conclusions

This article focuses on clinical and psychological assessment of development in children exposed *in utero* following the Chernobyl accident. In comparison in other investigations conducted among children exposed *in utero* as a result of the Chernobyl accident [2,3] our study is characterized by prospective investigation (during 6 years) of relatively large group of children (500 persons). Advantage of our study is the reconstructed prenatal thyroid doses that were used in clinical and dosimetry analysis of obtained data.

The main conclusions of our investigation are the following:

1. At the age 6–7 the children of the exposed group had a lower mean full-scale IQ and a relatively more cases of a low average range of full-scale IQ (IQ=80–89) as compared to the control group. By the age 10–12 years there were no statistically significant distinctions between mean IQs of the exposed and control groups.

2. The relative risk of mental and behavioural disorders has been estimated for emotional disorders OR=2.67, P<0.001. The frequency of the formation of mental retardation, hyperkinetic disorders and other mental and behavioural disorders in children from both groups was approximately the same.

3. Probably a significant role in the genesis of borderline intellectual functioning and emotional disorders in the exposed group of children was played by unfavourable social-psychological and social-cultural factors such as a low educational level of parents, the break of microsocial contacts and adaptational difficulties, which appear following the evacuation and relocation from the contaminated areas.

Acknowledgements

The work for this publication was funded by the Belarusian Found for Fundamental Research, Contract #B99–120.

References

1. Summary of the Conference Results: One Decade after Chernobyl. Summing up the Consequences of the Accident (IAEA, Vienna, 1996). p.3–17.
2. Johnson J.R. *Health Phys* **43** (1982) 573–582.
3. Lyaginskaya A.M., Terestchenko N.Ya. and Vasilenko I.Ya. Radiobiological aspects of damage of thyroid gland in children after accident at the Chernobyl atomic power station». Chernobyl disaster and medical-psychological rehabilitation of suffered people, (Minsk, 1992) pp.105–108. (in Russian).
4. Nyagu A.I., Loganovsky K.N., Cheban A.K. et al. *Social and Clinical Psychiatry* **6** (1996) 23–36 (In Russian).
5. Wechsler D. Manual for the Wechsler Intelligence Scale for Children. Third Edition (The Psychological Corporation, Ltd., London, 1992).
6. Spielberger C., Gorsuch R. and Lushene R. The STAI Manual. (Consulting Psychologist Press, Palo Alto, CA, 1970).
7. Zvonova I.A. and Balonov M.I. The Chernobyl paper, edited by S.E.Mervin, M.I.Balonov (Research Enterprises Inc., Richland WA, 1993) pp.71–125.
8. Goulko G.M., Chumak V.V., Chepurny N.I. et al. *Radiat Environ Biophys* **35** (1993) 81–87.
9. Drozdovitch V.V., Goulko G.M., Minenko V.F. et al. *Radiat Environ Biophys* **36** (1997) 17–23.
10. Drozdovitch V.V. Uncertainties of the thyroid dose estimates used to evaluate radiological consequences of the Chernobyl accident (IPEP, Minsk, 1999) (In Russian).
11. Zanzonico P.B. and Becker D.V. The thyroid and pregnancy, edited by C.Beckers, D.Reinwein (Schattauer, Stuttgart–New York, 1991) pp.189–125.
12. Ahlbom A. and Norrell S. Introduction to Modern Epidemiology. 2nd edn. (Epidemiology Resources Inc., 1990).