A Review of Health Effects following the Chornobyl Accident: What can we expect from Fukushima?

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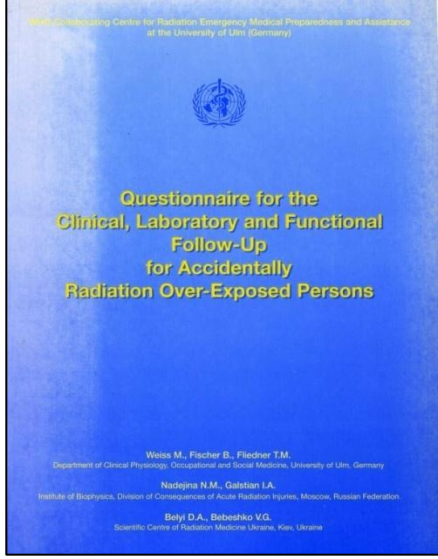
Health Effects of Chornobyl

- Effects due to ionizing radiation
  - High dose effects
  - Low-dose effects
- Effects due to a combined action of radiation and confounding factors
- Effects due to influence of psycho-social factors

Acute radiation syndrome

Degree	Number of patients under follow-up by periods			
	1986-1991	1992-1996	1997-2001	2002-2011
ARS-NC	93	81	63	54
ARS1-3	86	84	63	51
Total	**179**	**165**	**126**	**105**



Radiogenic effects were the main causes of late deaths (42):

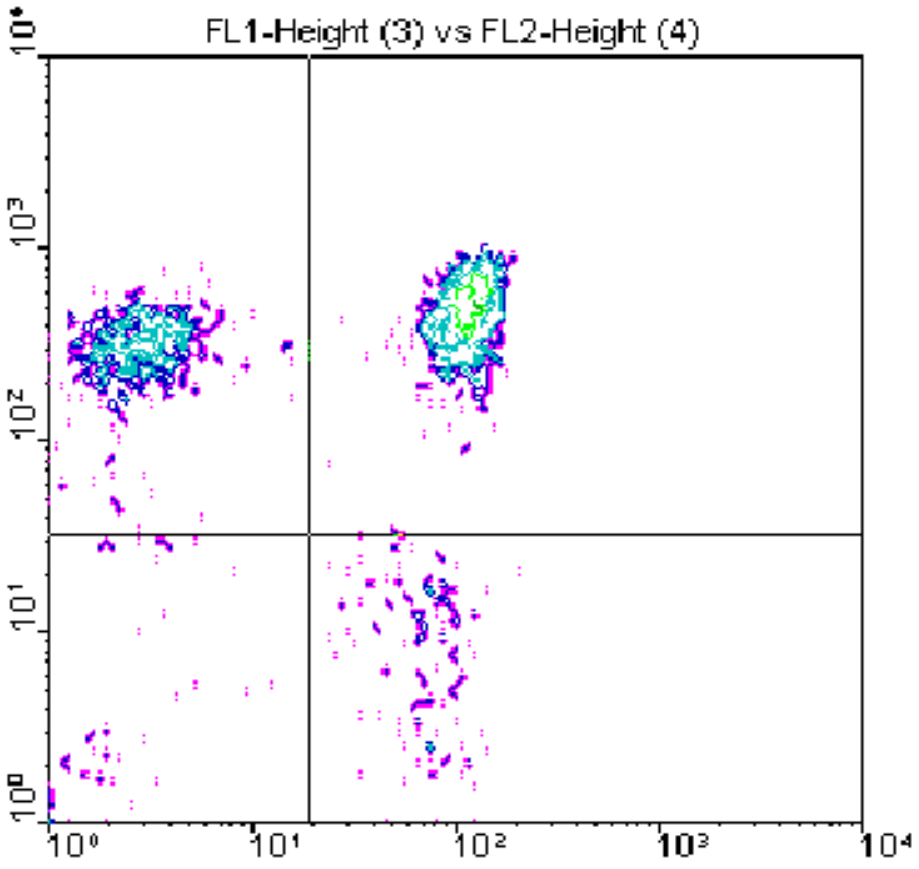
- Cancers and leukemia – **16**
- Cardiovascular – **14**

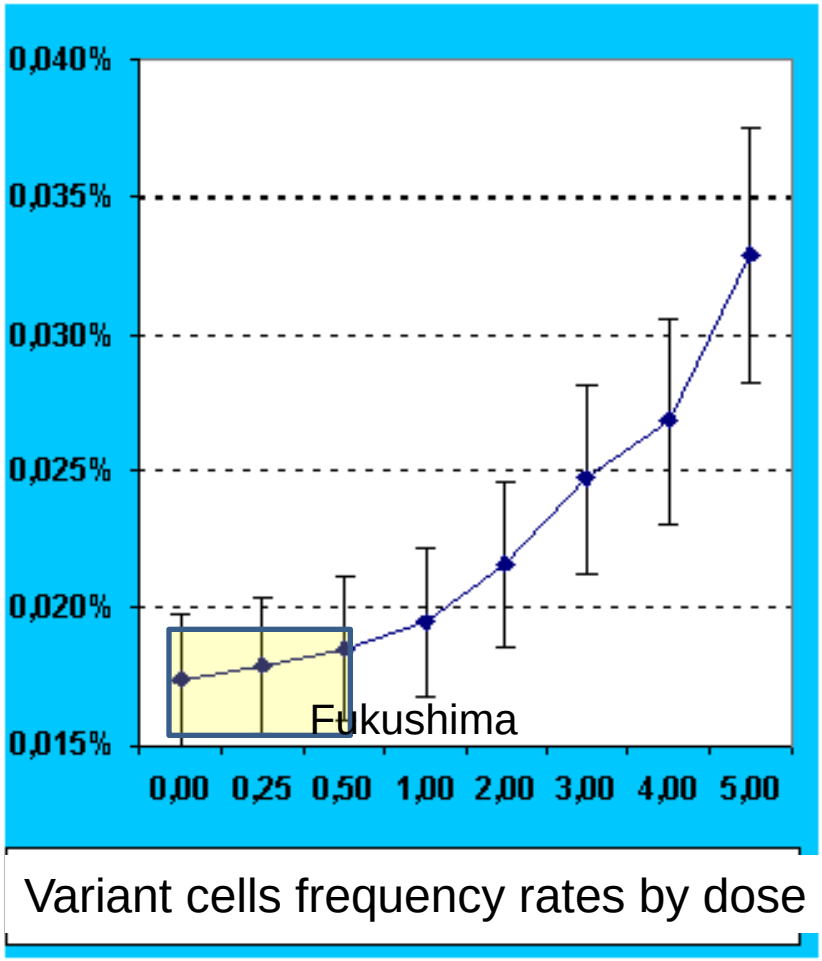
Immune system depression is still demonstrated in subjects with higher doses (over 2 Gy)

Mutations rates decrease with time

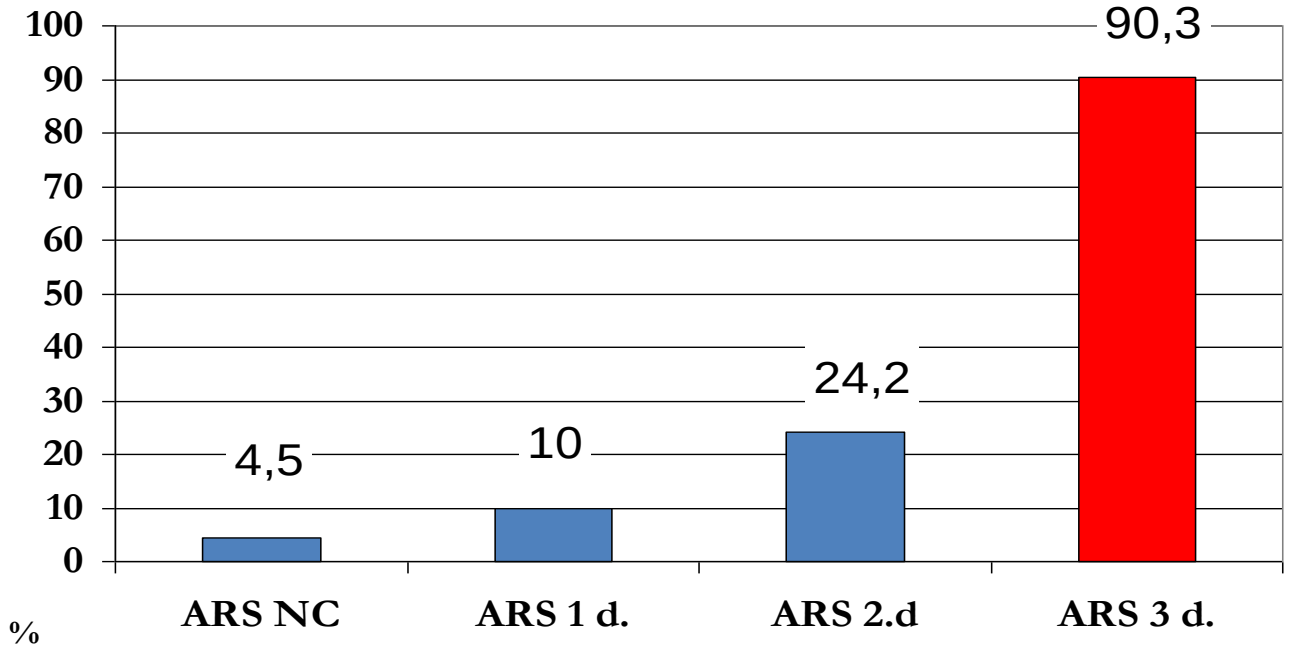
Belyi D, et al. Health Phys. (2010)

Radiation-induced non-lethal T-cell receptor changes



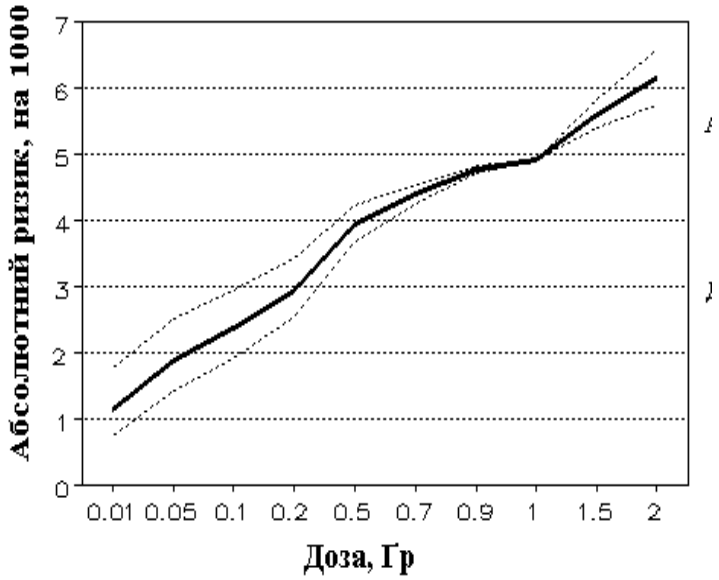


Radiation cataracts: 1 – ARS survivors



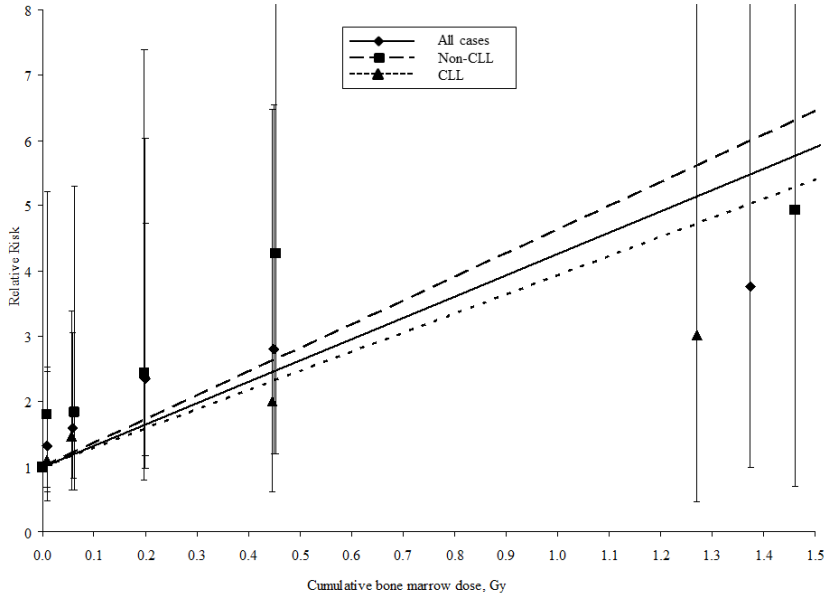
Radiation cataracts: 2 – exposed at low dose and rates

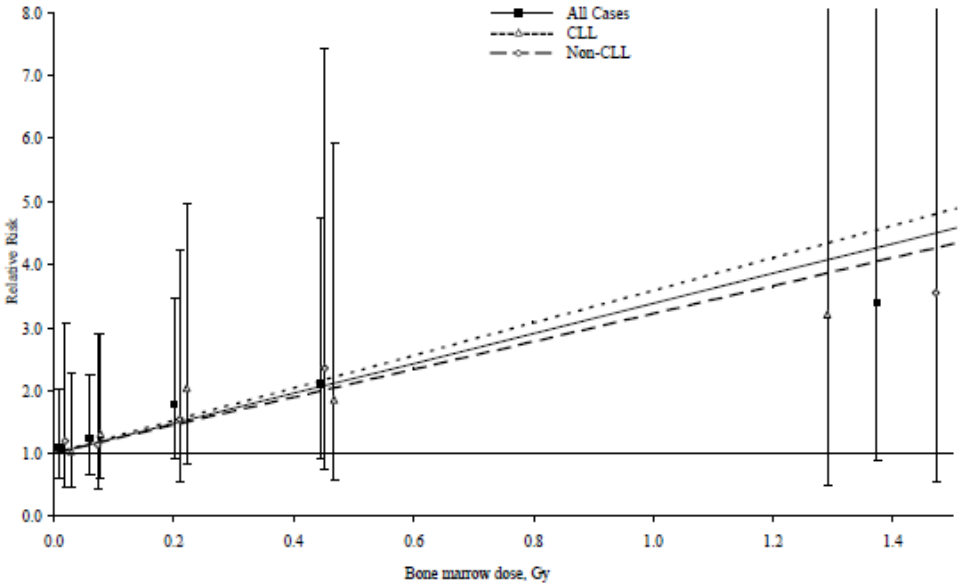
- The Ukrainian-American Chernobyl Ocular Study indicates that cataracts arising in cleanup workers cohort (n-8,000), corrected for the most important confounding factors, are related to the dose received.
- For the most part, the doses were less than 0.5 Gy of low-LET radiation acquired in a somewhat protracted/fractionated manner.
- A key finding was that the data were not compatible with a dose-effect threshold of more than 0.7 Gy



Additive-relative risk of:	Level	p
radiation cataract	3.451 (1.347; 5.555) per 1 Gy	< 0.05

Leukemia: the Ukrainian-American Study among Chornobyl Cleanup Workers from Ukraine





First **15 years**: ERR/Gy is **3,44** (95% CI 0,47; 9,78; p<0,01)

20 years: ERR/Gy is **2,38** (95% CI 0,49; 5,87; p<0,004)

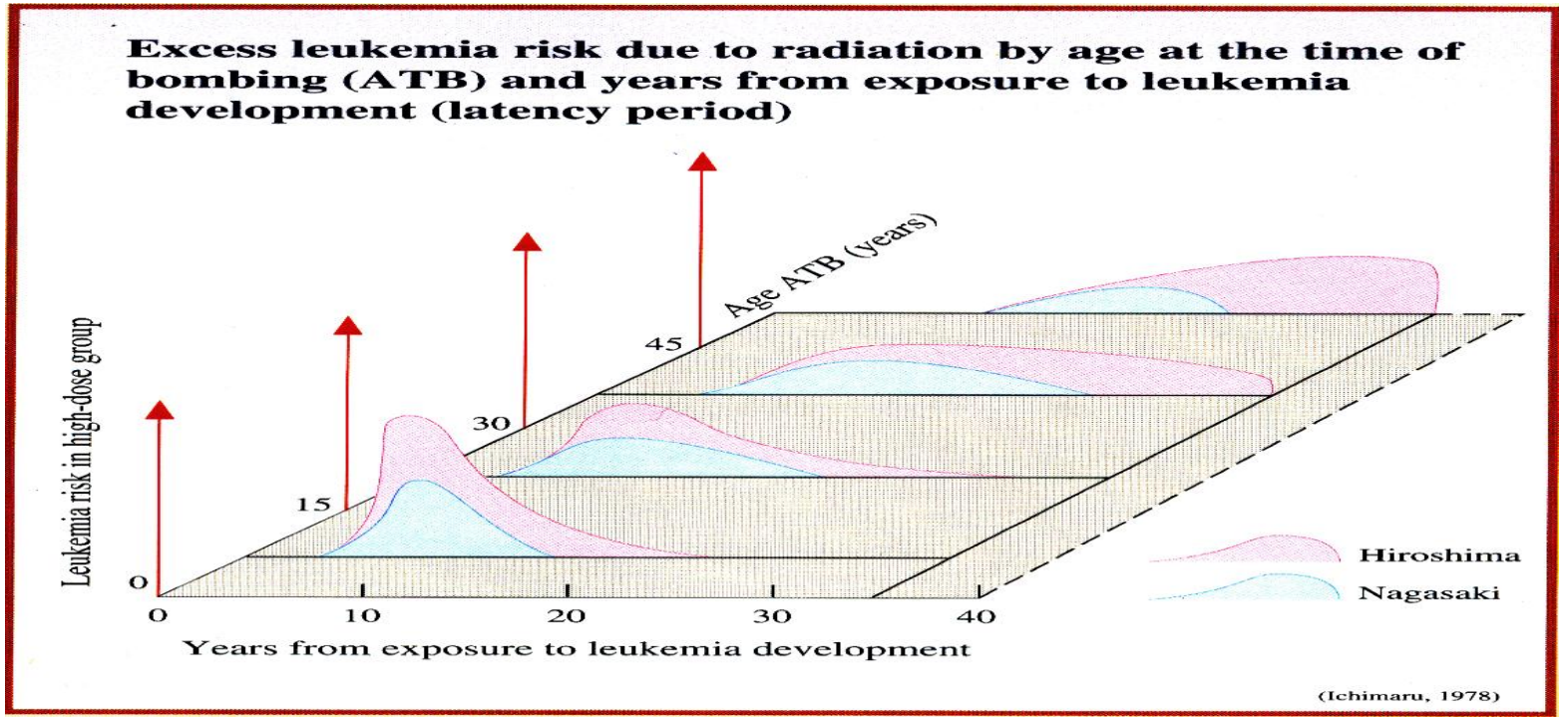
Cohort: 100,645 subjects. Exposure at low dose and low dose rates.
Mean bone marrow radiation doses:
- Cases -132.3 mGy (SD 342.6)
- Controls - 81.8 mGy (SD 193.7)

Romanenko A., et al., Radiation Research, (2008)
Zablotska et al., EHP (2012)

Excess relative risk per Gy (ERR/Gy) with 95% confidence interval (CI) for leukemia within categories of various factors.

Model Description	N cases	ERR/Gy (95% CI)	*P* value[a]	*P* interaction[b]
Year of case diagnosis				
1986-1994	33	6.70 (0.27, 27.10)		0.141[d]
1995-2000	36	2.69 (-0.04, 11.23)		
2001-2006	48	1.25 (<-0.69, 5.35)		

RCRM-NCI joint study:
Zablotska et al., EHP (2012)



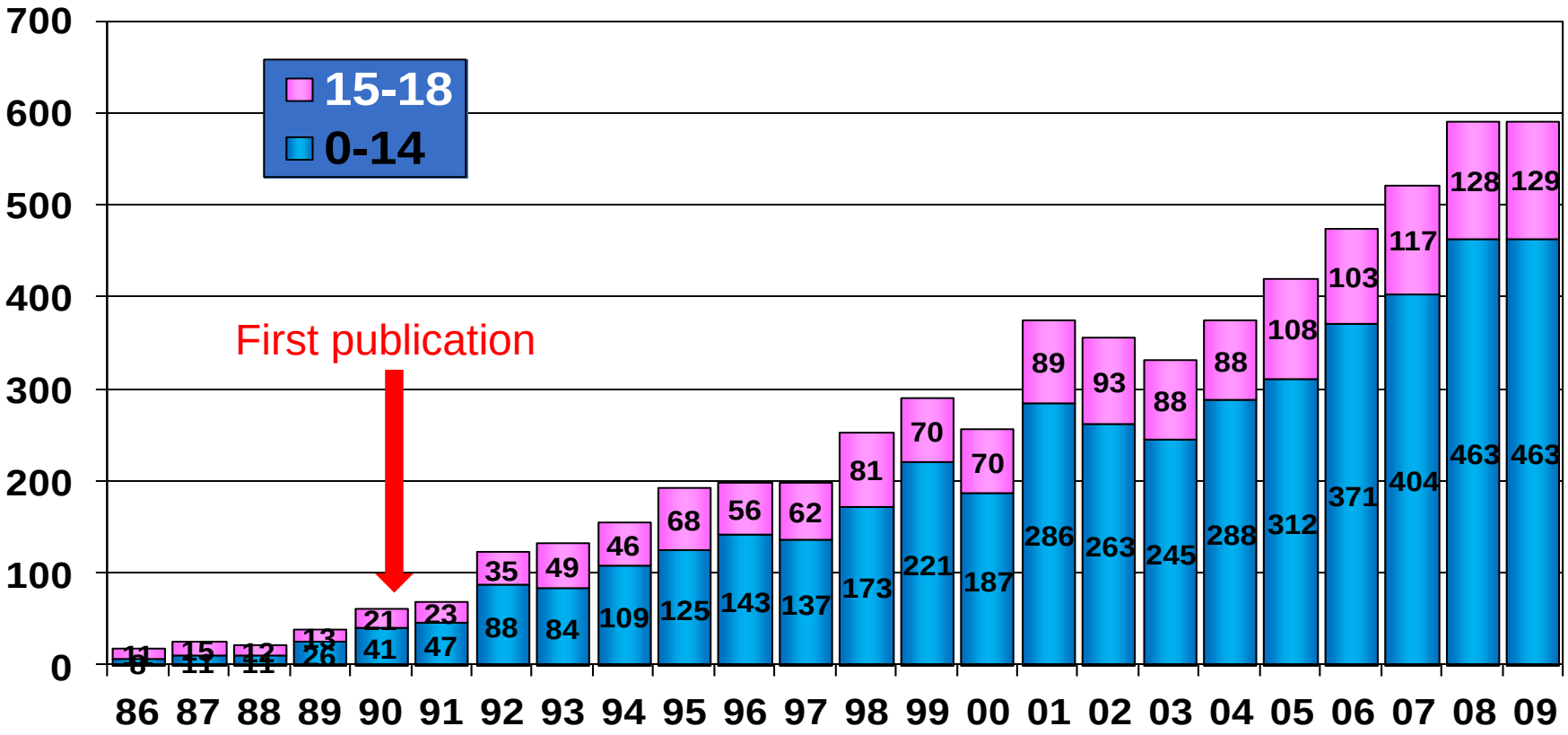
Comparison of accidents as a basis for estimation of health effects

	Chornobyl	Fukushima
Level	7	7
Iodine-131 release	1.8×10^{18} Bq	1.5×10^{17} Bq
Cesium-137 release	8.6×10^{16} Bq	1.2×10^{16} Bq
Radiation doses	85-95% realized	

Projection of Chornobyl health effects due to ionizing radiation to Fukushima (1)

	Chornobyl	Fukushima
Acute radiation syndrome	134	Not observed
Immunology /Cytogenetics	Marked changes in cleanup workers & population	Could be observed. Additional data needed
Radiation cataracts	Observed to higher extent than expected	Could be observed in exposed to less than 0.5 Gy
Non-CLL Leukemia (15 years follow-up)	ERR 2.73/Gy	ERR similar with regard to smaller dose & # of exposed
CLL (15 years follow-up)	ERR 4.09/Gy	questionable

Thyroid cancer (C73) among exposed as children and adolescents



As of 01.01.2012: a total of 6,576 patients exposed at age under 18 years underwent surgery for thyroid cancer

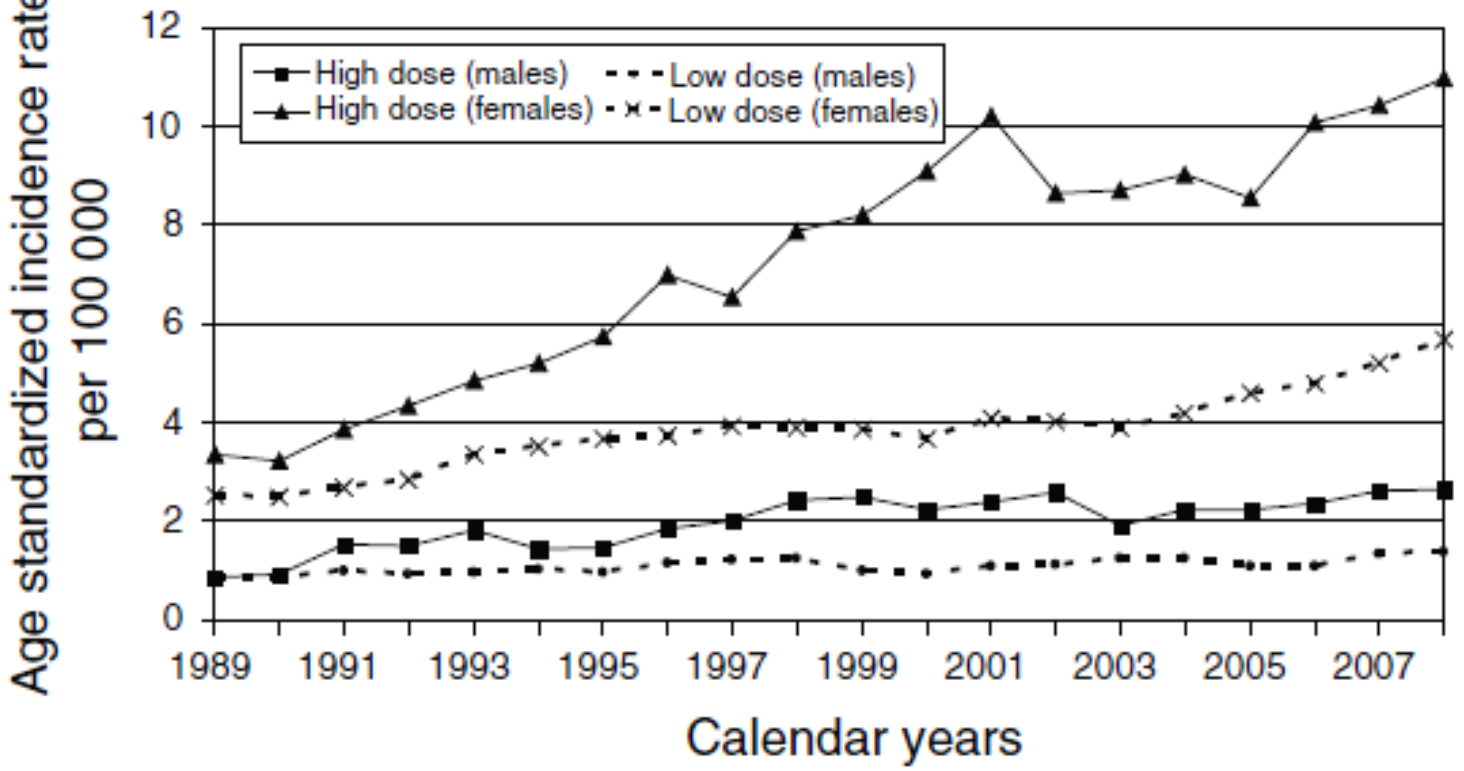
M. Tronko, et al. (2012)

Thyroid cancer in exposed groups (C73)

Group of exposed	Number of cases		SIR	95% CI
	Observed	Expected		
Male cleanup workers of 86/87	299	53	564.2	500.2-628.1
Evacuees from Prypiat and 30-km exclusion zone (1994-2007)	231	52.3	441.7	384.7-498.6
Population of contaminated territories (1990-2008)	317	232.8	136.2	121.2-151.1

A. Prysyazhniuk, et al. (2007)

Population: Trends in thyroid cancer incidence from 1989 through 2008 in Ukraine by gender and dose category



M. Fuzik et al., 2010

Influence of 131-I deposition

Gender	TASR per 100 000 population on territories of ^{131}I deposition (kBq/m^2)		
	≤ 100	100-200	≥ 200
Male	1.53 ± 0.26	2.20 ± 0.20	2.56 ± 0.25
Female	3.94 ± 0.26	10.36 ± 0.41	10.21 ± 0.46

Truncated age-adjusted incidence rate (TASR) in 1991-1999 in adolescents and adults inhabiting the Zhytomyr, Kyiv, and Chernihiv regions in territories with different levels of 131I deposition demonstrate the dependence on radioiodine

Cancer rates (C00-C96) for 1994 -2007 period

Group of exposed	Number of cases		SIR	95% CI
	Observed	Expected		
Male cleanup workers of 86/87	6649	7190	108.1	105,6-110,6
Evacuees from Prypiat and 30-km exclusion zone	2718	3318	81.9	78.9-85.0
Population of contaminated territories	3678	4753	77.4	74.9-79.9

Prysyazhniuk A., et al. (2011)

Female breast cancer

Groups of exposed	Study period	SIR	95% CI
Cleanup workers of 86/87 (1994-2006)	1994-1999	158,2	119,4-196,9
	2000-2006	152,2	125,1-179,3
Evacuees from Prypiat and 30-km exclusion zone (1994-2006)	1990-1997	58,8	45,3-72,4
	1998-2006	91,9	76,9-106,8
Population of contaminated territories (1990-2006)	1980-1991	50,2	46,2-54,1
	1992-2006	70,6	65,6-75,6

(A. Prysyazhniuk et al., 2007)

Projection of Chornobyl health effects due to ionizing radiation to Fukushima (2)

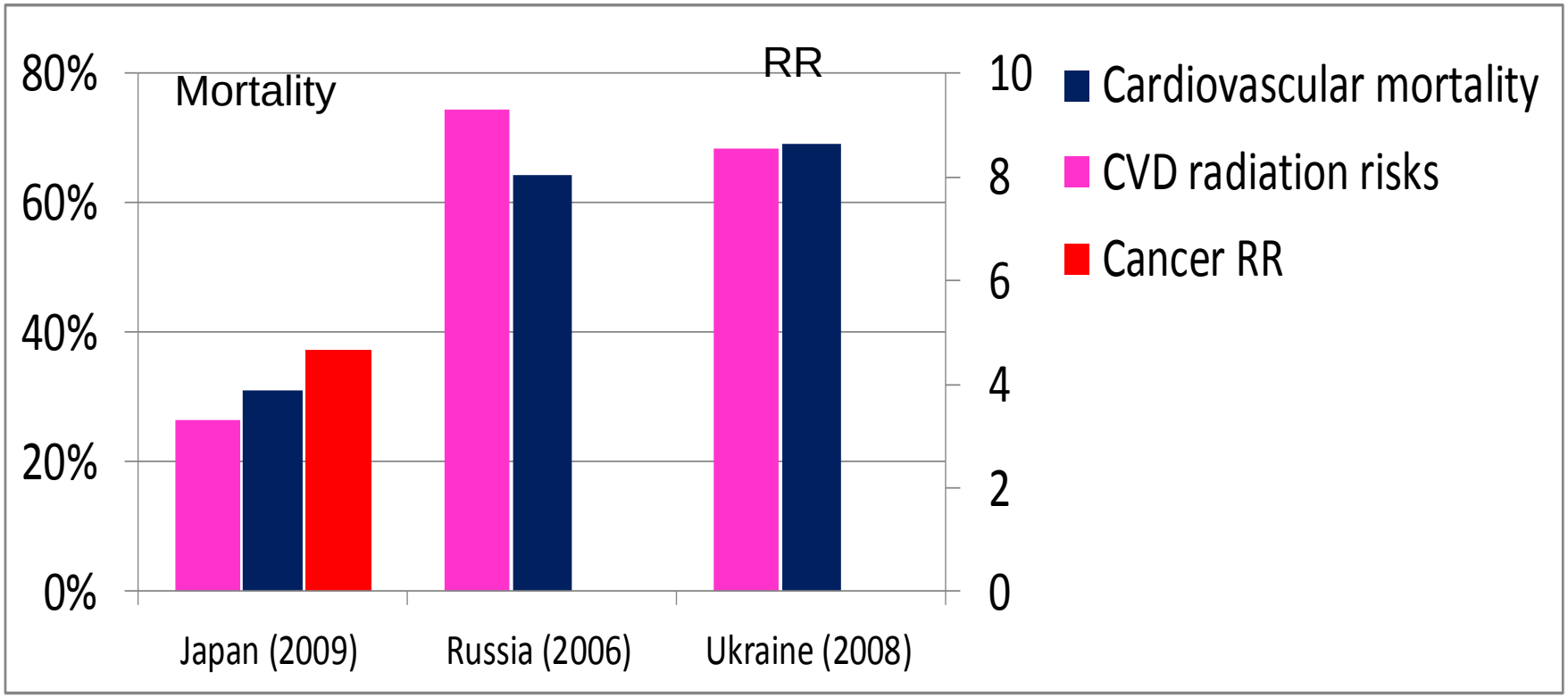
	Chornobyl	Fukushima
Thyroid cancer in children	Incidence higher than expected	Risks could be lesser than in Chornobyl
Thyroid cancer: Screening effect	Observed	Could be minimal due to the early start of ultrasound screening programs
Contribution of stable iodine deficiency	Present	no
Other cancers	Increase in some population groups	questionable

Non-cancer health effects 10-27 years after the accident:

- Cardiovascular diseases incidence and mortality in cleanup workers;
- Vascular eye pathology in different groups of exposed;
- Cerebrovascular diseases and cognitive dysfunction in cleanup workers;
- Thyroid abnormalities;
- Menthal health changes in children exposed *in utero*

Radiation Risks of Circulation Diseases

Radiation Risks of cardiovascular mortality could be comparable with cancer risks



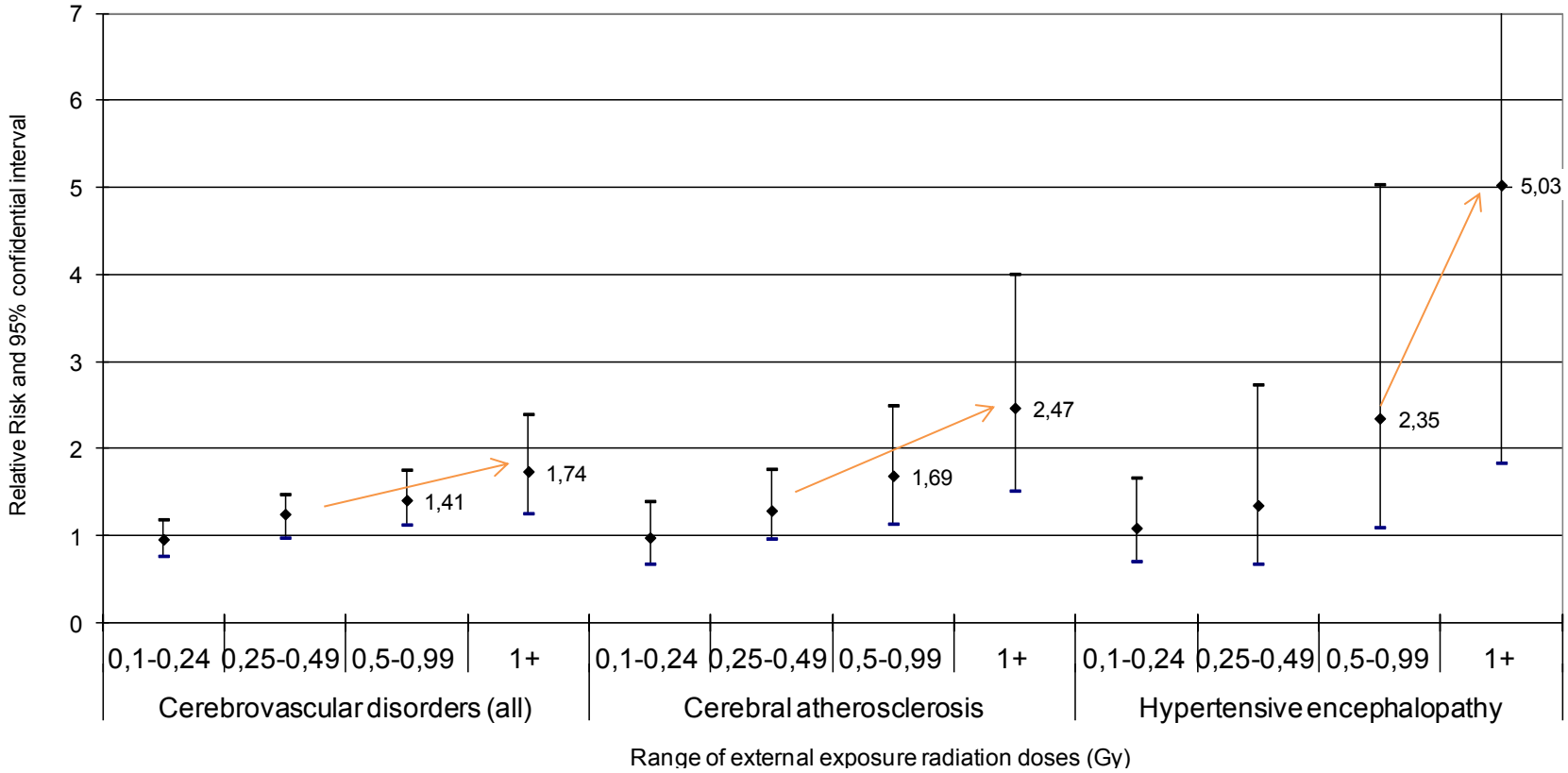
Estimates of Potential Population Risks of Circulatory Disease from Low-Level Exposure to Ionizing Radiation *M.P. Little, T.V. Azizova, D. Bazyka, S.D. Bouffler, E. Cardis, et al.,* ***EHP (2012)***

Relative risks for circulatory diseases (ICD-9 code: 390-459) in cleanup workers of 1986-1987 (n 68,145)

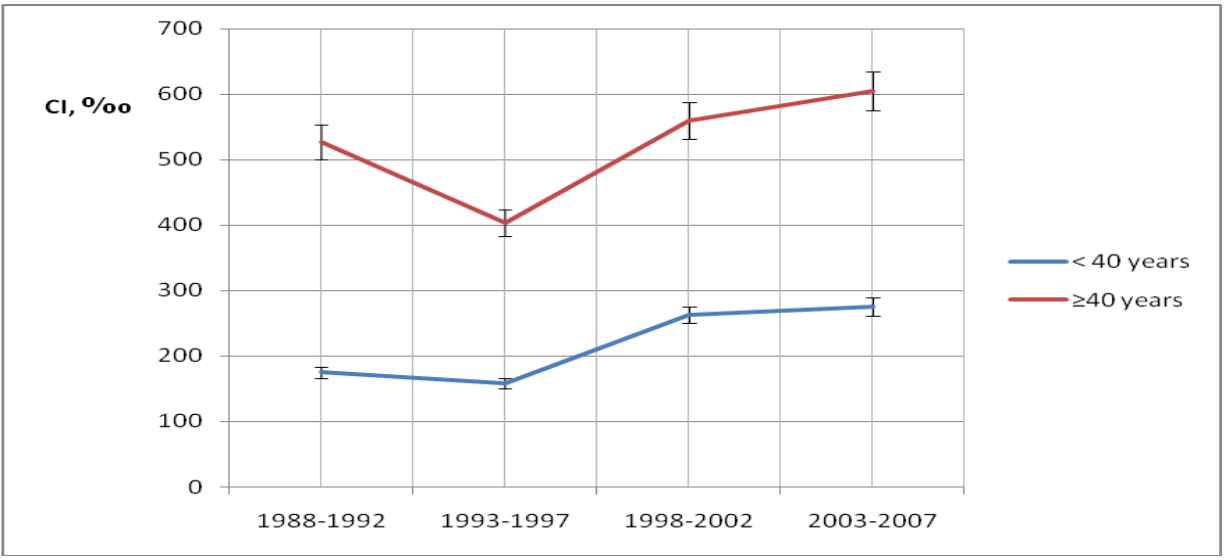
Dose groups (Gy)	Study periods (years after exposure)			
	5 (1988-1992)	6-10 (1993-1997)	11-15 (1998-2002)	16-20 (2003-2007)
0.05–0.099	0.98 (0.86; 1.13)	0.92 (0.8; 1.06)	1.17 (1.03; 1.33)	0.9 (0.74; 1.09)
0.1–0.199	1.15 (1.0; 1.32)	0.95 (0.82; 1.1)	0.96 (0.84; 1.11)	1.38 (1.14; 1.66)
0.2–0.249	0.9 (0.77; 1.05)	0.93 (0.82; 1.05)	1.27 (1.14; 1.41)	0.96 (0.83; 1.12)
0.25–0.7	1.06 (0.89; 1.26)	0.9 (0.78; 1.05)	1.24 (1.1; 1.41)	1.12 (0.94; 1.33)

Buzunov V., et al. (2011)

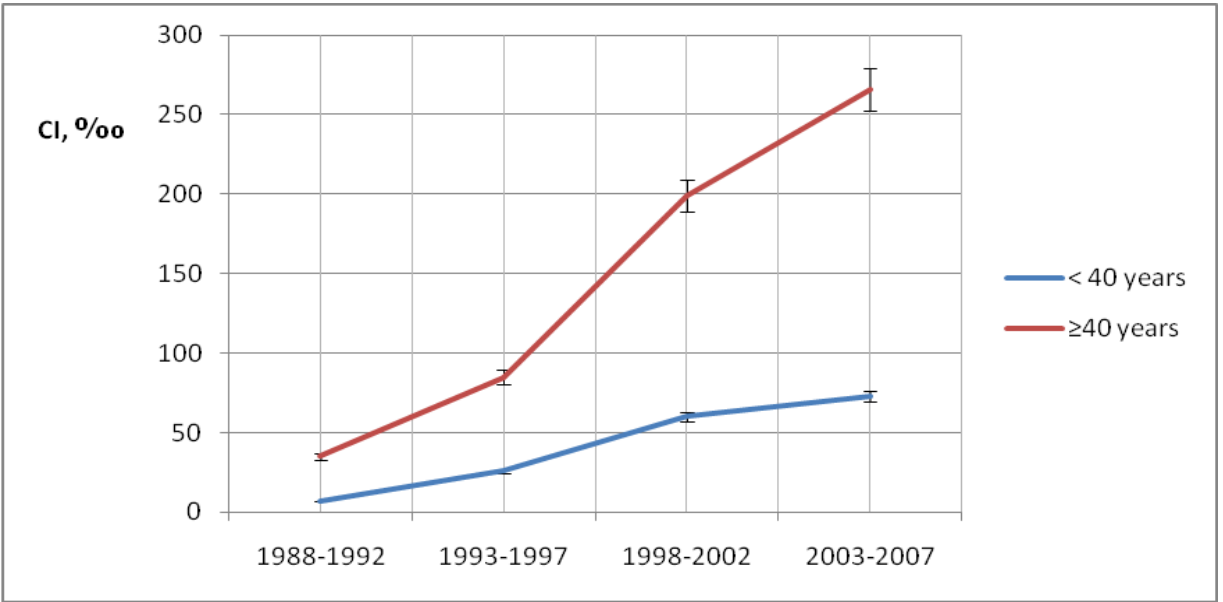
Relative risk of cerebrovascular disease in the male liquidators of 1986–1987 [Buzunov et al., 2008]



Confounding factors – age at exposure



Circulation diseases (ICD-IX: 390-459)



Cerebrovascular diseases (ICD-IX: 430-438)

Buzunov V., et al. (2011)

Other confounding factors

Groups	Presence of confounding factors (%)			P
	1-2 factors	2-3 factors	Total	
Cleanup workers	40	57.7	97.7	0.05
General population	55	34	89	

Main confounding factors other than ionizing radiation:

Genetic predisposition	31.7%
Body weight excess	38%
Smoking	55.2%

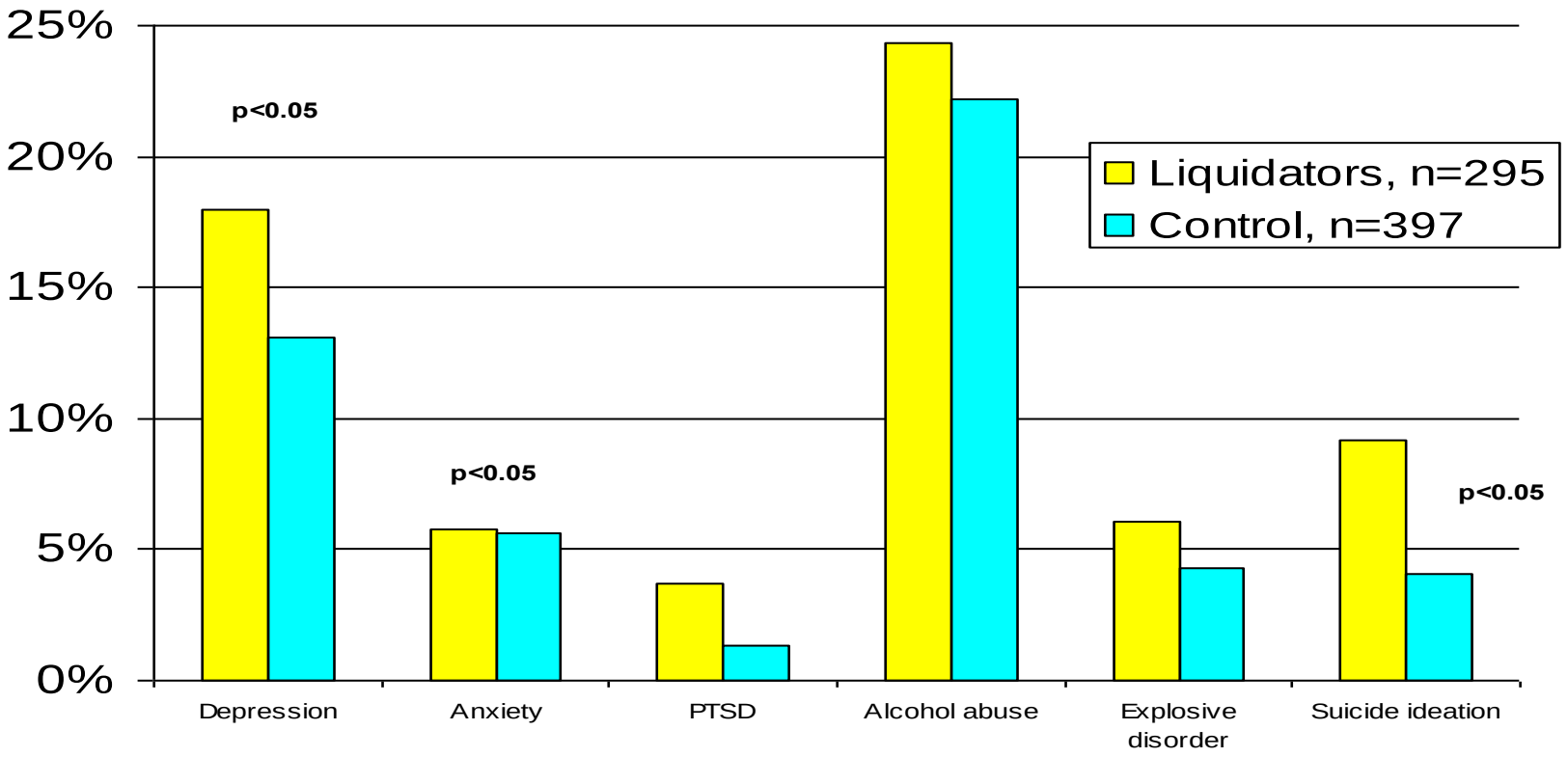
Khomaziuk I., et al. (2011)

Relative risks for non-cancer diseases in cleanup workers of 1986-1987 (n - 68,145)

Dose groups (Gy)	Study periods (years after exposure)			
	5 1988-1992	10 1988-1997	15 1988-2002	20 1988-2007
- acquired hypothyroidism	3.44 (1.38;8.6)	2.79 (1.41;5.5)		
- thyroiditis			1.25 (1.1;1.47)	1.27 (1.09;1.5)
Cataracts			1.27 (1.06;1.5)	1.39 (1.18;1.6)
Respiratory diseases	1.29 (1.12;1.5)	1.35 (1.2;1.47)	1.32 (1.24;1.4)	1.29 (1.2;1.37)

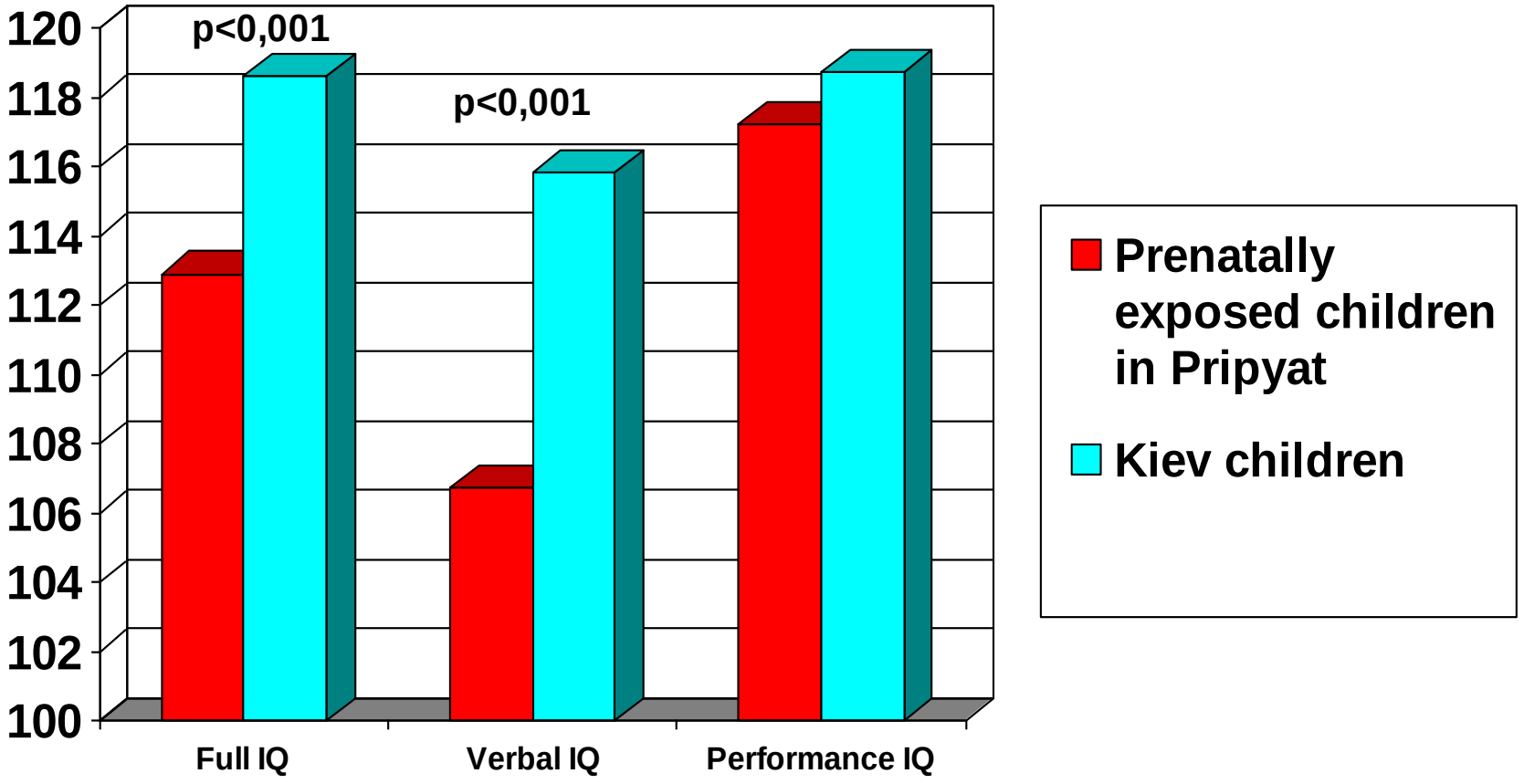
Buzunov V., et al. (2011)

Adverse long-term effect on mental health in adults

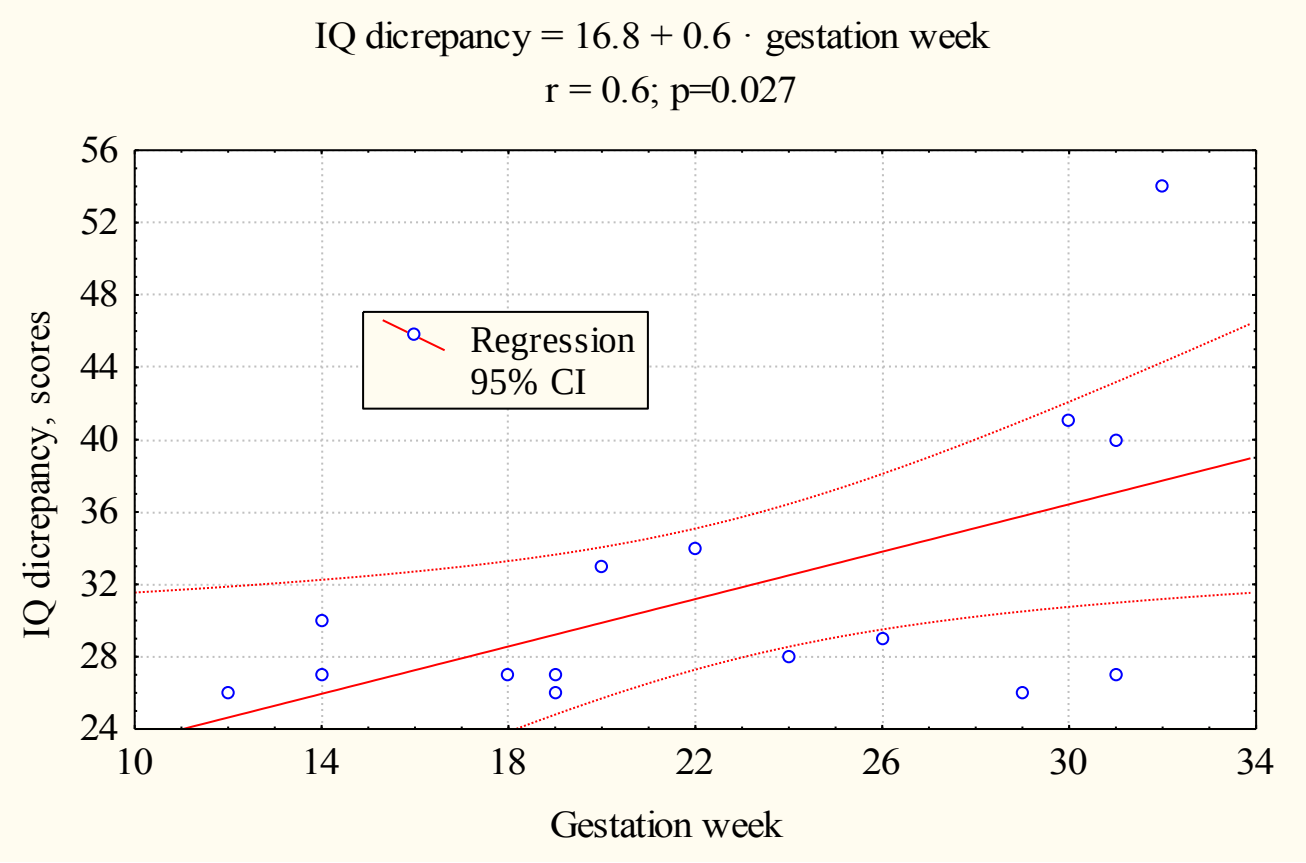


K. Loganovsky, J.M. Havenaar, N.L. Tintle, L.T. Guey, R. Kotov, E.J. Bromet (2008) The mental health of clean-up workers 18 years after the Chernobyl accident. Psychological Medicine, 38: 481-488

Previous studies of Intelligence in prenatally exposed children (WISC)



Dependence of IQ discrepancy (>25 points) on the gestation weeks at the time of the Chernobyl accident



Projection of Chornobyl health effects due to ionizing radiation to Fukushima (3)

	Chornobyl	Fukushima
Cardiovascular disease	high incidence & mortality	Low incidence in population
Cerebrovascular disease & cognitive dysfunction	high incidence	To be analyzed
Benign thyroid abnormalities	controversial	To be analyzed
Mental health changes in children exposed in utero	Analysis in process	

Non-radiation effects of radiation accident

Evacuated patients housed at Nihonmatsu Kyousei Center (2011.3.13)

- Non-radiation effects of radiation accident, such as economical, social and psychological could prevail and be much more important for the community than pure radiation factor.
- Of importance for the estimation of consequences of Fukushima Daichi accident is that for the first 10 years after the Chornobyl accident the health effects were significantly different from the predicted.
- Stress, alimentation changes and other negative factors brought significant contribution to the health decline of all categories of exposed population and form a background for the induction of a wide range of non-cancer somatic and psychosomatic diseases, influence disability and mortality.

Non-radiation effects of radiation accident (2)

- Lack or insufficiency of prepared guidelines on protection from this complex of factors that are understandable to population and authorities have contributed to the induction of the non-radiation health effects.
- Influence of the mentioned non-radiation factors as well as genetic predisposition could be substantial and has to be encountered when analyzing such radiation-induced effects as leukemia or solid cancers in population exposed to doses several times exceeding the natural radiation background.

Summary on Chornobyl health effects in Ukraine

- Leukemia: Radiation risks in cleanup workers comparable with hibakusha data; a controversy in exposed in utero;
- Thyroid cancer- radiation risks in children, increased incidence in exposed as adults: cleanup workers & evacuees;
- All forms of cancers: increased incidence only among cleanup workers of 1986/87; breast cancer – female cleanup workers;
- Cardiovascular mortality – excess in cleanup workers
- Cognitive function – decrease in cleanup workers:
- Increased risks of radiation cataracts;

Outlook for Fukushima:

- Longitudinal follow-up studies of traditionally recognized health effects due to ionizing radiation are needed for radiation workers, evacuees from the 20-kilometer zone, persons with high-dose exposure of thyroid, females pregnant at the moment of exposure and children;
- Special attention has to be delivered to non-cancer diseases, cognitive dysfunction during pre-natal period, radiation and vascular cataracts.
- Non-radiation factors of the accident could be substantial risk modifiers


Thank You