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Analysis of Hemogram of Radiation Workers in Tangshan, China

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Objectives: This study aimed to investigate changes in peripheral blood cells of radiation workers and explore the impact of long-term ionizing radiation (IR) on human peripheral hemogram. *Methods:* With a cohort method, we selected 1,392 radiation workers (case group) and 1,430 non-health-ray-exposure history persons (control group) to detect and analyze their peripheral hemogram. FAITH3000 automatic biochemical analyzer was used for blood testing. Examination of peripheral hemogram includes the examination of white blood cells (WBCs), platelet (PLTs), red blood cells (RBCs), hemoglobin (Hb), lymphocytes (LYMs), and mononuclear cells (MOs). The data analysis was conducted with software SPSS19.0. *Results:* All the peripheral hemogram indicators (WBCs, RBCs, Hb, PLTs, LYMs, and MOs) in the case group, in accordance with the order of radiology diagnostic medical group, industrial inspection group, petroleum logging group, and radiotherapy medical group, showed a significant decreasing trend and were lower than those in the control group (all $P < 0.05$). Besides, with the increase of radiation seniority and accumulative radiation dose, all the peripheral hemogram indicators (WBCs, RBCs, Hb, PLTs, LYMs, and MOs) in the case group dramatically decreased and were lower than those in the control group (all $P < 0.05$). Seniority was in negative association with the expressions of WBCs, PLTs, RBCs, Hb, LYMs, and MOs and radiation dose with Hb, LYMs, and MOs (all $P < 0.05$). *Conclusion:* Long-term IR has some effects on the health of radiation workers, thus protective measures should be further strengthened. J. Clin. Lab. Anal. **30**:682–688, 2016. © 2016 Wiley Periodicals, Inc.

Key words: ionizing radiation; accumulative radiation dose; hemogram; seniority; indicators; radiation workers

INTRODUCTION

Hemogram, formerly known as blood routine examination, usually refers to the examination of the quantity and quality of the blood cells in peripheral blood (1). The testing indicators include red blood cell (RBC) count, hemoglobin (Hb), white blood cell (WBC) count, platelet (PLT) count, the number and proportion of lymphocytes (LYM), the number and ratio of mononuclear cells (MOs), red cell volume (RCV), mean corpuscular volume, mean corpuscular Hb, mean corpuscular Hb concentration, and so on (2–4). The purpose of hemogram examination lies in determining whether there are bacterial infections, hypersplenism, the need for antiretroviral therapy, aplastic anemia, and so on (5). Generally, the increased number of neutrophils and LYM, respectively, indicates bacterial infections and viral infections (6). Significantly, hemogram detection can be used to diagnose some diseases, especially for the diagnosis of diseases caused by radiation. As

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for radiation, ionizing radiation (IR) has become one of the commonest and severest phenomena in modern work, which brings about vast damage to people's health (7).

IR, as a kind of radiation that has sufficient energy to cause an electron to leave atoms, is the general name of all radiations that can cause material ionization and it is typically named as radiation (8). IR includes various types, such as high-speed charged particles—α particles, β particles, and protons—and no-charge particles—X-ray and γ-ray (9). Specifically, it can be divided into direct IR and indirect IR; the former is composed of direct-ionized particles that have sufficient kinetic energy and can cause ionized charged particles in the collision, while the latter is made up of uncharged particles (10,11). In terms of the direct and indirect radiation effects, the energy imparted to biological media comes out mainly by ionization, which generates a number of secondary species following the radiation track, such as radicals, ions, and secondary electrons (11). The source of IR contains natural radiation coming from the sun, cosmic rays, and radionuclide emission and artificial radiation originating from medical equipment (such as imaging equipment), research and teaching institutions, and nuclear reactor and its auxiliary facilities (such as uranium and nuclear fuel plant) (12).

With the extensive development and application of nuclear technology, high-energy IR equipment has been widely applied. IR brings great benefits to mankind but it also has a variety of damaging effects on people's daily life, especially for radiation workers (13). On the one hand, IR can cause changes in cells' chemical balance and some of these changes may cause cancer; on the other hand, IR can cause genetic material DNA damage in cells and even spread to the next generation, leading to generational newborn deformity or congenital leukemia, and it can lead to death after exposure to a large number of irradiations that can cause disease in a few hours or days (14,15). There is no doubt that long-term radiation workers are significantly affected by IR; therefore, in the current study we focus on the impact of IR on radiation workers by anal sizing hemogram examinations.

MATERIALS AND METHODS

Ethics Statement

This research was carried out in strict adherence to the protocols established by the Ethics Committee of Central Laboratory, College of Public Health, North China University of Science and Technology, Tangshan. All the experimental procedures in this study were in accordance with the Declaration of Helsinki (16). Informed consent was obtained from all subjects participating in this cohort design approved by the local institutional review board.

Subjects

We selected 1,392 personnel engaged in radiation work in Tangshan from January to December 2012 as the case group, including 621 medical workers and 771 industrial and enterprise personnel and excluding patients with blood and immune system diseases. Additionally, we selected 1,430 healthy personnel, without the history of exposure to radiation and poison, recent medication, infectious diseases, and other conditions substantially similar to the case group, as the control group.

General Survey

A questionnaire was carried out with a uniform questionnaire by investigators, including basic information, disease history, contact history of toxic and hazardous substances, smoking condition, and so on. Contact ray species, accumulative exposure time, accumulative radiation dose, and other information all came from the health records of radiation workers. The accumulative radiation dose before 1987 was estimated according to normalized workload dose (Ministry of Health, People's Republic of China. GB/T16135-1995 estimation principle of personal external irradiation dose in radiation accident [S]. Beijing: People's Medical Publishing House, 1995), while the accumulative radiation dose after 1987 was directly measured by the measurement meter of LiF (Mg, Cu, P) (Ministry of Health, People's Republic of China. GBZ128-2002 individual monitoring specifications of occupational external irradiation [S]. Beijing: People's Medical Publishing House, 2002).

Hemogram Examinations

Venous blood (1~2 ml) was collected into a vacuum tube containing EDTA-K2 anticoagulant for examination. FAITH3000 automatic biochemical analyzer (Gauteng, Nanchang, P.R. China) was used for blood testing in compliance with the manufacturer's instruction. Examinations of peripheral hemogram include the examination of WBCs, PLTs, RBCs, Hb, LYMs, and MOs.

Statistical Methods

Data analysis was conducted with software SPSS19.0 (Statistical Product and Service Solutions, v. 19.0), categorical data were analyzed by chi-square test, and continuous data were presented as mean ± standard deviation (SD) analyzed by *t*-test and variance. In addition, correlation analysis between the two variables was simultaneously performed and multiple linear regression analyses were conducted. $P < 0.05$ indicates that the results were statistically significant.

TABLE 1. Results of Peripheral Hemogram Examinations in Both the Case Group and the Control Group

Groups	Number	WBCs ($\times 10^9$/l)	RBCs ($\times 10^{12}$/l)	Hb (g/L)	PLTs ($\times 10^9$/l)	LYMs ($\times 10^9$/l)	MOs ($\times 10^9$/l)
Control	1,430	7.83 ± 2.62	4.53 ± 0.96	146.62 ± 29.31	267.19 ± 51.27	3.54 ± 0.91	0.62 ± 0.13
Study	1,392	5.24 ± 1.17	4.41 ± 0.93	142.59 ± 14.38	238.77 ± 55.22	2.72 ± 0.67	0.50 ± 0.17
t		34.06	3.37	4.66	14.16	42.30	21.02
P		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

RESULTS

Baseline Characteristics

In this study, 1,392 personnel (1,195 males and 197 females) engaged in radiation work in Tangshan were selected as the case group, including 621 medical workers (379 in radiodiagnosis group, 242 in radiotherapy group) and 771 industrial workers (568 in industrial inspection group, 203 in industrial radiation source group), with a mean age of 32.79 ± 2.61 years and radiation seniority of 15.52 ± 9.75 years, of which 723 people had a radiation seniority less than 10 years, 532 people had a radiation seniority of 10∼20 years, and 317 people had a radiation seniority more than 20 years. The dose range of radiation was 0.2∼19.88 mSv/year, the average annual effective dose was 1.37 mSv, and per capita accumulative effective dose was also 13.7 mSv. A total of 453 people had a accumulative radiation dose of less than 10 mSv, 352 people ∼10 mSv, 438 people ∼20 mSv, and 149 people beyond 50 mSv. Simultaneously, 1,430 healthy people were chosen to be the control group (1,190 males and 240 females), with a mean age of 32.80 ± 2.61 years. Differences in the age and gender of two groups were not statistically significant (all $P > 0.05$).

Comparison of Changes in Peripheral Hemogram

The results of changes in all the peripheral hemogram indicators of all subjects were presented in Table 1; peripheral hemogram indicators (WBCs, RBCs, Hb, PLTs, LYMs, MOs) in the case group were significantly lower than the control group and the difference between them was statistically significant ($P < 0.05$).

Work Types and Peripheral Hemogram

The changes in peripheral hemogram indicators of different types of radiation workers were displayed in Table 2. All the peripheral hemogram indicators (WBCs, RBCs, Hb, PLTs, LYMs, MOs) of radiation workers in the case group in radiology diagnostic medical group, industrial inspection group, petroleum logging group, and radiotherapy medical group displayed a significant decreasing trend and were lower than in the control group. Compared with the control group, WBCs and LYMs in the radiology diagnostic medical group; WBCs, PLTs, LYMs, and MOs in the industrial inspection group; WBCs, Hb, PLTs, LYMs, and MOs in the petroleum logging group; WBCs, RBCs, Hb, PLTs, LYMs, and MOs in the radiotherapy medical group in the case group had significantly decreased and the difference was statistically significant (all $P < 0.05$). Compared with the radiology diagnostic medical group, WBCs, LYMs, and MOs in each group; RBCs, Hb, and PLTs in the radiotherapy medical group; and PLTs in the petroleum logging group had distinctly declined and the difference was also statistically significant (all $P < 0.05$). Additionally, compared with the industrial inspection group, PLTs and LYMs in the petroleum

TABLE 2. Results of Peripheral Hemogram Examinations in Different Work Types in the Case Group

Groups	Number	WBCs ($\times 10^9$/l)	RBCs ($\times 10^{12}$/l)	Hb(g/L)	PLTs ($\times 10^9$/l)	LYMs ($\times 10^9$/l)	MOs ($\times 10^9$/l)
Control	1,430	7.83 ± 2.62	4.53 ± 0.96	146.62 ± 29.31	267.19 ± 51.27	3.54 ± 0.91	0.62 ± 0.13
RDM	379	6.06 ± 1.08[a]	4.50 ± 0.93	144.86 ± 17.54	263.84 ± 46.19	3.22 ± 0.48[a]	0.61 ± 0.14
II	568	5.24 ± 0.91[a,b]	4.49 ± 1.04	144.49 ± 15.80	260.65 ± 43.50[a]	2.84 ± 0.51[a,b]	0.49 ± 0.16[a,b]
PL	203	5.02 ± 1.16[a,b]	4.49 ± 0.83	140.15 ± 20.72[a]	205.76 ± 40.53[a,b,c]	2.56 ± 0.50[a,b,c]	0.48 ± 0.17[a,b]
RIA RM	242	4.13 ± 0.85[a,b,c,d]	4.30 ± 0.68[a,b]	136.62 ± 14.67[a,b,c]	175.84 ± 37.61[a,b,c,d]	1.81 ± 0.32[a,b,c,d]	0.34 ± 0.10[a,b,c,d]
F		334.4	4.478	10.97	252.2	367.3	302.7
P		<0.0001	0.0013	<0.0001	<0.0001	<0.0001	<0.0001

[a]Compared with the control group, $P < 0.05$
[b]Compared with RMD, $P < 0.05$
[c]Compared with II, $P < 0.05$
[d]Compared with PL, $P < 0.05$.
RDM, radiology diagnostic medical; II, industrial inspection; PL, petroleum logging; RIA RM, RIA radiotherapy medical.

TABLE 3. Peripheral Hemogram Results of Different Seniority in the Case Group

	Case group					Control group				
	<10 (n = 723)	10~20 (n = 352)	>20 (n = 317)	F	P	<10 (n = 727)	~10 (n = 394)	>20 (n = 309)	F	P
WBCs ($\times 10^9$/l)	5.60 ± 1.20	5.14 ± 1.02[a]	4.52 ± 0.90[a,b]	109.742	<0.001	7.86 ± 2.64[c]	7.83 ± 2.58[c]	7.77 ± 2.61[c]	0.159	0.853
RBCs ($\times 10^{12}$/l)	4.54 ± 1.03	4.50 ± 0.96[a]	4.30 ± 0.85[a]	10.238	<0.001	4.58 ± 0.93	4.56 ± 0.96	4.49 ± 0.98[c]	1.291	0.275
Hb (g/l)	144.30 ± 12.44	143.74 ± 13.88[a]	143.74 ± 18.14[a]	10.841	<0.001	148.49 ± 26.34[c]	146.72 ± 30.09[c]	145.77 ± 30.07[c]	0.933	0.394
PLTs ($\times 10^9$/l)	249.80 ± 55.12	229.62 ± 39.15[a]	223.77 ± 64.67[a]	32.321	<0.001	270.99 ± 47.65[c]	267.26 ± 50.31[c]	265.55 ± 53.21[c]	1.222	0.295
LYMs ($\times 10^9$/l)	2.83 ± 0.74	2.73 ± 0.60[a]	2.44 ± 0.49[a,b]	39.54	<0.001	3.59 ± 0.94[c]	3.53 ± 0.88[c]	3.52 ± 0.93[c]	0.554	0.575
MOs ($\times 10^9$/l)	0.55 ± 0.17	0.47 ± 0.14[a]	0.38 ± 0.14[a,b]	137.278	<0.001	0.63 ± 0.14[c]	0.62 ± 0.13[c]	0.62 ± 0.12[c]	0.646	0.524

[a] $P < 0.05$ in the comparison with cases of seniority length <10.
[b] $P < 0.05$ in the comparison with cases of seniority length between 10 and 20.
[c] $P < 0.05$ in the comparison with controls of the same seniority length correspondingly.

logging group, WBCs, Hb, PLTs, LYMs, and MOs in the radiotherapy medical group were significantly lower and the difference was statistically significant (all $P < 0.05$). Moreover, comparing WBCs, PLTs, LYMs, and MOs in the radiotherapy medical group with the petroleum logging group, we found that WBCs, PLTs, LYMs, and MOs in the radiotherapy medical group were significantly lower than in the petroleum logging group (all $P < 0.05$).

Seniority Length and Peripheral Hemogram

Changes in peripheral hemogram indicators in cases and controls with different seniorities were presented in Table 3. In the case group, seniority (<10, 10~20, and >20 years) was in negative association with expressions of the six peripheral hemogram indicators (all $P < 0.05$). Comparing with cases with seniority <10 years in the expressions of WBCs, Hb, PLTs, LYMs, and MOs, cases with seniority between 10 and 20 and >20 years exhibited markedly lower expressions while controls with seniority <10 years displayed significantly higher expressions (all $P < 0.05$). In comparison with cases with seniority between 10 and 20 years, cases with seniority >20 years had significantly lower expressions of WBCs, LYMs, and MOs while controls with seniority between 10 and 20 years presented apparently higher expressions (all $P < 0.05$). Cases with seniority >20 years had significantly lower expressions of the six peripheral hemogram indicators than controls with seniority >20 years (all $P < 0.05$).

Accumulative Radiation Dose and Peripheral Hemogram

Findings of changes in peripheral hemogram indicators of different accumulative radiation dose of radiation workers were presented in Table 4. All the peripheral hemogram indicators (WBCs, RBCs, Hb, PLTs, LYMs, and MOs) in the case group had dramatically decreased with the increase of accumulative radiation dose and were lower than in the control group. WBCs and LYMs in the accumulative radiation dose <10 years group; WBCs, PLTs, LYMs, and MOs in ~10 years group; WBCs, Hb, PLTs, LYMs, and MOs in ~20 years group; and WBCs, RBCs, Hb, PLTs, LYMs, and MOs in >50 years group were significantly lower than those in the control group and the difference was statistically significant (all $P < 0.05$). Compared with the accumulative radiation dose <10 years group, WBCs, LYMs, and MOs in each group; RBCs, Hb, and PLTs in >50 years group; and PLTs in ~20 years group were obviously lower (all $P < 0.05$). Compared with the accumulative radiation dose of ~10 years group, PLTs and LYMs in ~20 years group and WBCs, Hb, PLTs, LYMs, and MOs in >50 years group showed great reduction and the difference between them

TABLE 4. Correlations Between Accumulative Radiation Dose and Changes in Peripheral Hemogram

Cumulative radiation dose	Number	WBCs ($\times 10^9$/l)	RBCs ($\times 10^{12}$/l)	Hb (g/l)	PLTs ($\times 10^9$/l)	LYMs ($\times 10^9$/l)	MOs ($\times 10^9$/l)
Control	1,430	7.83 ± 2.62	4.53 ± 1.96	146.62 ± 29.31	267.19 ± 51.27	3.54 ± 0.91	0.62 ± 0.13
<10	453	6.56 ± 0.65[a]	4.45 ± 0.95	145.80 ± 15.40	265.12 ± 32.32	3.43 ± 0.35[a]	0.61 ± 0.09
~10	352	5.16 ± 1.23[a,b]	4.41 ± 0.89	143.75 ± 7.95	241.70 ± 31.69[a]	2.83 ± 0.23[a,b]	0.52 ± 0.04[a,b]
~20	438	4.93 ± 1.34[a,b]	4.37 ± 0.91	140.75 ± 8.44[a]	221.95 ± 47.59[a,b,c]	2.29 ± 0.28[a,b,c]	0.37 ± 0.06[a,b]
>50	149	3.31 ± 1.38[a,b,c,d]	4.15 ± 0.97[a,b]	136.43 ± 11.62[a,b,c]	152.53 ± 50.67[a,b,c,d]	1.60 ± 0.27[a,b,c,d]	0.35 ± 0.06[a,b,c,d]
F		347.8	2.719	10.09	<0.0001	524.8	658.3
P		<0.0001	0.0282	<0.0001	273.3	<0.0001	<0.0001

[a]Compared with the control group, $P < 0.05$.
[b]Compared with accumulative radiation dose <10 group, $P < 0.05$
[c]Compared with accumulative radiation dose ~10 group, $P < 0.05$.
[d]Compared with accumulative radiation dose ~20 group, $P < 0.05$.

TABLE 5. Analysis of Peripheral Hemogram and Seniority of Radiation Workers

Parameters	*R*-value	*P*-value
WBCs	−0.334	<0.05
RBCs	−0.109	<0.05
Hb	−0.101	<0.05
PLTs	−0.176	<0.05
LYMs	−0.200	<0.05
MOs	−0.367	<0.05

TABLE 6. Analysis of Peripheral Hemogram and Accumulative Radiation Dose of Radiation Workers

Parameters	*R*-value	*P*-value
WBCs	−0.857	<0.05
RBCs	−0.096	<0.05
Hb	−0.565	<0.05
PLTs	−0.636	<0.05
LYMs	−0.843	<0.05
MOs	−0.856	<0.05

was statistically significant (all $P < 0.05$). Furthermore, comparing WBCs, PLTs, LYMs, and MOs in the accumulative radiation dose >50 years group with ~20 years group, we discovered that the former was significantly lower than the latter and there was statistically significant difference between them (all $P < 0.05$).

Correlations of Accumulative Radiation Dose and Seniority Length With Changes in Peripheral Hemogram

Correlation analysis revealed that seniority length and accumulative dose radiation dose were in negative association with the expressions of WBCs, PLTs, RBCs, Hb, LYMs, and MOs (all $P < 0.05$, Tables 5 and 6).

Multiple Linear Regression Analyses

With seniority and accumulative radiation dose as dependent variables and thoe six peripheral hemogram indicators as independent variables, multiple linear regression was performed. Multiple linear regression revealed that seniority length was in negative association with the expressions of WBCs, PLTs, RBCs, Hb, LYMs, and MOs and radiation dose with Hb, LYMs, and MOs (all $P <$ 0.05, Table 7).

TABLE 7. Multiple Linear Regression Analyses on the Basis of Seniority Lengths and Accumulative Radiation Doses

	Seniority length		Accumulated radiation dose	
	t	*P*	*t*	*P*
WBCs	−4.28	<0.001	−1.03	0.301
RBCs	−2.52	0.012	−1.79	0.073
Hb	−8.99	<0.001	−5.74	<0.001
PLTs	−5.5	<0.001	−1.15	0.251
LYMs	−24.58	<0.001	−5.54	<0.001
MOs	−13.3	<0.001	−4.46	<0.001

DISCUSSION

IR was generally regarded as one of the commonest radiation in people's life, seriously affecting people's health. IR can activate the cytoplasmic signal transduction pathways related to cells' proliferation and their survival mechanisms, including receptors of cell growth factor, changes in stress-response kinases, and cytoplasmic calcium levels (17). Additionally, different types of IR may cause different traumas to people's body, mainly embodied in hemogram, which may not only cause significant changes in the expression of WBCs, RBCs, Hb, PLTs, LYMs, and

MOs but also cause changes in cell genetics (18, 19). With the continuous expansion of business scale, new production equipment constantly emerged, and frequent use of large-scale equipment can easily produce large amounts of IR, gradually causing physical damage when acting on the body. With the prolonging time of those equipments, radiation doses exposed to radiation personnel were gradually accumulated and would lead to serious physiological and pathological changes when they reach a certain level, or even cause severe cell damages and with the risk of inducing cancers, thereby affecting patients' prognosis (20–22).

The findings of this study illustrated that hemogram indicators of radiation workers were almost in line with the normal, indicating that the radiological protection work of hospitals and industrial enterprises is safe and effective because it is helpful in the improvement of patients' prognosis (23, 24). WBCs, RBCs, Hb, PLTs, LYMs, and MOs in the case group were significantly lower than in the control group, indicating that with long-term exposure to IR environment, the hematopoietic function of the body will have different degrees of changes. Besides, in the order of the radiology diagnostic medical group, industrial inspection group, petroleum logging group, and radiotherapy medical group, all the peripheral hemogram indicators (WBCs, RBCs, Hb, PLTs, LYMs, and MOs) in the case group were notably lower than in the control group, revealing that ray types and radiation doses received by radiation workers in different types of work are somewhat different and changes in hemogram are also different.

Results obtained in our study also showed that WBCs, RBCs, Hb, PLTs, LYMs, and MOs in case groups with different seniority length were all evidently lower than in the control group, which revealed that radiation damage was correlated with ray contact age. Long-term low-dose IR will exert a certain impact on the hematopoietic system of radiology staff, but the extent of the impact will depend on the regulation of many factors, including types of IR, dose of IR, irradiation conditions of IR, and the body's sensitivity. Hence, in practical work, we must strictly control the radiation dose and exposure time of radiation workers, implement effective personal protection, and regularly carry out medical examination of radiology staff to grasp their health conditions in time in order to ensure the scientific and rational development and operation of work (25–27). Simultaneously, there are also some limitations in this study, we chose only 1,392 Tangshan radiation workers in 2012 and 1,430 healthy persons as our study objects to explore the relationship between IR and changes in hemogram indicators (WBCs, RBCs, Hb, PLTs, LYMs, and MOs), which, to some extent, may impact the accuracy of results in this study.

CONCLUSIONS

IR can affect the health of radiation workers. Different radiation workers with different work types have received different radiation damages, and the radiation damage is connected with ages of ray contact. Furthermore, we have identified that the longer the radiation seniority, the higher the accumulative radiation dose. More importantly, there is an obvious negative correlation between WBCs, RBCs, Hb, PLTs, LYMs, and MOs and the accumulative radiation dose. Therefore, there is a large scope for further studies in future.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

ABBREVIATIONS

Hb	=	hemoglobin
IR	=	ionizing radiation
LYM	=	lymphocyte
MO	=	mononuclear cell
PLT	=	platelet
RBC	=	red blood cell
RCV	=	red cell volume
SD	=	standard deviation
WBC	=	white blood cell

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