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Ionizing radiation impact on hematopoietic cells system in hospitals radiation workers

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Abstract—Health monitoring of radiation workers due to radiation exposure can be done by examination of the hematopoietic system, especially white blood cells which are very sensitive to radiation exposure and can be used as an indicator of body damage. The purpose of this study was to determine the differences in the biological effects of ionizing radiation on the hematopoietic system of radiation workers and non-radiation workers as controls. A total of 3 mL of blood from 57 people (34 radiation workers and 23 subjects as a control) were taken using a syringe and then put into an EDTA tube and shaken slowly to avoid clotting. The blood was examined using the ABX Micros 60 hemoanalyzer instrument with standard procedure in the PTKMR Laboratory. An independent sample T-test was used to determine the significant differences between radiation workers and controls. Pearson chi-square test was used to evaluate the significance of each parameter through p-value ($p<0.05$). The results showed that the numbers of hemoglobin, erythrocytes, leukocytes, platelets, hematocrits, MCV, MCH, MCHC, RDW, MPV, PDW, lymphocyte, monocytes, granulocytes,% lymphocytes,% monocytes,% granulocytes of radiation workers did not decrease and still within normal limit. The results of the statistical test did not show a significant difference between radiation workers and controls ($p> 0.05$). It was concluded that radiation workers did not have any impact due to work with radiation.

Keywords— Radiation workers, hematology, ionizing radiation effects, low doses

1. Introduction

Health checks for radiation workers are carried out periodically so that it is expected to be known as early as possible in the event of health problems. Because in carrying out their duties radiation workers are faced with the risk of the effects of radiation exposure directly or indirectly, which can lead to a decrease in endurance so as to increase the likelihood of being attacked by certain diseases. Radiation workers or Radiographers with assignments and responsibilities must be protected for occupational health and safety. considering that the work of a radiation worker is related to X-rays which have characteristics that can cause deterministic (tissue damage) and genetic effects. [1,2]

Blood consists of two parts, namely the liquid (blood plasma) and blood cells. Blood cells include erythrocytes, leukocytes, and platelets. Leukocytes function as the body's immune system. Erythrocytes with hemoglobin function in tissue oxygenation and platelets play a role in the blood clotting system. These blood cells are produced in the bone marrow. Radiosensitivity of various types of blood cells varies, the most sensitive cells are lymphocyte cells and the most resistant cells are erythrocyte cells. [3] Decreasing the number of blood cells will have a very serious impact if not addressed immediately because blood has an important role in the functioning of the human body such as immunity, oxygenation, hemostasis, and other roles. [4]

Acceptance of low radiation doses but for a long time can cause delayed effects that are not immediately apparent after exposure, but sometime later. For examples disturbances in the lens of the eye, and an increase in cancer incidence and the possibility of genetic changes. It has been known that low-level radiation, which is 0.25 Gy, can cause changes in blood-composing organs, namely the cessation of blood cell formation (hematopoiesis) due to changes either by direct damage to the hemopoietic tissue or due to the influence of neurohormonal mechanisms. [5]. In general, the main biological effects that occur in various mammals, including humans, as a result of ionizing radiation are damage to the hematopoietic system and lymphatic tissue. It has also been known that whole-body irradiation in mammals will cause interference with blood cells, namely by decreasing the production of blood cells caused by the inhibition of mitosis in stem cells in the marrow and lymphoid system. Several studies have shown that chronic exposure to low-dose ionizing radiation has a genotoxic effect on somatic DNA [6-8]. The dose of 100 rad in rabbit results in a decrease in leukocytes, lymphocytes up to 50%, and a dose of 300 rad decrease to 90%. [9,10]

The hematopoietic tissue is the most sensitive tissue to exposure to ionizing radiation, for example bone marrow, digestive tract, skin, central nervous system, lungs, heart, liver,kidneys, and mammalian lymphocytes are known to be the most sensitive blood cells to radiation. [11] Radiation in a certain amount can cause ionization in the cells of the human body.The nature and level of the influence of this radiation depend on the dose received by the tissue cells, bone cells including active cells proliferate so that bone marrow cells including cells that are susceptible to damage due to exposure to ionizing radiation. [12] The hemopoietic syndrome is generally characterized by the occurrence of thrombocytopenia, granulocytopenia, and lymphocytopenia. Mammalian deaths due to exposure to ionizing radiation are generally caused by hemopoietic, gastrointestinal disorders, central shaking, and reduced immune resistance of the bible infection. Deaths due to hemopoietic syndromes occur approximately three times slower than gastrointestinal deaths, while gastrointestinal deaths occur 3 times slower than central nervous death. The death of mice due to hemopoietic syndrome occurs in 9-30 days, the central nerve in the hour order, gastrointestinal deaths occur within 4 days. [13]

The purposeof this study was to determine the prevalence of diseases suffered by radiation workers based on indications of complete blood tests concerned. Besides that, it is expected to be able to know the presenceof indications of disease or abnormality due to the receipt of radiation exposure both directly and indirectly.

2. Materials and methods

2.1 Research Ethic

Research ethics were obtained from the Health Research Ethics Commission, Health Research and Development Agency, Ministry of Health of the Republic of Indonesia, Number LB.02.01/5.2.KE.079/2017.

2.2 Subjects of research

A total of 57 people consists of34 radiation-exposed workers and 23 non-radiation workers. Radiation-exposed workers consist of radiologists, radiographers, technicians, and medical physicist, while non-radiation workers consist of administrative workers. Blood is taken as much as 3 mL using a syringe and put into a tube containing anti-coagulant (EDTA) then shaken gently so as not to clot.

2.3 Hematological examination

Blood samples of radiation workers mixed with EDTA anticoagulant was examined using hematology analyzer ABX Micros 60 according to Laboratory standards.

2.4 Statistical analysis

All statistical calculations were carried out using the Medcalc Version 12.7.0.0 software for Kolmogorov-Smirnov and Mann-Whitney U test (independent samples).Thestatistical test was carried out with a seventeen mean values. Parameters of hematological examination between groups of radiation workers with controls. The t-test ($p<0.05$) was considered to have a statistically significant difference.

3. Outcomes

A complete of 57 individuals answeredthe questionnaires giving the response charge to be 100%.Background information for all individuals in this study is presented in Table 1. The total workers who were the object of the study (n=34) consisting of 17 males and 17 females, the percentage of respondent sex distribution were 50% of males and 50% of females. Percentage of distribution based on the age of respondents from the age group 50 years and over as many as 4 subjects (11.7%) and the age group of 25-49 years as many as 30 subjects(88.3%). The control group (n=23) consists of 13 males and 10 females, the percentage of male distribution is 57% and femaleis 43%. Percentage of distribution based on the age of respondents from the age group 50 years and over as many as 5 (21.7%) and the age group 25-49 years as many as 18 subjects (78.3%). The average annual dose of radiation workers is 0.25 mSv/year. All radiation-exposed workers and unexposed radiation workers were obtained from the same hospital.

Table 1. Demographic characterization of the study population

	Radiation-exposed workers (n=34)		Non-radiation workers (n=23)	
Gender	Number of subjects	Percentage (%)	Number of subjects	Percentage (%)
Males	17	50	13	57
Females	17	50	10	43
Total	34	100	23	100
Age	Number of subjects	Percentage (%)	Number of subjects	Percentage (%)
Age 33 – 49 years	30	88,3	18	78,3
Age > 50 years	4	11,7	5	21,7
Total	34	100	23	100

Hematological examination results for both radiation workers and the control group are presented in Table 2. The results on the analysis of hemoglobin, erythrocytes, leukocytes, platelets, hematocrit, MCV, MCH, MCHC, RDW, MPV, PDW, lymphocytes, monocytes, granulocytes,%lymphocytes,% monocytes, and % granulocytes showed that no significant difference ($p>0.05$) between radiation workers and control group. The number of leukocytes did not experience a significant decrease and is still within the normal range for adults ($4000\text{-}10{,}000 \times 10^3/\mu L$). The increase of lymphocytes, eosinophils, and monocytes can be used as indicators of leukemia sufferers, while a decrease in the number shows symptoms of anemia and an increase in eosinophils and basophils shows the presence of parasitic infections or the presence of allergies.

Table 2. Hematological parameters of the study population

Types of hematological examination	Radiation workers(n = 34) Mean ± STD	Control (n = 23) Mean ± STD	Reference Value	p-value
Hemoglobin (g/dL)	13.58 ±1.69	13.78 ± 1.69	11-16,5	0.66
Erythrocytes(count x10^6/µL)	4.43 ± 0.56	4.65 ± 0.56	3.80 - 5.80	0.14
Leukocytes(count x10^3/ µL)	7.19 ± 1.53	7.23 ± 1.70	4 - 10	0.92
Platelets(count x10^3/ µL)	259.61± 188.84	252.30 ± 79.76	150 - 390	0.86
HCT/Hematrocrit(%)	54.32 ± 73.97	43.25 ± 4.80	35 - 50	0.47
MCV (fL)	95.61± 6.48	93.21 ± 6.55	80 - 97	0.17
MCH (pg)	30.25 ± 5.55	29.67 ± 2.84	26.5 - 35	0.64
MCHC (g/dL)	30.62 ± 6.99	31.87 ± 1.05	31.5 – 35	0.40
RDW (%)	11.31 ± 4.75	12.01 ± 0.55	10 – 15	0.09
MPV (fL)	6.28 ± 6.99	6.52 ± 0.92	6.5 – 11	0.42
PDW (%)	11.57 ± 4.75	13.07 ± 4.24	10 – 18	0.22
Lymphocyte(10^3/µL)	1.80 ± 0.53	1.64 ± 0.51	1.2 – 3.2	0.26
Monocytes(10^3/µL)	0.77 ± 0.25	0.72 ± 0.17	0.3 – 0.9	0.36
Granulocytes(10^3/µL)	4.77 ± 1.07	5.01 ± 1.35	1.2 – 6.8	0.45
Lymphocyte(%)	31.20 ± 36.02	21.30 ± 4.25	17 – 48	0.19
Monocytes(%)	11.17 ± 3.76	11.27 ± 2.71	4 – 10	0.91
Granulocytes(%)	58.22 ± 10.30	57.64 ± 12.36	43 – 76	0.02

HCT: Hematocrit, MCV: Mean Corpuscular Volume, MCH: Mean Corpuscular Hemoglobin, MCHC: MCH Concentration, RDW: RBCs Distribution Width, MPV: Mean Platelet Volume, PDW: Platelet Distribution Width

*. The mean difference is significant at the 0.05 level.

4. Discussion

Certain amounts of radiation can cause ionization in the cells of the human body. The nature and extent of the influence of this radiation depend on the dose received by the tissue cell. Bone marrow cells include cells that actively proliferate so that bone marrow cells are cells that are susceptible to damage due to exposure to ionizing radiation. It is known that cells of the hematopoietic system are very radiosensitive [11]. The role of functional cells of lymphopoiesis and the granulocytopoiesis system is very important for immune protection against infection. Thrombocytopoiesis is one of the most radiosensitive hematopoietic cell lines, damage to the hematopoiesis system can cause bleeding and anemia. [9,12] However, this change depends on the range of effective radiation doses and exposure time. [15]

Blood is a liquid that is present in humans as a means of transportation to transmit substances and oxygen needed by body tissues, to transport chemicals produced by metabolism, and also as a defense of the body against viruses or bacteria. It has been known that low-level radiation can cause changes in blood-forming organs, namely the cessation of the formation of blood cells. The erythropoietic system produces erythrocytes ripe for circulation. There is a rapid proliferation of two adult forms of the erythropoietic system, such as erythroblast and basophilic rubriblast and is more sensitive than other immature forms, namely, polychromatic erythroblasts, normoblasts and reticulocytes and therefore, as cell apoptosis can occur by radiation. [16]

In the bone marrow, the myelopoiesis system produces mature granulocytes, namely, neutrophils, eosinophils, and basophils, to circulate blood. Neutrophils have an important role in preventing infection. Cell stem cells and cells are found in developing phases, that is, dividing and differentiating more radiosensitive to ionizing radiation. That is why, myeloblast and myelocytes are more radiosensitive compared to other immature forms, such as metamyelocyte and stem shape. Renewal of thrombopoiesis cells produces platelets, which are produced by megakaryocytes in the bone marrow in peripheral blood circulation. Adult platelets and megakaryocytes are relatively radioresistant but stem cells and adult megakaryocytic stages are very radiosensitive. Ionizing radiation can damage, stem cells from the hematopoietic system and as a result can change the production of bone marrow elements, exposure to ionizing radiation can reduce bone marrow production in the formation of blood cells and can induce a decrease in hematopoietic cell circulation, adult blood cells from the bone marrow are transported out from the bone marrow to enter the bloodstream and perform their respective functions. These cells are resistant to ionizing radiation, but precursor cells are vulnerable to radiation. [17]

Leukocytes function to protect the body against invasion of foreign objects, such as bacteria and viruses. Decreasing leukocyte production can cause a decrease in the immune system so that radiotherapy patients are susceptible to disease due to infection, bacteria, or viruses. Tissue infection or damage results in an increase in the total number of leukocytes. Leukocytes are one of the lymphocytes that are most sensitive to ionizing radiation and hence radiation can reduce white blood cells and platelets and, as a result, there will be immunity inherited in viruses or bacteria. Because lymphocytes are very radiosensitive and therefore the immune system is susceptible to ionizing radiation. A previous study showed that the average number of white blood cells significantly decreased in workers exposed compared to controls and cells. [16] Lymphocytes are the most radiosensitive cells [13,19], radiation can suppress immune responses due to cell damage [12,13,20]. The immune system has an important role in fighting with disease and radiation can reduce this system which can lead to the development of cancer.

Although in this study ionizing radiation exposure did not significantly influence blood cell development, in some other studies ionizing radiation exposure can affect the cellular DNA damage. Some previous studies showed that radiation exposure received by radiation workers, even in low doses, will cause the appearance both of comet DNA and micronucleus as biomarkers of DNA damage.Every exposure received by radiation-exposed workers of 1 mSv will increase the number of micronuclei by 16.3. It was also found that exposure to ionizing radiation was strongly associated with age, equivalent dose, and years of employment. [21] While in the comet assay, a long-tailed DNA can be used to determine the breakage of the DNA.DNA tails formed show an increasingly high level of damage. The percentage of long-tailed nuclei was significantly higher in the exposed group compared to the control group. This fact showed that DNA damage can be affected by radiation exposure in radiation-exposed workers. [22] Exposure to ionizing radiation together with genetic polymorphisms can increase the risk of cancer emergence. This is because genetic polymorphisms affect the instability of cellular DNA, the ability of cells to repair themselves and trigger the appearance of cancer cells. [23,24]

3. Conclusion

In conclusion, the number of leukocytes, absolute lymphocytes, and counts of blood cell types of radiation workers were still within normal limits. The statistical test showed that the treatment group, when compared with the control, did not show a significant difference ($p > 0.05$). There were no indications of diseases due to the effects of radiation either directly or indirectly. This is probably because the radiation officers in carrying out their activities have followed the safety and health provisions of radiation workers.

4. References

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