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Hematologic Parameters among Radiation Exposed Workers: An Observational Study

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Abstract

Increased exposures to radiation were dangerous to tissues such as the bone marrow, the gastrointestinal tract, and skin. This study investigated on the hematologic parameters of radiation exposed workers in a government hospital in Jakarta. An observational cohort study type was implored. Sampling was generally done randomly among n70 research subjects. From the n70 it was further divided into 2 groups having n35 who had direct exposure to radiation and n35 who were non-directly exposed. Eosinophil was the most significant (SD 0.69-1.22), followed by erythrocytes (SD 0.64-1.20), hematocrit (SD 0.66-1.20), Neutrophil (SD 0.64-1.21), lymphocytes (SD 0.67-1.23), monocytes (SD 0.66-1.23), MCV (SD 0.64-1.24), MCH (SD 0.65-1.25), MCHC (SD 0.63-1.25), basophile (0.66-1.23), and hemoglobin (0.37-1.23). Hematologic parameters that needs to be frequently measured were eosinophil (p<0.05), erythrocyte (p=0.03), MCV (p=0.03), MCH (p=0.03), and MCHC (p=0.03) among radiation exposed workers.

Keywords: *Hematology; healthcare; medicine; observational study; radiology.*

Introduction

There is a worldwide concern about the use of ionization radiations (IR) in the medical field such as X rays, gamma (γ) rays and particles: α-particle, β-particle, protons and neutrons (International Atomic Energy Agency, 1996; Jabeen et al, 2010). The IR is being extensively used in diagnosis as well as in therapeutic use for cancer patients (Crownover et al, 1999). Research on hematologic parameters of radiation exposed workers examined to whether there is any abnormalities caused by exposure to radiation in the workplace (Jabeen et al, 2010). Ionization radiations influence human health as they break chemical bonds of the molecules and damage DNA by the production of free radicals and hence proliferative cells can undergo apoptosis (Vakifahmetoglu et al. 2008). Therefore, the frequent use of machines by technicians such as X-ray diagnostic units as well as therapy units, Computerized tomography scans, PET (positron emission tomography), SPECT (single photon emission computed tomography), gamma cameras, brachytherapy units, Co teletherapy units, linear accelerators, dose calibrators, radioimmunoassay counters and different radiopharmaceuticals pose health risks to occupational workers (Jabeen et al., 2010; Masood et al., 2013).

The effects of radiation are caused by two types of irradiation, the first being a single irradiation with high radiation doses over a short period of time called acute irradiation (International Atomic Energy Agency, 1996). The second low exposure is the long term, and the result will arise in a few years (Budioro., 1992). With the routine blood hematology examination parameters workers is then given medical provisions (Hartati, 2000; Fliedner and Graessle, 2012). The activities related to the use of sources of radioactive materials must obtain a permit and be supervised by Nuclear Energy Agency (Mondjo, 1999; Sjahriar, R. et al, 1992; Budjang, N., 1993). The level of radioactive contamination should be monitored and determined qualitatively and quantitatively (Walter et al, 1999). Monitoring qualitatively by conduct medical check-up, meant the possibility of internal contamination of radiation workers due to the use of cobalt 60, cesium 137, and radium in addition to the use of x-rays (Smirnova, 2010; Walter et al, 1999). While quantitative monitoring is done by doing blood extraction among radiation exposed workers with a personal inspection from registered physicians (Mondjo, 1999; Walter et al, 1999).

Globally, 99% of all hospitals progressed with their health care facilities because of the use of radiation rays (Sjahriar, R. et al, 1992). Hematologic investigation among radiation exposed workers globally, is recommended by the ICRP (International Committee on Radiological Protection) and Nuclear Energy Agency (International Atomic Energy Agency, 1996).

For radiation workers in Indonesia their health condition needs a routine blood sample measurements (Hartati, 2000; Budioro, 1992; Badan Pengawas Tenaga Nuklir, 1999). In particular, the hematological parameters are the hemoglobin, hematocrit, erythrocytes, MCV, MCH, MCHC, basophils, eosinophils, neutrophils, lymphocytes, and monocytes, in addition to their medical and physical check-up every year (Mondjo, 1999; Sjahriar, R. et al, 1992; Budjang, N., 1993). This is because in Indonesia, it is estimated that 90% of radiation workers receive a radiation dose of 43-77% of dose limit for radiation workers at 20 mSv / year (Mukhlis, 2000; Badan Tenaga Nuklir Nasional, 1988). Health development in Indonesia covers health efforts and resources in an integrated and sustainable manner to achieve optimal health functioning for those who are highly exposed to hazardous environments (Budjang, N., 1993). This is also influenced by the increasing needs and demands of the public to obtain health services (Mondjo, 1999; Budjang, N., 1993).

The use of radiation particularly in hospitals in Jakarta has started since 1898 through the use of X-ray equipment for medical examinations (Budjang, N., 1993; Mondjo, 1999). Until 2015, 90% of all hospitals and clinics across Jakarta used more than 10,000 radiology installed for health examination purposes (Mondjo, 1999; Hartati, 2000). It is estimated that radiation workers in Indonesia receive a radiation dose of 43-77% of dose limit for radiation workers at 20 mSv / year (Mondjo, 1999; Sjahriar, R. et al, 1992; Budjang, N., 1993).

Specifically, the department of radiotherapy at Dr. Cipto Mangunkusumo Hospital is the first radiotherapy service center in Indonesia and up to now keeps abreast of the existing technological developments so that its service is comparable to the cancer referral center in Asia. The use of radiation in the field of health services is a source of danger to radiation workers in the Division of radiology. In the national environment, the radiotherapy department at Dr. Cipto Mangunkusumo Hospital is seen as a tertiary radiotherapy service center that has the most complete services and equipment and is capable of performing the highest radiation techniques. It also has the equipment and facilities used in providing external radiation services.

Problem Statement

Increased exposure to IRs such as conventional radiology, Computed Tommography Scanning, Magnetic Resonance Imaging, and Ultra Sonography, and ionizing radiation are dangerous to tissues i.e., bone marrow, the gastrointestinal tract, liver, kidneys, and skin (Budjang, 1993; Arthur, 1995; Herman, 1983). Long term exposure to even low doses of IRs can affect proliferating cells (Fliedner and Graessle, 2012). Workers exposed to radiations are at risk of radiation scattering of IR dose due to long radiation exposure (Mukhlis, 2000; Badan Tenaga Nuklir Nasional, 1988; International Atomic Energy Agency, 1996). By the effects of radiation, either low or high levels will affect the circulatory system therefore routine hematologic investigations are done among radiation exposed workers (Mondjo, 1999; Hartati, 2000; Budioro, 1992; Badan Pengawas Tenaga Nuklir, 1999).

Acute radiation syndrome occurs in humans after the entire body receives a large dose of ionizing radiation in a short time and manifests in four major stages, the prodromal, latent pain, manifest pain, and healing or death (Arthur, Ganong, 1999; Rasad et al, 1992).

The prolonged radiation syndromes are manifested on abnormal hematologic parameter which means that the blood investigation resulted to a deviation from its normal values (Walter et al, 1999; Vakifahmetoglu et al, 2008; Masood et al, 2013; Ganong, 1999).

Objective

On account of these issues, this study investigated on the hematologic parameters of radiation exposed workers in a government hospital in Jakarta.

Operational Definitions

In this study, there are two categories operationally defining radiation workers.

Category A direct exposure: radiation workers who may receive radiation doses equal to or greater than 15 mSv per year (Hartati, 2000; Budioro, 1992; Badan Pengawas Tenaga Nuklir, 1999; International Atomic Energy Agency, 1996).

Category B non-direct exposure: radiation workers who may receive radiation doses smaller than 15 mSv per year (Mukhlis, 2000; Badan Tenaga Nuklir Nasional, 1988; Badan Pengawas Tenaga Nuklir, 1999; International Atomic Energy Agency, 1996).

While the dose limits for radiation workers in Indonesia as noted from the safety series no. 115, of Standard Safety (International Atomic Energy Agency, 1996) is the effective dose of 20 mSv per year, averaged over 5 consecutive years; the effective dose of 50 mSv for one year; the equivalent dose of the eyepiece is 150 mSv in one year; the equivalent dose on the extremities (hands and feet) or skin is 500 mSv in one year; the averaged for an area of 1 cm^2 from the area of skin that receives the highest irradiation.

Table 1. *shows the definition of the hematologic parameters and their reference values*

Hematologic parameters	Definition	Reference Values	Unit
Erythrocytes	Red blood cells that contain hemoglobin that is only able to survive for 120 days	4,0 – 5,0 (F) 4,5 – 5,5 (M)	M/µl
Hemoglobin (Hb)	A part of erythrocytes that is a biomolecule that binds oxygen	12,0 – 14,0 (F) 13,0 – 16,0 (M)	g/dL
Hematocrit	the ratio of the volume of red blood cells to the total volume of blood	40 – 50 (F) 45 – 55 (M)	%
Basophils	Type of granulocytes fighting off viruses, bacteria, and fungi	0,0 – 1,0	%
Eosinophils	Type of granulocyte to fight bacteria, regulate the release of chemicals, and to remove the damaged cells	1,0 – 3,0	%
Lymphocytes	Type of mononuclear aggranulocytes used for chronic inflammatory tissue	20,0 – 40,0	%
Monocyte	Type of aggranulocytes removing injured or dead cells, cell fragments and microorganisms	2,0 – 8,0	%
The rate of sedimentation of blood	It measures the degree of inflammation present in the body	< 15 (F) < 10 (M)	mm/ hours
Leukocytes	White blood cells for defense	5,0 – 10,0	10^3/µl
MCH	Abbreviation for mean cell hemoglobin, which is the average amount of hemoglobin in the average red cell	27 – 31	pg
MCHC	Abbreviation for mean cell hemoglobin concentration, which is the average concentration of hemoglobin in a given volume of blood	32 – 36	g/dL
MCV	Abbreviation for mean corpuscular volume which is the average volume of red cells	80 – 96	fl
Thrombocytes	Platelets in the blood that forms thrombin and stimulates fibrinogen to make fibrin or threads for blood clotting	150 – 400	10^3/µl

Methodology

Study Site

The study was conducted at Dr. Cipto Mangunkusumo hospital which is government owned. The cohort was located at Jalan Diponegoro no. 71 Central Jakarta, and had a bed capacity of 1,033. Dr. Cipto Mangunkusumo Hospital had about 6,000 people covering several types of manpower both medical personnel and non-medical personnel.

Population, Sampling Technique and Sample Size

The population in this cohort had a total of 85 radiation exposed workers. Table 2 enumerated the total workers exposed to radiation. Sampling was generally done randomly, by pooling in all the populations and selecting the subjects for observation without biases. Of the n85, only n70 were observed. The calculation for selecting the sample is shown in figure 1.

$$n = \frac{85}{1 + 85(0.05)^2}$$

$$n = \frac{85}{1.212} = 70\ radiation\ workers$$

Figure 1. Sample size calculation

From the n=70 samples to be observed, the authors divided it further into 2 groups having n=35 who had direct exposure to radiation and n=35 who were non-directly exposed.

Table 2. *Radiation exposed workers*

NO.	Workers exposed to radiation	Total	%
1.	Radiologist	7	8.77
2.	Radiotherapist	21	21.93
3.	Medical Phisician	7	6.15
4.	Nurse	17	23.68
5.	Technician	5	4.38
6.	Admission	18	21.93
7.	Servant	10	13.16
Total		85 radiation workers	

Instrumentation

An observational checklist was used. Table 3 shows the descriptive criteria of the variables and its measured scales from the observational checklist. Data from the observational checklist are analyzed based on the specific objectives found on table 4.

Table 3. *Procedures of data collection*

VARIABLES	CRITERIA
Age level	1.< 25 years 2. 25-35 years 3. 36-45 years 4. 46-55 years 5. >56 years
Gender	1. Male 2. Female
Length of work	1. 1 – 5 years 2. 6 – 10 years 3. 11 – 15 years 4. >15 years
Type of work	1.Direct Contact Radiation 2.Non Direct contact radiation

Hemaglobin	1.**Normal** (If Male : 13 – 17 gram/dl Female : 12 – 15.5 gram/dl) 2. **Abnormal** (If Male : < 13 and > 17 gram/dl Female : < 12 and > 15.5 gram/dl)
Hematocrit	1.**Normal** (If Normal Male : 45 – 55 % Female : 40 – 50 %) 2. **Abnormal** (If Male: < 45 and > 55 % Female :< 40 and > 55 %)
Erythrocyte	1.**Normal** (if Male : $4.5 \times 10^6 – 5.5 \times 10^6/\mu l$ Female : $4.0 \times 10^6 – 5.0 \times 10^6/\mu l$) 2. **Abnormal** (If Male : $< 4.5 \times 10^6$ and $> 5.5 \times 10^6/\mu l$ Female : $< 4.0 \times 10^6$ and $> 5.0 \times 10^6/\mu l$)
MCV	1.**Normal** (If 80 – 96 fl) 2. **Abnormal** (If < 80 and > 96 fl)
MCH	1.**Normal** (If 27 – 31 pg) 2. **Abnormal** (If < 27 and > 31 pg)
MCHC	1.**Normal** (If 32 – 36 g/dl) 2. **Abnormal** (If < 32 and > 36 g/dl)
Basophils	1.**Normal** (If 0.0 – 1.0 %) 2. **Abnormal** (If < 0.0 and > 1.0 %)
Eosinophils	1.**Normal** (If 1.0 – 3.0 %) 2. **Abnormal** (If < 1.0 and > 3.0 %)
Neutrophils	1.**Normal** (If 0.0 – 1.0 %) 2. **Abnormal** (If < 0.0 and > 1.0 %)
Lymphocyte	1.**Normal** (If 20.0 – 40.0 %) 2. **Abnormal** (If < 20.0 and > 40.0 %)
Monocyte	1.**Normal** (If 2.0 – 8.0 %) 2. **Abnormal** (If < 2.0 and > 8.0 %)

Table 4. *Techniques of data analysis*

Specific Objectives	Research Questions	Technique of Analysis
Identify routine hematologic parameter among the radiation exposed workers.	What are the routine hematologic parameters used among the radiation exposed workers?	Frequency and percentile ranking Paired T-Test
Identify evidences of abnormalities on hematologic parameters among the radiation exposed workers	What are the evidences of abnormalities on hematologic parameters among the radiation exposed workers?	Mann Whitney U test

Ethical Consideration

This research was done after the approval from Lincoln University College Research Management Center in Malaysia for academic purposes. The radiotherapy department of Dr Cipto Mangunkusumo hospital also gave consent to observe their radiation exposed workers.

Results and Findings

Demography

The distribution of workers at health facilities in the radiotherapy department is found on table 5.

Table 5. *Distribution of workers based on radiology department*

Radiology department	Radiation workers	
	Direct exposures	Non-direct exposures
Synergy room	3	2
Synergy Platform	5	2
Varian Unique	5	2
Tomotherapy	5	2
Brakytherapy	5	3
Simulator	2	8
CT Simulator	2	3
TPS	2	1
Mouldroom	-	4
Dosimetry	6	1
Policlinic	-	5
Counter	-	2

Based on calculated sample size, the subjects were divided into n=35 are the direct contact radiation workers and n=35 non direct contact radiation workers were obtained. The number of direct exposure to radiation (n35) consisted of Radiologist (n7), Radiotherapist (n21), and Medical Physician (n7). The non-direct exposures to radiation (n35) consisted of nurse (n7), Technician (n5), Admission (n18), and Servant (n5). The age, gender, and length of work are found on table 6.

Table 6. *Frequency distribution of age, gender and length of work*

Variable	Categories	Frequency	%
Gender	Male	29	41,4
	Female	41	58,6

Age	< 25 years old	12	17,1
	25-35 years old	26	37,1
	36 – 45 years old	14	20,0
	46 – 55 years old	13	18,6
	> 55 years old	5	7,1
Length of Work	1 – 5 years	30	42,9
	6 – 10 years	21	30,0
	11 – 15 years	10	14,3
	> 15 years	9	12,9

Hematological Parameter Among Radiation Exposed Workers

Of the n70 subjects observed, eosinophil was the most significant hematologic parameter among workers who has direct and non-direct radiation exposed workers (SD 0.69-1.22).

Erythrocytes were the next significant hematologic parameter (SD 0.64-1.20). Even though the hematocrit (SD 0.66-1.20), Neutrophil (SD 0.64-1.21), lymphocytes (SD 0.67-1.23) and monocytes (SD 0.66-1.23) have the lesser deviation on non-directly exposed radiation worker, it is still marked as abnormal for n1 subjects of the n70.

The MCV (SD 0.64-1.24), MCH (SD 0.65-1.25), MCHC (SD 0.63-1.25), and basophile (0.66-1.23) are also identified to be standard hematologic parameters since radiation exposed workers also had an evidenced abnormal deviation.

By using *T-Test* we have identified the significant hematological parameters found on table 7, and we have removed from the table, the hematologic parameters with a result of 0.001-0.400 standard deviations and level of significance of $p \geq 0.05$ (non direct).

Table 7. *Hematologic parameters*

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Type of work - Hemoglobin	.28571	.76410	.09133	.10352	.46791	3.128	69	.003
Pair 2	Type of work - Hematrocit	.38571	.66579	.07958	.22696	.54447	4.847	69	.000
Pair 3	Type of work - Erythrocyte	.37143	.64091	.07660	.21861	.52425	4.849	69	.000
Pair 4	Type of work - MCV	.34286	.67857	.08110	.18106	.50466	4.227	69	.000
Pair 5	Type of work - MCH	.34286	.67857	.08110	.18106	.50466	4.227	69	.000
Pair 6	Type of work - MCHC	.34286	.67857	.08110	.18106	.50466	4.227	69	.000
Pair 7	Type of work - Basophils	.28571	.76410	.09133	.10352	.46791	3.128	69	.003
Pair 8	Type of work - Eosinophils	.25714	.79282	.09476	.06810	.44619	2.714	69	.008
Pair 9	Type of work - Neutrophils	.34286	.72002	.08606	.17117	.51454	3.984	69	.000
Pair 10	Type of work - Lymphocyte	.32857	.75607	.09037	.14829	.50885	3.636	69	.001

Pair 11	Type of work - Monocytes	.30000	.78666	.09402	.11243	.48757	3.191	69	.002
Pair 12	Age - Hemoglobin	1.40000	1.23241	.14730	1.10614	1.69386	9.504	69	.000
Pair 13	Age - Hematrocit	1.50000	1.20085	.14353	1.21367	1.78633	10.451	69	.000
Pair 14	Age - Erythrocyte	1.48571	1.20076	.14352	1.19940	1.77203	10.352	69	.000
Pair 15	Age - MCV	1.45714	1.24744	.14910	1.15970	1.75458	9.773	69	.000
Pair 16	Age - MCH	1.45714	1.24744	.14910	1.15970	1.75458	9.773	69	.000
Pair 17	Age - MCHC	1.45714	1.24744	.14910	1.15970	1.75458	9.773	69	.000
Pair 18	Age - Basophils	1.40000	1.23241	.14730	1.10614	1.69386	9.504	69	.000
Pair 19	Age - Eosinophils	1.37143	1.22972	.14698	1.07821	1.66465	9.331	69	.000
Pair 20	Age - Neutrophils	1.45714	1.21209	.14487	1.16813	1.74615	10.058	69	.000
Pair 21	Age - Lymphocyte	1.44286	1.23518	.14763	1.14834	1.73738	9.773	69	.000
Pair 22	Age - Monocytes	1.41429	1.23350	.14743	1.12017	1.70840	9.593	69	.000
Pair 23	Gender - Hemoglobin	.37143	.66314	.07926	.21331	.52955	4.686	69	.000
Pair 24	Gender - Hematrocit	.47143	.65323	.07808	.31567	.62719	6.038	69	.000
Pair 25	Gender - Erythrocyte	.45714	.65244	.07798	.30157	.61271	5.862	69	.000
Pair 26	Gender - MCV	.42857	.64989	.07768	.27361	.58353	5.517	69	.000
Pair 27	Gender - MCH	.42857	.64989	.07768	.27361	.58353	5.517	69	.000
Pair 28	Gender - MCHC	.42857	.62720	.07496	.27902	.57812	5.717	69	.000
Pair 29	Gender - Basophils	.37143	.66314	.07926	.21331	.52955	4.686	69	.000
Pair 30	Gender - Eosinophils	.34286	.69960	.08362	.17604	.50967	4.100	69	.000
Pair 31	Gender - Neutrophils	.42857	.64989	.07768	.27361	.58353	5.517	69	.000
Pair 32	Gender - Lymphocyte	.41429	.67013	.08010	.25450	.57407	5.172	69	.000
Pair 33	Gender - Monocytes	.38571	.66579	.07958	.22696	.54447	4.847	69	.000
Pair 34	Length of work - Hemoglobin	.75714	1.10906	.13256	.49270	1.02159	5.712	69	.000
Pair 35	Length of work - Hematrocit	.85714	1.06711	.12754	.60270	1.11159	6.720	69	.000
Pair 36	Length of work - Erythrocyte	.84286	1.07185	.12811	.58728	1.09843	6.579	69	.000
Pair 37	Length of work - MCV	.81429	1.12021	.13389	.54718	1.08139	6.082	69	.000
Pair 38	Length of work - MCH	.81429	1.12021	.13389	.54718	1.08139	6.082	69	.000
Pair 39	Length of work - MCHC	.81429	1.10719	.13234	.55028	1.07829	6.153	69	.000
Pair 40	Length of work - Basophils	.75714	1.10906	.13256	.49270	1.02159	5.712	69	.000
Pair 41	Length of work - Eosinophils	.72857	1.12831	.13486	.45954	.99761	5.402	69	.000
Pair 42	Length of work - Neutrophils	.81429	1.12021	.13389	.54718	1.08139	6.082	69	.000
Pair 43	Length of work - Lymphocyte	.80000	1.13699	.13590	.52889	1.07111	5.887	69	.000
Pair 44	Length of work - Monocytes	.77143	1.15685	.13827	.49559	1.04727	5.579	69	.000

Abnormalities on Hematological Parameters

Research subjects in this study were further divided into 2 groups – direct and non-direct exposures. The p value is distinguished only on the direct exposure.

Researchers used *Mann-whitney U test* to identify the abnormalities on hematological parameters among the radiation exposed workers both direct and non-direct with a probability value of ≥0.05.

Table 8 shows the most significant hematologic parameter such as the erythrocyte (*p=0.03*), MCV (*p=0.03*), MCH (*p=0.03*), and MCHC (*p=0.03*) as these were necessary to be examined among radiation exposed workers.

Table 8. *Haematology Results on the Radiation Exposed Workers*

Haematology	Direct Exposure				Non – Direct Exposure				P value
	Normal		Abnormal		Normal		Abnormal		
	N	%	N	%	N	%	N	%	
Haemaglobin	22	31.4	13	18.6	33	47.1	2	2.9	0.001
Hematocrit	28	40.0	7	10.0	34	48.6	1	1.4	0.025
Erythrocyte	29	41.4	6	8.6	32	45.7	3	4.3	0.03
MCV	27	38.6	8	11.4	32	45.7	3	4.3	0.03
MCH	27	38.6	8	11.4	32	45.7	3	4.3	0.03
MCHC	27	38.6	8	11.4	32	45.7	3	4.3	0.03
Basophils	22	31.4	13	18.6	33	47.1	2	2.9	0.001
Eosinophils	20	28.6	15	21.4	33	47.1	2	2.9	0.001
Neutrophils	25	35.7	10	14.3	34	48.6	1	1.4	0.003
Lymphocyte	23	32.9	12	17.1	35	50.0	1	1.4	0.003
Monocyte	21	30.0	14	20.0	35	50.0	1	1.4	0.003

Discussion

One of the weaknesses of our study is our inability to control the variables. We are not allowed to interfere with the blood extraction, as we are only observing the results from the hematology department. Therefore, there are no interventions done in this study.

Finally, the study took 6 months before we are able to come up with a conclusion. The cohort was also the limitations of this study as it cannot be generalized to all radiologists worldwide. However, if the findings are used by other countries, or hospitals, it should be taken with caution looking at the demography of the subjects (Indonesians) and the setting of the cohort.

The strength of this study is its design. Our observational study has an explanatory, and response variable. The Indonesian National Committee on Radiation Protection guideline says that radiation exposure as the causative variable should be made as minimal as possible (Badan Pengawas Tenaga Nuklir, 1999; Herman, 1983; Mondjo, 1999; Munir, 1998; Speicher and Smith, 1996; Togap, 2000). This can be achieved through appropriate radiation control procedures (Togap, 2000; Singgih, 1993). The purpose of the radiation control provides radiation benefits to radiation exposed workers (Budioro, 1992). When IR serves as a stimulus and biological effects function as a response, it can be said that there is a no-threshold relationship between the radiation dose and the biological effect (Susworo, 2007; Suma'mur, 1989; Rasad, 1999). Therefore there is no radiation that is completely safe (Bomford, et al, 1979).

The hemaglobin levels among direct and non direct radiation exposed workers had alterations. It can be seen that direct radiation exposed workers have abnormal hemoglobin level of 18.6% while non-direct radiation workers have abnormal hemoglobin level of 2.9%. Generally, hemoglobin is essential for carrying oxygen to all parts of the body (Fliedner and Graessle, 2012). Radiation exposures to the genetic coding of Southeast Asians such as Indonesians are prone to alteration of hemoglobin as a hematologic component, eventually, this leads to anemia (Rasad, 1999; Singgih, 1993).

The analysis also shows that radiation exposed workers direct and non direct, had alterations with hematocrit levels. It can be seen that direct radiation exposed workers have abnormal hematocrit levels of 10% whereas non-direct radiation exposed workers also have 1.4%. The hematocrit measures the volume of erythrocytes compared to the total blood volume and also used to check for hemolytic and sickle cell anemia. Low hematocrit levels among Indonesians may lead to bone marrow diseases, chronic inflammatory diseases, lymphoma, kidney failures, and deficiencies in nutrients such as iron, foliate and vitamin B 12 (Susworo, 2007; Walter et al, 1999; Vakifahmetoglu et al, 2008). This means that radiation exposure will easily alter the hematocrit levels of Indonesians.

It can also be seen that direct radiation exposed workers have abnormal erythrocyte content of 8.6% whereas non-direct radiation workers also have abnormal erythrocyte content of 4.3%. Erythrocytes regenerate and mature every 120 days (Walter et al, 1999). When erythrocytes mature, radiosensivity decreases (Lombardi, 1999). A radiation dose of 0.1-0.5 gray (10-50 rad) reduces the amount of erythrocytes in the bloodstream (Lombardi, 1999; Walter et al, 1999). Erythrocytes begin to reshape, one month after radiation (Jabeen et al, 2010). Cleavage of erythrocytes among Indonesians due to radiation and irradiation can cause anemia that worsens with the bleeding throughout the body (Ganong, 1999; Budioro, 1992). Determination of the average value of erythrocytes is used to diagnose the type of anemia (Lombardi, 1999; Walter et al, 1999; Masood et al, 2013; Ganong, 1999).

Similarly, an abnormal MCV levels of 11.4% can also be seen among direct radiation exposed workers and non-direct radiation exposed workers of 4.3%. MCV is elevated or decreased in accordance with average red cell size (Arthur, 1995; Ganong, 1999). MCV indicates microcytic (small average erythrocyte size), normocytic (normal average erythrocyte size), and macrocytic (large average erythrocyte size) (Walter et al, 1999; Archambeau et al, 1972). MCV among male adults are often reduced as they aged together with the erythrocytes (Walter et al, 1999). Male adults age faster than females together with a decreased in MCV especially when exposed to radiations (Archambeau et al, 1972; Arthur, 1995; Budioro, 1992).

Alterations with MCH levels on the other hand can be seen that direct radiation exposed workers with an abnormal MCH levels of 11.4% while non-direct radiation exposed workers have MCH Abnormal levels of 4.3%. Low MCH iron deficiency and microcytic anemia (Archambeau et al, 1972; Arthur, 1995; Budioro, 1992; Walter et al, 1999). High MCH scores are common among Indonesians, leading to signs of macrocytic anemia (Budioro, 1992; Arthur, 1995; Ganong, 1999). This condition is worsened when the blood cells are exposed to radiation and becomes too big, which can be a result of not having enough vitamin B12 or folic acid in the body (Budjang, 1993; Budioro, 1992; Jabeen et al, 2010).

Alterations with MCHC levels can also be seen among direct radiation exposed workers with an abnormal MCHC level of 11.4% while non-direct radiation exposed workers have abnormal MCHC levels of 4.3%. Hypochromic microcytic anemia commonly results in low MCHC (Masood et al, 2013). This condition is common among brown race Asians having smaller erythrocytes than the usual and having a decreased level of hemoglobin (Singgih, 1993; Suma'mur, 1989).

Radiation exposed workers direct and non direct, had alterations with Basophil levels. It can be seen that direct radiation exposed workers have abnormal basophile level of 18.6% while non-direct radiation exposed workers also have abnormal basophile level of 2.9%. Alterations in basophils can result from certain blood cancers (Crownover et al, 1999; Bachtiary et al, 2003). This is common when the Leukocyte count falls and exposed on radiation (Arthur, 1995).

Radiation exposed workers direct and non direct, also had alterations with Eosinophil levels. It can be seen that direct radiation exposed workers have abnormal eosinophils of 21.4% while non-direct radiation exposed workers also have abnormal eosinophils of 2.9%. Cushing's disease, peripheral arterial disease, and other forms of cancer is the effect because of low levels of eosinophils conditioned by low leukocytes counts due to radiation exposure (Crownover et al, 1999; Bachtiary et al, 2003).

Similarly, radiation exposed workers direct and non direct, had alterations with Neutrophils levels. It can be seen that direct radiation exposed workers have abnormal Neutrophils level of 14.3% while non-direct radiation exposed workers also have abnormal neutrophils levels of 1.4%. Alterations of neutrophils are particularly caused by radiation exposure (Arthur, 1995; Budjang, 1993). For adults, counts of less than 1,500 neutrophils per microliter of blood are considered to be neutropenia (Budioro, 1992; Bomford et al, 1979).

Again, radiation exposed workers direct and non direct, had alterations with Lymphocyte levels. It can be seen that direct radiation exposed workers have abnormal lymphocyte level of 17.1% while non-direct radiation exposed workers also have abnormal lymphocyte level of 0%. Low lymphocyte count due to radiation exposure is a greater risk of infection (Crownover et al, 1999). Other conditions that can cause lymphocytopenia include genetic abnormality among Southeast Asians (Singgih, 1993; Suma'mur, 1989; Budioro, 1992).

Finally, radiation exposed workers direct and non direct, had alterations with Monocytes levels. It can be seen that direct radiation exposure workers have abnormal monocyte levels of 20% whereas non-direct radiation exposed workers have abnormal monocyte levels of 0%. A low number of monocytes in the blood (monocytopenia) due to radiation exposure can be caused by a decrease in the overall leukocyte count (Speicher and Smith, 1996). Among Southeast Asians, alterations in monocytes counts can lead to bloodstream infection, or a bone marrow disorder (Rasad, 1999; Singgih, 1993; (Budjang, 1993; Budioro, 1992; Jabeen et al, 2010). Aside from the mentioned hematologic parameters in this study, after radiation exposure, the mitotic activity of the stem cells is stunted or stalled however, depending on the radiation dose (Susworo, 2007; Budjang, 1993; Budioro, 1992; Jabeen et al, 2010). Thus a number of blood cells decrease with sensitivity and life expectancy, in which the first lymphocytes act as the most sensitive to radiation, followed by granulocytes, platelets and ultimately erythrocytes (Togap, 2000; Walter et al, 1999; Vakifahmetoglu et al, 2008). In 1990 the International Commission stipulated that the effect of X-rays can cause haemopoetic damage (blood disorders) such as: Anemia, Leukemia and Leukopeni the decrease in the number of leukocytes (below normal or < 6.000 m^3) (Ganong, 1999; Fliedner and Graessle, 2012; Crownover et al, 1999). A number of biological components will undergo changes after radiation exposure as a direct result of radiation damage and in response to cell repair and regeneration processes (Vakifahmetoglu et al, 2008).

Hematopoitic indicators commonly used as an indication of radiation exposure are the counts of absolute (1) lymphocytes, (2) neutrophils, and (3) red blood cells (Lusiyanti dan Syaifudin, 2004; Jabeen et al, 2010). In relation to radiation protection conducted to determine how much radiation is concerned and its effect on the workers it is necessary to monitor the dose of per cent and regular health inspection of radiation workers performed at least once a year as stated in PP. 63 year 2000 on the safety of work against radiation (Rasad et al, 1999). In the radiology section there are several workers who are in charge of operating X-ray equipment hereinafter called Radiation Workers. According to the Decree of the Minister of Health No. 375 of 2007 on Standards of Professional Radiographers that a radiographer in general has duties and responsibilities, among others (Badan Tenaga Nuklir Nasional, 1988; Badan Pengawas Tenaga Nuklir, 1999): (1) Conducting Radiographic examination of patients including radiodiagnostic and imaging examinations including nuclear and ultrasound (Rasad et al, 1999); (2) Conducting radiation irradiation techniques on radiotherapy (Archambeau et al, 1972). Conducting accuracy and safety of radiation protection measures in operating radiological equipment and / or radiation sources (Arthur, 1995).

Recommendations

Hematologic parameters such as eosinophil, erythrocyte, MCV, MCH, and MCHC among radiation exposed workers are to be frequently measured. The regenerative ability of lymphocyte and other hematologic parameters depends on the radiation and other supporting factors such as food consumed (Arthur, 1995). If the radiation is low and consumption of foods is high in nutrition, then the ability to regenerate will be faster (Archambeau et al, 1972). For that besides with radiation protection need also effort of procurement of supplementary food with high nutrition to hemoglobin, and hematocrit (Walter et al, 1999). This is in accordance with the technical guidelines of the radiodiagnostik service in hospitals which says that high nutritional supplements should be provided for workers working on radiation (Walter et al, 1999; Rasad et al, 1999; Arthur, 1995).

A radiation worker must receive protection for health and safety before starting work, while working and after completion of work (Togap, 2000). The importance of the use of personal protective equipment should be emphasized while on duty in the radiation exposed areas (Susworo, 2007; Wardhana, 1993). Regular medical checkups for radiation workers need to be done every year, so that health conditions can be monitored continuously (Walter et al, 1999; Badan Pengawas Tenaga Nuklir, 1999). In addition, highly nutritious diet recommended by physicians and dieticians may help improve the blood circulation of high risk radiographers frequently exposed to radiations (Walter et al, 1999).

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