EVALUATION OF THE LONG-TERM EXPOSURE TO LOW DOSES OF IONIZING RADIATION ON CATHETERIZATION PROCESS WORKERS

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ABSTRACT Background: Workers in cardiac catheterization centers that employ X-rays may be exposed to low quantities of ionizing radiation for long periods of time, causing damage to human cells and tissues. Blood cell composition testing is an important monitoring technique in the typical diagnostic examination. Objectives: The present study has been designed to evaluate Ionizing radiation's impact on the haematological parameters of occupational exposure in a cardiac catheterization lab at Azadi teaching hospital in Duhok City, Iraq. **Methods:** The study involved 40 hospital employees working in medical radiation centres exposed to lower doses of ionizing radiation during Radiotherapy or diagnostic and the 32 unexposed workers as control. The correlation between the total dose and the haematological indices of exposed workers is examined using a bivariate regression analysis program. **Results:** The results looked to be significantly different ($p<0.05$) compared to the respective controls in all blood parameters. Nevertheless, there is no significant difference ($p>0.05$) in Mean corpuscular volume, Mean Corpuscular Hemoglobin, Mean Corpuscular Hemoglobin Concentration, White blood cells, and Lymphocyte values obtained as compared with the control. **Conclusions:** The study found that almost some haematological parameters are affected by radiation. Further research should incorporate a variety of other independent factors, such as (chromosomal aberrations and genetic polymorphisms) to study other low-dose radiation's long-term effects on personnel exposed to it.

KEYWORDS low-level penetrating radiation, Long-period exposure, Blood cell composition, Radiation-exposed employees, X-Ray

Introduction

Radiation in the form of electromagnetic radiation refers to energy transferred from one place to another. It may be ionizing or non-ionizing, depending on the amount of energy it possesses. An X-ray is a ionizing radiation used in medical imaging. Exposure to ionizing radiation might be harmful at any dose. The doses used in medical imaging had been linked to the development of cancers [1,2 and 3]. Medical imaging modalities that use ionizing radiation make up two-thirds of radiological procedures [4]. Radiographers are exposed to low ionizing radiation doses during radiological procedures. Ionizing radiation can induce different forms of cell harm, including the prospect of chance the occurrence of chromosomal abnormality. Routine medical checks often employ analyses of haematological parameters such as blood cell count. Ionizing radiation is highly toxic to hematopoietic cells, and long-period exposure to lower doses of ionizing radiation can harm humans cell, particularly the peripheral blood cell count. Changes in the haematological

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parameters of a radiation worker may serve as an indicator of ionizing radiation's health consequences.

Many research works have been performed on the effect of ionizing radiation on the haematological indices of a radiation worker. Long-term ionizing radiation (IR) exposure has been shown to impair cell division, especially in sensitive tissues like bone marrow, skin, and gastrointestinal organs. Formation of the blood, which serves to carry oxygen and protects against viruses and germs, may be reduced if the bone marrow is weak. A study conducted in south-south Nigeria [2] found a low count of White Blood Cells (WBC), Neutrophils, Lymphocytes, and abnormal blood cell morphologies across a wider range. An Indonesian study [3] reported that workers exposed to radiation have greater red blood cell and monocyte counts. Study [4] in a Palestinian observed mean values with low and high hematocrit and corpuscular haemoglobin disruption in a few more medical radiographers. There appeared to be no significant variations in the amounts of red and white blood cells and platelets in the control and radiographer workers.

On the contrary, many recent studies noted that the lymphocyte counts of the control group and radiation workers differed significantly [5,6]. Additional to blood parameters, the damages to the DNA and chromosomal demolition, at the molecular level, indicate the harm produced by ionizing radiation. In previous studies, Micronuclei, a DNA damage biomarker, were considerably greater in exposed workers than in controls [7,8]. Changes in the haematological characteristic on the radiation workers can be used to predict radiation damage. The present study aimed to assess the accumulated effects as Long-period effect of lower doses irradiation (X-ray) on radiation employees' haematological parameters at the Cardiac Catheterization Laboratory (Radiology and Radiotherapy centres) in the Azadi Teaching Hospital in Duhok-Kurdistan region of Iraq. The duration of exposure extends from 3 to 15 years of employment. The correlations between the total dose and the haematological composition have been tested by a bivariate regression analysis test using SAS-JMP Pro 14.3.0 software [9].

Materials and Methods

Study Population

The study involved 40 medical radiation workers (aged 25-60 years) who were exposed to low radiation (X-rays) on the job for intermittent periods (5 to 8 operations per day, 3 days per week) for a number of years in radiology and radiotherapy units. The control workers were hospital employees who had not been irradiated or did not work with radiation-emitting unites and were of the same age group mentioned above. After being briefed about the study's scope and experimental details, all participants gave informed consent. All of the participants were asked standardized questionnaires to identify their socio-demographical data, gender, age, smoking status, years of experience, and the average number of operations per week, all are factors to consider.

Depending on the measured dose of the patient and the location of each worker from the radiation source, the total dose per year for each worker was calculated by the inverse square law of radiation. $\frac{D_2}{D_1} = \frac{(d_1)^2}{(d_2)^2}$, where D1 is the patient's dose, d1 is the patient's distance from the sources, D2 is the worker's dose, d2 is the worker's distance from sources [10].

Collection of Blood Samples

Blood samples were taken from the entire group according to the standard protocols. In September 2021, 3 millilitres of blood were drawn from each of 40 X-ray technician assistants in Azadi teaching hospital participants by a vacutainer tube including an anticoagulant (EDTA). They gently turned upside down to avoid blood clots. Haematological parameters (HPs) or (CBC) for all subjects are measured by an Automatic haematology Swelab Alfa basic boule medical a.b analyzer (SN: 11018) at the laboratory of Azadi Teaching Hospital. At the same time, the same protocol was applied to another 32 healthy, non-risk individuals from hospital staff in other departments to serve as a control group. The results were analyzed and compared with each other. Twelve haematological parameters were measured for all individuals exposed to ionizing radiation and those unexposed, which include haemoglobin (Hb in g/dL), red blood cells (RBC), white blood cells (WBC), platelet (PLT), hematocrit (PCV or Packed Cell Volume), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), RBC distribution width (RDW), lymphocytes (LYM), monocytes (MON), and Neutrophils.

Statistical Analysis

The general characteristics of blood composition of those exposed to radiation and those unexposed groups were represented in number and percentage or meant and standard deviation. The Comparison of general characteristics between cases and controls was examined in independent t-tests or Pearson Chi-squared tests. Comparisons of red and white blood cell measurements between the exposed and unexposed groups were measured in an independent t-test. The correlation of the total exposure dose with haematological measurements was calculated by bivariate regression analysis. A p-value was used to determine the significance of the difference of $P < 0.05$. Statistical analyzes were performed with JMP Pro 14.3.0 software generated at SAS Institute Inc. It offers advanced features for more complex analysis, including predictive modelling and cross-validation techniques [9].

Results

Study Population

Basic information for all study participants is presented in Table 1. Among all employees exposed to radiation, n = 40, mean age = 38.08 ± 5.54 years, and most (30) were male. Among all controls (n = 32, with mean age = 40.26 ± 6.02 years), 19 were male. Of all subjects, nine radiation workers (22.50%) and six controls (18.75%) are smokers. Radiation workers were exposed during catheterization operations to a radiation dose ranging from 0.00231 to 0.3328 mGy /operation with an average of 0.2194± 0.11759 mGy/operation. Therefore, the average dose accumulated during the working years is 1271.35 ± 750.52 mGy, with a range of 194.7 - 4153.3 mGy.

Workers exposed to radiation from various professions were selected, including X-ray technicians, radiological doctors, nurses, and radiologists in the catheterization lab. At the same time, the office employees, nurses, physicians, administrative staff, and technicians are among the controls. All of them are from the government Azadi Teaching Hospital in Duhok City. Both groups were selected from the same radiological background to focus on the effect of X-ray exposure.

Table1: Demographic characteristics of the study population

Characteristics	Study groups		P-value (two-sided)
	Exposed group (n=40)	Unexposed group (n=32)	
Age Mean (SD)	38.08 (±5.54)	40.26 (±6.02)	0.1135[a]
Gender no (%)			
Male	30 (75.00)	19 (59.38)	0.1581[b]
Female	10 (25.00)	13 (40.63)	
Occupation no (%)			
Anesthetic	6 (15.00)	0 (0.00)	**<0.0001**[b]
Doctor	7 (17.50)	0 (0.00)	
Employed	0 (0.00)	11 (34.38)	
Nurse	8 (20.00)	0 (0.00)	
Radiographer	10 (25.00)	0 (0.00)	
Technician	9 (22.50)	0 (0.00)	
Unemployed	0 (0.00)	21 (65.63)	
Smoking no (%)			
No	31 (77.50)	26 (81.25)	0.6970[b]
Yes	9 (22.50)	6 (18.75)	
Years of employment			
Mean (SD)	9.6 (±3.96)	-	-
Range	3 - 15		
Dose/operation (mGy)			
Mean (SD)	0.2194(0.11759)	-	-
Range	0.00231-0.3328		
Total exposure dose (mGy)*	1271.5 (750.52)	-	
Range	(194.7-4153.3)		

[a] an independent t-test ad [b] Pearson Chi-squared test performed for statistical analyses.

*Total exposure dose (mGy) was calculated per number of operations for years of service.

Haematological Parameters Analyses

The results of haematological parameter tests are reported in Tables (2&3) and Figures (1&2). It has been found that several of the haematological parameter values (Hemoglobin, RBC, PCV, RDW, Platelet count, Neutrophils, and Monocytes) of the exposed workers are significantly different from controls. For instants, the values of haematological parameters found in X-ray employees relative to controls are the following: Hemoglobin 15.36(1.27) opposite 12.38(0.79), P<0.001; RBC 5.29 (0.28) versus 9.30 (8.20), P= 0.0028; PCV 41.71(2.86) versus 37.31(1.89), P<0.001; RDW 10.93(1.04) versus 12.45(0.82), P<0.001; Platelet 223.30 (56.82) versus 258.08 (54.80), P=0.0107; Neutrophils 3.65(0.75) versus 4.51(1.94), P=0.0123; Monocytes 0.50(0.23) versus 0.69 (0.24), P<0.0001. The study also indicates statistically certain there is not much of a difference with p>0.05 in the haematological parameters: MCH 28.71 (2.61) versus 28.92 (2.46), P=0.7299; MCHC 36.48 (1.02) versus 36.51 (2.53), P=0.9433; WBC count 6.33 (1.40) versus 6.92(2.42), P=0.1939; and Lymphocytes 3.42(0.85) versus 3.71(1.09), P= 0.1977. Also, a very low significant difference is obtained in the MCV levels of the subjects, 75.86 (12.29) when compared with the control, 70.54 (12.74) at P= 0.0771 (Table 2 & Figure 1).

Correlation between total doses to haematological parameters The total exposure dose for cumulative radiation workers during the previous years of services ranged (from 194.688 - 4153.344 mGy) with an average dose of 1271.35±750.52 mGy, as displayed in Table 1. Linear bivariate regression analysis evaluated the correlation between the total dose and haematological parameters. Table 4 shows that there is a positive correlation and non-significant relationship found between the total dose and the most haematological parameters (P > 0.05), while negative correlations and non-significant relationship in the other haematological parameters such as Hemoglobin, RBC, and Platelet counts. However, there is a low negative correlation significant relationship (P > 0.10) between the total dose and the MCHC at

Table 2: Comparisons of red blood cells measurements between the exposed group and unexposed group to radiological exposures

Haematological parameters (RBC)	Ref. Range	Study group Mean (SD)		P-value (two-sided)
		Exposed group (n=40)	Unexposed group (n=32)	
Haemoglobin (g/dl)	13.0 – 17.0	15.36 (1.27)	12.38 (0.79)	**<0.001**
RBC count (x10¹²/l)	4.5 – 6.1	5.29 (0.28)	9.30 (8.20)	**0.0028**
PCV (%)	36.1 – 44.3	41.71 (2.86)	37.31 (1.89)	**<0.001**
MCV (fl)	80.0 – 100.0	75.86 (12.29)	70.54 (12.74)	0.0771
MCH (pg)	27.0 – 33.0	28.71 (2.61)	28.92 (2.46)	0.7299
MCHC (g/dl)	33.0 – 37.0	36.48 (1.02)	36.51 (2.53)	0.9433
RDW (%)	11.6 – 14.6	10.93 (1.04)	12.45 (0.82)	**<0.001**

An independent t-test was performed for statistical analyses.

Table 3: Comparisons of white blood cells measurements between the Exposed group and unexposed group to radiological exposures

Hematological parameters (WBC)	Ref. Range	Study group Mean (SD)		P-value (two-sided)
		Exposed group (n=40)	Unexposed group (n=32)	
Platelet count (x10^9/l)	150 - 450	223.30 (56.82)	258.08 (54.80)	**0.0107**
WBC count (x10^9/l)	4.0 -11.0	6.33 (1.40)	6.92 (2.42)	0.1939
Neutrophils (10^9\µl)	2.0 – 7.0	3.65 (0.75)	4.51 (1.94)	**0.0123**
Lymphocytes (10^9 /µl)	1.0 – 3.5	3.42 (0.85)	3.71 (1.09)	0.1977
Monocytes (10^9/µl)	0.2 – 1.0	0.50 (0.23)	0.69 (0.24)	**<0.0001**

An independent t-test was performed for statistical analyses.

Table 4: Correlation of total dose exposure with haematological measurements in the exposed group

Haematological measurements	Total dose	
RBC Measurements	**r-value**	**P-value**
Haemoglobin (g/dl)	-0.0392	0.8103
RBC count (x10¹²/l)	-0.1896	0.2412
PCV (%)	0.0491	0.7635
MCV (fl)	0.0835	0.6086
MCH (pg)	0.1050	0.5192
MCHC (g/dl)	-0.2736	0.0875
RDW (%)	0.3338	**0.0353**
WBC measurements	**r-value**	**P-value**
Platelet count (x10^9/l)	-0.1883	0.2447
WBC count (x10^9/l)	0.2839	0.0758
Neutrophils (10^9\µl)	0.0905	0.5787
Lymphocytes (10^9 /µl)	0.0878	0.5901
Monocytes (10^9/µl)	0.0136	0.9335

Figure 1 Comparisons of red blood cells measurements between Exposed group and unexposed group to radiological exposures.

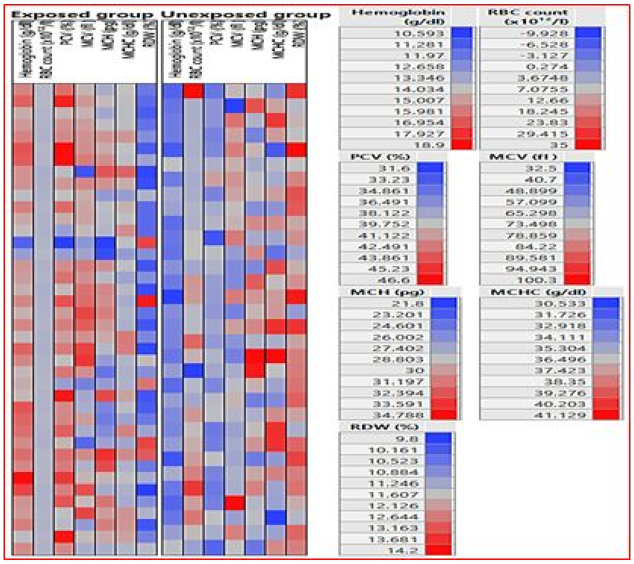


Figure 2 Comparisons of blood cells measurements between Exposed group and unexposed group to radiological exposures.

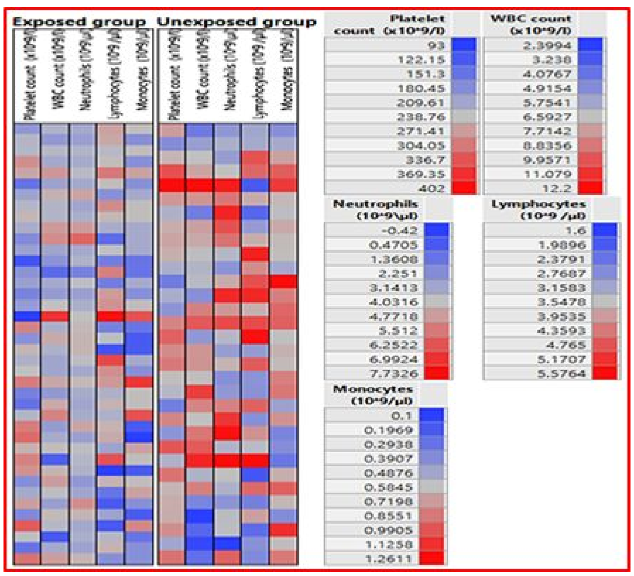
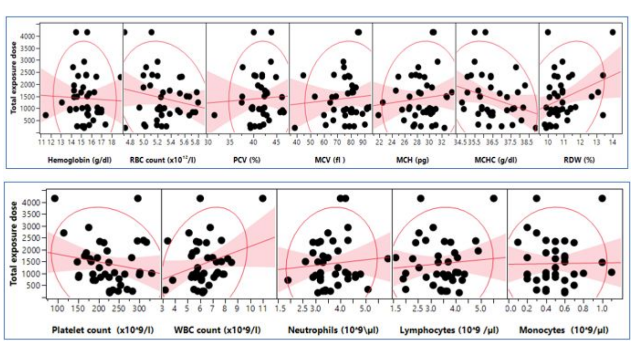


Figure 3 Scatter matrix of correlation of the total dose exposure with hematological measurements in exposed group.



P=0.0875 and a low positive correlation between the WBC count and total dose at P= 0.0758. While there is a considerable positive relationship between the total accumulated dose and the Red Blood Cell distribution RDW at p= 0.0353, as demonstrated in Figure (3).

As it is well known, irradiation is dose and time-dependent, so it has been found in previous studies to have a negative effect on erythrocytes [11]. While dose-dependent, ionizing radiation causes a considerable decrease in blood cell count, which is probably considered a series health risk during exposure to ionizing radiation[12].

Discussion

Prolonged intermittent exposure to lower levels of ionizing radiation may damage body tissues and cells of hospital radiation personnel, predominantly peripheral blood cells [13]. The research's modernity is the study of haematological and susceptibility consequences in people who have been exposed to low irradiation for a long time in separate doses, especially in hospital radiation workers in Duhok City. These effects may result in various haematological disorders. The sampling procedure is based on a survey of workers in cardiac catheterization centers at Azadi teaching hospital in Duhok City. As controls, we obtained 40 radiation workers and 32 other unexposed workers out of those centres. The values of twelve haematological markers were measured in this study, and the relationship between the total dose and haematological parameters was analyzed.

It is found in the present study that the values of Hemoglobin, PCV, and MCV haematological parameters significantly rise in employees exposed to radiation relative to controls. This result is consistent with findings of other research [13], which also reported similar results among employees exposed to low levels of ionizing radiation for a Long time in comparison to a control group. In addition, while this finding is inconsistent with the findings of the studies conducted [4, 14, and 15], which reported lower values of MCV and PCV among radiation workers exposed to low doses with at least 5 years of experience within one year of study, also reported higher values of lymphocytes and MCH.

The present study clarifies that RBC, RDW, Platelet, Neutrophils, and Monocytes counts are significantly lower among exposed workers, refer to Table 2. This result is similar to the finding study [16], which also showed similar results among subjects exposed to ionizing radiation in short-term effects. Meanwhile, this observation is consistent with that found of other studies [15,17], which also reported lowering values in the RBC, Monocytes, RDW, and platelet counts amongst employees exposed to low levels of ionizing radiation as long-term compared to a control group. While the present results are not in agreement with the finding of the studies carried out [5], which stated that Long-term exposed employees had considerably greater red blood cell and monocyte counts than controls, with no change in platelet and neutrophil counts between radiation and non-radiation workers. Conversely, the increase in monocyte levels due to exposure to X-ray displays a compensating technique by which the body of a human (bone marrow) maintains monocyte levels in a steady placement. This compensating mechanism is so essential because, In the human immune system, monocytes play an important function [10]. The haematological parameters that were unaffected by radiation and found to be nearly identical are MCH, MCHC, WBC, and lymphocytes. As shown in Table (2&3), this finding is in keeping with the study's results [17], a cross-sectional study that includes employees who worked in a catheter lab for more than two years and were exposed to radiation. The study showed that MCH, MCHC, and WBC parameters have no relationship between workers in the field of Long-term radiation-exposed workers compared to controls. As well as the present results are in agreement with what had been found by Alnahhal M et al. [4], which observed that white blood cells level did not demonstrate any statistically significant variation between the two groups.

Furthermore, according to the study, no significant variations in MCH and MCHC are seen between workers and the control group [18,19]. The present results differ slightly from the study's [5], which reported that white blood cells, MCH, MCHC, and lymphocyte values were considerably lower in long-term X-ray-exposed workers than in the unexposed group. Maybe the difference in PCV, MCHC, and MCH values could be related to RBC hemolysis due to radiation [20]. The discrepancies between some parameters of the present results compared to other studies can be explained by the fact that both groups were selected from the same radioactive background environment to focus on the effect of X-ray exposure only.

According to these results, it is clear to suppose that Prolonged intermittent exposure to low-level radiation leads to reduced white blood cell (WBC) levels, stem cell loss through the apoptotic mechanism, and decreased ability of cells to proliferate [12]. It is found that white blood cells are more sensitive to radiation in comparison to other components of blood. Studies [5, 13] showed that the means of overall WBCs was considerably reduced in exposed employees compared to the control. A comparable mechanism is taking place at PCV, MCV, and lymphocyte levels. In addition to, dehydration through the erythrocyte membrane may cause reduced erythrocyte parameters. Hematopoietic stem cell (HSC) infection is the leading reason for dying after incidental or purposed exposure to a high or moderate irradiation dose. Such radiation could injure or destroy hematopoietic stem cells and cause a variety of free radicals to form cells that are alive. This free radical/Reactive Oxygen Species (ROS) could lead to apoptosis in hematopoietic cells, reducing the capability of cells to reproduce. Due to the high sensitivity of the hematopoietic system to radiation, this is extremely probable to happen. This system also supplies blood clots to the blood vessel [5, 21].

Several previous studies have been conducted regarding the effect of radiation doses on erythrocyte levels. The study [14,22] found that changes in the density of white blood cells, platelets, and erythrocytes vary due to the exposure dosage rate. The optimal radiation-exposed dose rate for negative effects on leukaemia blood samples started at a dose rate of radiation (43.25±1.206 μSv/hr) for both men and women. Certainly, it must be taken into account the DNA damage levels, particularly double-strand break [4]. Finally, it is good to note that almost all haematological parameters are within the reference range or on the boundary.

Conclusion

It is found in the present study that some of the haematological parameters in radiation-exposed workers have much greater levels than in controls, such as Hemoglobin, PCV, and MCV. At the same time, some other haematological parameters become significantly lower among irradiated personnel compared to controls, such as RBC, RDW, platelet, neutrophil, and monocyte count. Additionally, the haematological parameters that were unaffected by radiation and found to be nearly identical were MCH, MCHC, WBC, and lymphocytes. The total dosage and the red cell distribution width (RDW) parameter, which quantifies the amount of red blood cell volume and size variation, have a significant association at (P=0.0353). The current study recommends additional studies with a larger size of the sample and the inclusion of several independent parameters such as genetic polymorphism, chromosomal abnormality, and the impact of low-dose radiation on micronucleus regularity for intermittent exposure for long time on workers to radiation. It's also important to look into the correlation between blood parameter changes and the amount of DNA harm from ionizing radiation exposures.

Ethical approval:

The study was conducted per the ethical principles originating in the Declaration of Helsinki. It was done with patients' verbal and analytical approval before the sample was taken. The study protocol, subject information, and consent form were reviewed and approved by the Duhok Health Directorate ethics committee according to the reference number 22062021-6-10 on 22 Jun 2021.

Competing interests

There are no conflicts of interest identified by the authors.

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Financial interest

There are no relevant financial or non-financial interests to disclose for the authors.

Consent to participate

Each individual participant in the study gave their informed consent.

Data availability

This published article contains all of the data generated or analyzed during this study.

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