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Original Article

Effects of long-term X-ray exposure on CBC among radiological department staff in Sulaimani city

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الملخص

أهداف البحث: يعتقد أن الأشعة المؤينة المستخدمة في أجهزة الأشعة يمكن أن تؤثر على أنسجة الجسم لدى موظفي قسم الأشعة. تهدف هذه الدراسة إلى مقارنة آثار التعرض طويل الأمد للأشعة السينية على خلايا الدم لدى الموظفين العاملين في أقسام الأشعة المختلفة في المستشفيات المختلفة في مدينة السليمانية / حكومة إقليم كردستان.

طريقة البحث: أجريت هذه الدراسة المقطعية في الفترة من 2021 إلى 2022 على 250 موظفا في أقسام الأشعة المختلفة، والتي شملت أخصائيي الأشعة، ومصوري الأشعة، وغيرهم من الطاقم الطبي (طبيب، ممرض، ....إلخ)، وكانت لها معايير الاشتمال، على مستوى المستشفيات في مدينة السليمانية التابعة لحكومة إقليم كردستان. تم جمع البيانات باستخدام استبيان تم ملؤه من قبل المشاركين بعد أخذ الموافقة الشفهية. تم جمع عينة الدم من 250 من موظفي الأشعة ثم إرسالها إلى المختبر للتحقق من مؤشرات الدم. تم تحليل البيانات المجمعة وتم التحقق من المقارنة والعلاقات بين البيانات من خلال الاختبارات الإحصائية الوصفية.

النتائج: أظهرت النتائج أن معظم العينات الذكور كانوا من فنيي الأشعة الحاصلين على درجة الدبلوم. كان هناك فروق ذات دلالة إحصائية بين مجموعتي الجنسين فيما يتعلق بمؤشرات الدم من خلايا الدم الحمراء، واختبار الهيماتوكريت، وحجم الكريات، والصفائح الدموية. كان هناك فروق ذات دلالة إحصائية بين المجموعات المهنية من حيث عرض توزيع خلايا الدم الحمراء - معامل التباين وعرض توزيع خلايا الدم الحمراء - الانحراف المعياري وفرق ذو دلالة إحصائية بين الموظفين الذين لديهم تاريخ من التدخين وغير المدخنين و المدخنين سابقاً من حيث متوسط كريات الدم البيضاء والخلايا الليمفاوية ووجود فرق ذو دلالة إحصائية بين الموظفين الذين لديهم تاريخ في استهلاك الكحول وغير الكحوليين ومدمني الكحول السابقين من حيث متوسط كريات الدم البيضاء.

الاستنتاجات: بناء على نتائج هذه الدراسة يمكن استنتاج أن متغيرات الدم مثل عرض توزيع خلايا الدم الحمراء - معامل التباين وعرض توزيع خلايا الدم الحمراء - الانحراف المعياري تتأثر بناء على نوع الوظيفة ومدة التعرض لأشعة اكس.

الكلمات المفتاحية: التعرض على المدى الطويل؛ أشعة اكس؛ عد دموي شامل؛ موظفي قسم الأشعة

Abstract

Objectives: Ionizing rays used in radiology devices are believed to affect the body tissues of radiology department employees. This study was aimed at comparing the effects of long-term exposure to X-rays on the blood cells of staff working in the radiology departments of several hospitals in the Sulaimani City/Kurdistan region government.

Methods: This cross-sectional study was conducted from 2021 to 2022 on 250 employees—including radiologists, radiographers, and other medical staff such as physicians or nurses—in the radiology departments of hospitals in the city of Sulaimani, Kurdistan region government. Data were collected with a questionnaire completed by the participants after verbal consent was provided. Blood samples were collected from 250 radiology staff and sent to a laboratory for measurement of blood parameters. The collected data were analyzed in SPSS version 26 software, and relationships in the data were investigated with descriptive statistical tests, Student's t test, and ANOVA.

Results: Most male participants were radiographers with a diploma degree. A statistically significant difference in

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RBC, HCT %, MCV, and PCT blood parameters was observed between sexes. Moreover, statistically significant differences were observed in RDW-CV and RDW-SD between occupational groups; in mean WBC and lymphocytes among staff who were current, never, or former smokers; and in mean WBC among employees who were current, never, or former drinkers ($p < 0.01$).

Conclusion: Blood parameters such as RDW-CV and RDW-SD were concluded to be affected by job type and X-ray exposure duration.

Keywords: CBC; Long-term exposure; Radiology staff; X-ray

Introduction

The use of electromagnetic waves in many aspects of industrial science and medical devices has enabled important technological advances.[1] Ionizing radiation, particularly from X-rays and radioactive substances, is used extensively in medicine for both diagnosis and treatment.[2] X-rays are a form of electromagnetic radiation with high energy (100 eV−100 keV) and wavelengths between 0.01 and 10 nm. This energy is sufficient to ionize atoms and break molecular bonds.[3,4] Ionizing radiation at both low and high doses can cause cellular damage, depending on the target, dose rate, sex, and age. Direct interaction refers to ionizing radiation reacting directly with important targets, such as DNA. Indirect interaction describes a reaction between ionizing radiation and the water inside cells, thereby creating both ions and free radicals.[5] In general, radiation-induced effects can be divided into two groups: deterministic effects, which have a threshold dose below which health effects are rare, and stochastic effects, such as cancer, which have no threshold dose and can occur at any level of radiation exposure.[6] Ionizing radiation is a workplace risk factor that can severely harm workers.[7] During radiological operations, radiographers are exposed to low levels of ionizing radiation. Ionizing radiation can potentially cause chromosomal aberrations, among other types of cell damage.[8] Radiation exposure has been estimated to raise the lifetime chance of developing cancer by 0.6%−1.8% by the age of 75 years.[9] Although radiation workers are not exposed to diagnostic levels of radiation, stochastic effects due to chronic low-dose radiation exposure cannot be ruled out. In addition, the effects of ionizing radiation can be classified as acute or chronic. Acute effects result from high levels of radiation exposure and occur shortly after irradiation. In contrast, chronic effects are believed to result from relatively low levels of long-term exposure to ionizing radiation.[10] The radiosensitivity of human body tissues and cells varies, from high sensitivity to radioresistance.[11] Ionizing radiation affects blood cells in humans and other animals,[12] and can alter hematological parameters.[13] Because the cells of the hematopoietic system are extremely susceptible to radiation, the peripheral blood count may be a useful biological indicator for determining the extent of biological radiation damage.[14] Although some studies have reported that exposure to low-dose radiation suppresses the immune system,[15] other studies have reported no effects.[16] Mohsen et al. (2016) have reported that the overall mean RBC, WBC, and PLT counts among medical professionals do not considerably deviate from standard ranges.[11] According to Mohamed et al. (2015), exposure to various gamma-radiation doses results in considerably lower RBC count, HGB, and HCT than observed in controls.[17] Given the need to evaluate the health status of radiology staff exposed to long-term low-dose radiation, the contradictory results of previous studies, and the findings of previous studies on gamma rays, we sought to compare the effects of long-term low X-ray exposure on blood cells among radiology staff.

Materials and Methods

Study design and setting

This cross-sectional study was conducted from 2021 to 2022 in the hospitals in the city of Sulaimani, Kurdistan region government.

Participants

A total of 250 staff members provided samples in this study. All radiology department staff, such as radiologists, radiographers, and other medical staff (e.g., physicians, nurses, and anesthesia assistants) who were exposed to radiation in departments using radiation (such as general X-ray departments, and those performing computed tomography (CT) scans, mammography, fluoroscopy, etc.) received explanations of the study purpose, and were included in the study after providing informed consent. The inclusion criteria were healthy radiology staff with more than 1 year experience working in a radiology department. The exclusion criteria were staff with thalassemia, hemophilia, thrombocytopenia, or use of drugs during the study.

Study instruments

A questionnaire was used to collect data on demographic variables including sex, marital status, profession, place of residence, education level, hospital type, hospital department, smoking status, and alcohol consumption status. An automated cell counter (Sysmex-XN-350, compact five-part differential analyzer, Germany) was used to measure the blood parameters in the samples.

Study procedure

After the necessary permits were obtained from the research center and the hospital authorities, the researchers explained the study process and obtained informed consent from the participants. The demographic questionnaire was then completed by the participants, and a 3 cc sample of venous blood was collected and sent to a laboratory for analysis of blood parameters, such as the numbers of white blood cells, red blood cells, and platelets.

Data analysis

The data were analyzed in SPSS statistical software version 26 with descriptive statistical tests, Student's t test, and ANOVA, with a significance threshold of $P < 0.05$.

Results

Demographic analysis of the 250 participating personnel indicated that 60.80% of the participants were men, 39.20% were women, and 73.60% were married. A total of 74.80% were radiographers, 12.80% were radiologists, and the remaining participants had other jobs. Most surveyed participants (67.20%) lived in the city. Most participants had a diploma degree, 8.00% of participants had a bachelor's degree, and only 1.20% had a doctorate degree. A total of 80.40% of participants were employed in public hospitals, whereas 16.00% were employed in private hospitals; 3.60% worked in teaching hospitals. Most staff worked in a CT department (59.20%), whereas 25.20% worked in a fluoroscopy unit, and 6.80% worked in a magnetic resonance imaging unit. Among the participants, 81.60% were smokers, and 91.20% consumed alcohol (Table 1).

The distribution of blood parameters by sex is shown in Table 2. The mean RBC, mean hemoglobin, and mean HCT % were significantly higher in men than women ($P \leq 0.001$). The mean MCV was significantly higher in men than women ($P \leq 0.02$), whereas the mean PLT was significantly higher in women than men ($P \leq 0.01$). The mean PCT was also significantly higher in women than in men ($P \leq 0.002$).

In addition, we investigated the complete blood count parameter status among participants by job type. The mean RDW-CV and RDW-SD significantly differed by job. The mean RDW-CV was significantly higher in radiologists than in radiographers or participants with other occupations ($P \leq 0.05$). Moreover, the mean RDW-SD was significantly higher in radiologists than participants with other occupations ($P \leq 0.03$). No differences were observed in other complete blood count (CBC) parameters (Table 3).

In this study, 81.60% of participants had never smoked, 9.60% were current smokers, and 8.80% had a history of smoking. Analysis of the status of CBC parameters among employees indicated significant differences in mean WBCs and lymphocytes by smoking status: the mean WBC was significantly higher in non-smokers than in smokers or former smokers ($P \leq 0.05$). The mean lymphocytes were significantly higher in smokers than in non-smokers or former smokers, ($P \leq 0.01$). Other CBC parameters did not significantly differ (Table 4).

We next investigated the status of CBC parameters according to alcohol consumption. A difference in only mean WBC was observed among current drinkers, never-drinkers, and former drinkers. The mean WBC was significantly higher in never-drinkers than the other two groups ($P \leq 0.01$). No statistical difference was observed in other CBC parameters according to alcohol consumption status (Table 5).

Subsequently, we compared CBC values among men and women according to the number of working hours per day (less than 5 h per day, 5–9 h per day, or more than 9 h per

Table 1: Participants' basic demographic data.

Demographic data	Characteristics	No. cases	Percentage
Sex	Male	152	60.80%
	Female	98	39.20%
Marital status	Married	184	73.60%
	Single	66	26.40%
Occupational type	Radiographer	187	74.80%
	Radiologist	32	12.80%
	Other	31	12.40%
Residence	Inside city	168	67.20%
	Outside city	82	32.80%
Education	Diploma degree	204	81.60%
	Bachelor degree	20	8.00%
	High diploma degree	18	7.20%
	Master's degree	5	2.00%
	Doctorate degree	3	1.20%
Type of hospital	Public	201	80.40%
	Private	40	16.00%
	Public teaching hospital	9	3.60%
Department	CT scan unit	148	59.20%
	Fluoroscopy unit	63	25.20%
	General X-ray unit	4	1.60%
	Mammography unit	8	3.20%
	Magnetic resonance imaging unit	17	6.80%
	Other unit using X-rays	10	4.00%
Smoking status	Never smoke	204	81.60%
	Current smoker	24	9.60%
	Former smoker	22	8.80%
Alcohol consumption status	Never drink	228	91.20%
	Current drinker	6	2.40%
	Former drinker	16	6.40%

Table 2: Blood parameters among radiology staff by sex.

Blood parameters	Male mean ± SD	Female mean ± SD	P-value[a]
WBCs × 10^9/l	6.8 ± 1.6	6.8 ± 1.7	0.84
Neutrophils × 10^9/l (Neu %)	60.3 ± 12.2	60.4 ± 10.5	0.97
Lymphocytes × 10^9/l (Lym %)	34.0 ± 10.5	34.2 ± 33.6	0.94
Monocytes × 10^9/l (mon %)	6.7 ± 2.3	6.4 ± 2.6	0.49
Eosinophils × 10^9/l (Eos %)	2.5 ± 2.1	1.9 ± 1.5	0.09
Basophils × 10^9/l (Bas %)	0.6 ± 0.4	0.6 ± 0.4	0.7
RBCs × 10^{12}/l	5.2 ± 0.6	4.8 ± 0.5	0.001
Hb (g/dl)	14.5 ± 1.7	13.3 ± 1.5	0.001
HCT %	43.5 ± 4.8	40.2 ± 4.1	0.001
MCV (fl)	83.0 ± 8.9	80.0 ± 11.8	0.02
MCH (pg)	29.8 ± 9.3	28.9 ± 7.6	0.42
MCHC (g/dl)	33.2 ± 2.8	33.0 ± 3.4	0.76
RDW-CV	13.1 ± 3.8	13.2 ± 1.8	0.83
RDW-SD	47.1 ± 9.4	48.2 ± 9.4	0.36
PLT × 10^9/l	242.8 ± 49.5	260.7 ± 60.1	0.01
MPV	8.4 ± 1.1	8.7 ± 1.4	0.11
PDW	11.5 ± 8.3	19.6 ± 8.25	0.23
PCT	0.2 ± 0.0	0.2 ± 0.1	0.002
P-LCR	24.1 ± 9.8	26.5 ± 10.2	0.07
P-LCC	62.7 ± 28.1	66.6 ± 18.4	0.35

[a] Independent *t*-test, $P < 0.05$

day). Examination of CBC in men indicated that the mean WBC significantly decreased with increasing working hours ($P \leq 0.001$), whereas the mean basophils decreased significantly with increasing working hours. Employees working fewer than 5 h/day had higher mean basophils ($P \leq 0.001$). The mean PLT in men also significantly decreased with increasing working hours per day ($P \leq 0.001$). Examination of the mean CBC in women according to working hours indicated that the mean WBC, MCV, RDW-SD, and P-LCC significantly decreased with increasing working hours ($P \leq 0.05$). Moreover, the mean P-LCR in women significantly increased with increasing working hours per day ($P \leq 0.02$) (Table 6).

The mean CBC was compared between male and female radiologists according to work experience (10 years or fewer, 10−20 years, and 21 years or more). Examination of CBC in men according to work history indicated that the mean PDW significantly increased with increasing numbers of working years ($P \leq 0.04$). Examination of CBC in women according to the number of years of work indicated that the mean

Table 3: Distribution of CBC among radiology staff by job description.

Blood parameters	Occupation			P-value[a]
	Radiographer	Radiologist	Other medical staff	
	Mean ± SD	Mean ± SD	Mean ± SD	
WBCs × 10^9/l	6.70 ± 1.50	6.80 ± 1.90	7.10 ± 2.00	0.56
Neutrophils × 10^9/l (Neu %)	60.20 ± 11.70	63.10 ± 11.20	57.40 ± 9.00	0.43
Lymphocytes × 10^9/l (Lym %)	35.10 ± 25.10	29.60 ± 11.10	32.40 ± 12.20	0.41
Monocytes × 10^9/l (mon %)	6.60 ± 2.40	6.70 ± 2.10	5.60 ± 2.70	0.34
Eosinophils × 10^9/l (Eos %)	2.20 ± 1.80	2.40 ± 1.90	2.10 ± 1.80	0.87
Basophils × 10^9/l (Bas %)	0.60 ± 0.40	0.50 ± 0.30	0.60 ± 0.40	0.81
RBCs × 10^{12}/l	5.10 ± 0.60	5.00 ± 0.60	5.00 ± 0.60	0.91
Hb (g/dl)	14.10 ± 1.80	13.90 ± 1.60	13.90 ± 1.60	0.87
HCT %	42.00 ± 4.60	42.00 ± 4.60	41.30 ± 4.90	0.56
MCV (fl)	81.80 ± 10.30	80.30 ± 12.20	83.50 ± 7.30	0.48
MCH (pg)	29.80 ± 10.00	28.00 ± 1.70	28.50 ± 1.80	0.46
MCHC (g/dl)	33.10 ± 3.40	33.10 ± 1.10	33.40 ± 1.80	0.83
RDW-CV	13.00 ± 1.50	14.40 ± 7.60	12.80 ± 2.40	0.05
RDW-SD	46.70 ± 8.60	51.00 ± 7.20	48.70 ± 9.60	0.03
PLT × 10^9/l	250.30 ± 52.80	246.90 ± 73.2	249.8 ± 42.6	0.95
MPV	8.60 ± 1.30	8.40 ± 1.00	8.30 ± 1.00	0.44
PDW	15.90 ± 59.70	11.00 ± 1.30	10.70 ± 1.40	0.81
PCT	0.20 ± 0.10	0.20 ± 0.10	0.20 ± 0.10	0.33
P-LCR	25.00 ± 10.00	25.80 ± 7.40	24.20 ± 12.50	0.83
P-LCC	66.30 ± 25.90	60.70 ± 17.70	49.90 ± 16.30	0.07

[a] ANOVA, $P < 0.05$

Table 4: Distribution of CBC parameters among radiology staff by smoking status.

Blood parameters	Smoking status			P-value[a]
	Current smoker	Never smoker	Former smoker	
	Mean ± SD	Mean ± SD	Mean ± SD	
WBCs × 10^9/l	6.70 ± 1.50	7.60 ± 2.10	6.60 ± 1.80	0.05
Neutrophils × 10^9/l (Neu %)	60.70 ± 11.50	56.00 ± 8.30	60.00 ± 12.10	0.58
Lymphocytes × 10^9/l (Lym %)	32.70 ± 10.70	31.70 ± 9.80	48.80 ± 67.50	0.01
Monocytes × 10^9/l (mon %)	6.50 ± 2.40	7.30 ± 2.20	5.60 ± 2.30	0.30
Eosinophils × 10^9/l (Eos %)	2.30 ± 1.90	1.90 ± 0.40	1.60 ± 1.00	0.48
Basophils × 10^9/l (Bas %)	0.60 ± 0.40	0.40 ± 0.20	0.50 ± 0.30	0.28
RBCs × 10^{12}/l	5.00 ± 0.60	5.30 ± 0.60	5.10 ± 0.40	0.06
Hb (g/dl)	13.90 ± 1.70	14.70 ± 1.80	14.20 ± 1.30	0.08
HCT %	41.90 ± 4.90	44.20 ± 4.70	42.20 ± 3.60	0.08
MCV (fl)	81.50 ± 10.10	84.40 ± 9.90	81.90 ± 12.20	0.42
MCH (pg)	29.00 ± 7.50	31.40 ± 12.50	31.40 ± 13.00	0.25
MCHC (g/dl)	33.10 ± 3.30	33.10 ± 1.30	33.80 ± 1.60	0.60
RDW-CV	13.20 ± 3.30	12.90 ± 2.80	12.70 ± 1.30	0.71
RDW-SD	47.50 ± 8.40	48.80 ± 12.10	46.20 ± 7.70	061
PLT × 10^9/l	252.10 ± 57.20	246.30 ± 40.5	231.5 ± 37.1	0.25
MPV	8.60 ± 1.30	8.20 ± 0.80	8.10 ± 0.90	0.06
PDW	15.50 ± 56.90	10.60 ± 0.70	10.60 ± 1.30	0.86
PCT	0.20 ± 0.10	0.20 ± 0.00	0.20 ± 0.00	0.15
P-LCR	25.70 ± 10.30	21.20 ± 7.80	22.10 ± 7.80	0.06
P-LCC	64.10 ± 19.60	53.30 ± 23.40	74.30 ± 56.20	0.16

[a] ANOVA, $P < 0.05$

lymphocytes significantly increased with increasing work experience ($P \leq 0.008$). In women, as the number of working years increased, the mean basophils significantly decreased ($P \leq 0.05$). The mean P-LCC significantly higher than in women with 10−20 years of experience and significantly lower than by two times in women with 20 years of work experience or more ($P \leq 0.031$) (Table 7).

A comparison of average CBC values between men and women indicated no significant differences according to the number of patients seen per day in men. However, the average lymphocytes in women significantly increased with increasing numbers of patients seen per day ($P \leq 0.001$). The average basophils in women also significantly differed according to the number of patients seen ($P \leq 0.05$). The

Table 5: Distribution of CBC parameters among radiology staff by alcohol consumption status.

Blood parameters	Alcohol consumption status			P-value[a]
	Current drinker	Never drinker	Former drinker	
	Mean ± SD	Mean ± SD	Mean ± SD	
WBCs × 10^9/l	6.70 ± 1.60	8.20 ± 1.20	7.60 ± 2.00	0.01
Neutrophils × 10^9/l (Neu %)	60.10 ± 10.80	79.10 ± 8.30	60.80 ± 15.60	0.25
Lymphocytes × 10^9/l (Lym %)	34.20 ± 23.20	29.70 ± 14.30	33.50 ± 12.80	0.88
Monocytes × 10^9/l (mon %)	6.60 ± 2.40	6.60 ± 2.90	6.00 ± 2.60	0.72
Eosinophils × 10^9/l (Eos %)	2.30 ± 1.90	0.70 ± 0.50	1.60 ± 0.90	0.22
Basophils × 10^9/l (Bas %)	0.60 ± 0.40	0.40 ± 0.30	0.40 ± 0.20	0.33
RBCs × 10^{12}/l	5.00 ± 0.60	5.00 ± 0.40	5.30 ± 0.60	0.16
Hb (g/dl)	14.00 ± 1.70	14.60 ± 1.60	14.20 ± 2.00	0.63
HCT %	42.10 ± 4.80	43.20 ± 4.20	42.50 ± 5.30	0.84
MCV (fl)	82.00 ± 9.80	87.10 ± 7.10	77.60 ± 15.40	0.12
MCH (pg)	29.30 ± 8.20	29.10 ± 2.50	31.80 ± 14.60	0.54
MCHC (g/dl)	33.10 ± 3.10	33.40 ± 1.90	33.30 ± 2.20	0.95
RDW-CV	13.10 ± 3.20	12.50 ± 1.90	14.30 ± 3.30	0.30
RDW-SD	47.60 ± 8.60	46.40 ± 17.90	46.80 ± 5.20	0.90
PLT × 10^9/l	250.10 ± 52.30	243.30 ± 45.00	247.9 ± 84.80	0.95
MPV	8.60 ± 1.20	8.00 ± 0.70	8.10 ± 1.50	0.28
PDW	15.00 ± 53.90	10.50 ± 0.80	10.50 ± 1.80	0.94
PCT	0.20 ± 0.10	0.20 ± 0.00	0.20 ± 0.10	0.59
P-LCR	25.20 ± 10.10	16.80 ± 3.50	24.10 ± 9.30	0.17
P-LCC	64.80 ± 25.30	62.00 ± 25.10	57.40 ± 16.60	0.66

[a] ANOVA, $P < 0.05$

Table 6: Comparison of CBC (mean ± SD) between men and women, according to number of hours working in the radiology unit.

Blood parameters	Hours of work							
	Male				Female			
	Fewer than 5 h/day	5−9 h/day	More than 9 h/day	P-value[a]	Fewer than 5 h/day	5−9 h/day	More than 9 h/day	P-value[a]
	Mean ± SD	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	Mean ± SD	
WBCs × 10^9/l	7.80 ± 2.00	6.60 ± 1.30	6.30 ± 1.30	0.001	7.470 ± 1.80	6.70 ± 1.60	6.00 ± 1.30	0.01
Neutrophils × 10^9/l (Neu %)	67.60 ± 10.80	59.00 ± 11.60	59.70 ± 13.30	0.20	61.00 ± 8.40	60.50 ± 10.90	59.60 ± 11.80	0.94
Lymphocytes × 10^9/l (Lym %)	33.50 ± 10.50	34.00 ± 11.00	34.40 ± 9.90	0.92	28.60 ± 10.20	31.30 ± 9.50	50.50 ± 72.90	0.06
Monocytes × 10^9/l (mon %)	5.40 ± 2.40	7.00 ± 2.10	6.60 ± 2.40	0.15	6.80 ± 3.90	6.40 ± 2.10	5.80 ± 2.20	0.59
Eosinophils × 10^9/l (Eos %)	3.10 ± 2.60	2.20 ± 2.10	2.50 ± 1.70	0.48	2.70 ± 2.10	1.70 ± 1.30	1.70 ± 0.90	0.07
Basophils × 10^9/l (Bas %)	1.10 ± 0.80	0.50 ± 0.30	0.50 ± 0.30	0.001	0.80 ± 0.60	0.50 ± 0.30	0.50 ± 0.20	0.09
RBCs × 10^{12}/l	5.20 ± 0.50	5.20 ± 0.60	5.10 ± 0.60	0.86	4.90 ± 0.40	4.80 ± 0.60	4.80 ± 0.50	0.93
Hb (g/dl)	14.60 ± 1.40	14.60 ± 1.60	14.30 ± 2.00	0.54	13.6 ± 1.30	13.1 ± 1.60	13.2 ± 1.5	0.29
HCT %	44.10 ± 4.00	43.20 ± 4.30	43.30 ± 6.10	0.65	41.3 ± 3.50	39.7 ± 4.20	39.9 ± 4.70	0.23
MCV (fl)	84.90 ± 6.10	81.90 ± 9.80	83.00 ± 9.50	0.25	84.1 ± 3.30	76.5 ± 15.70	80.6 ± 3.40	0.01
MCH (pg)	29.60 ± 7.50	30.50 ± 12.10	28.80 ± 3.90	0.64	29.9 ± 9.50	28.7 ± 7.70	27.7 ± 1.70	0.59
MCHC (g/dl)	32.90 ± 1.10	33.20 ± 4.00	33.40 ± 1.00	0.75	33.1 ± 1.20	33.5 ± 1.90	31.7 ± 7.00	0.15
RDW-CV	13.80 ± 7.10	13.00 ± 1.30	12.70 ± 1.90	0.41	12.9 ± 1.20	13.4 ± 2.40	13.2 ± 0.60	0.50
RDW-SD	49.10 ± 10.80	46.20 ± 8.90	46.80 ± 8.70	0.31	51.0 ± 6.80	46.9 ± 8.40	46.6 ± 5.30	0.04
PLT × 10^9/l	264.90 ± 51.4	231.40 ± 42.5	242.7 ± 53.40	0.001	271.7 ± 53.3	255.9 ± 67.7	256.1 ± 48.8	0.50
MPV	8.70 ± 1.50	8.40 ± 0.90	8.30 ± 1.00	0.27	9.0 ± 1.90	8.40 ± 0.9	8.80 ± 1.10	0.24
PDW	10.90 ± 1.10	10.70 ± 1.70	13.30 ± 15.40	0.24	11.10 ± 1.00	10.80 ± 1.30	53.2 ± 181.3	0.14
PCT	0.20 ± 0.10	0.20 ± 0.00	0.20 ± 0.10	0.08	0.20 ± 0.10	0.20 ± 0.10	0.20 ± 0.00	0.93
P-LCR	23.50 ± 13.00	24.90 ± 7.80	23.10 ± 9.70	0.63	24.70 ± 9.50	25.10 ± 8.40	32.20 ± 12.90	0.02
P-LCC	72.00 ± 49.60	61.20 ± 17.00	60.10 ± 25.20	0.35	62.90 ± 22.60	62.50 ± 15.90	76.40 ± 16.30	0.03

[a] ANOVA, $P < 0.05$.

average MCHC in women significantly decreased with increasing numbers of patients seen ($P \leq 0.01$). In addition, the average PDW and P-LCC in women significantly increased with increasing numbers of patients seen (Table 8).

Discussion

Ionizing radiation at low or high doses can have negative effects on people.[18] Radiation sensitivity varies among cells, and hematopoietic cells are the most radiation-sensitive cell types.[19] Long-term exposure to low levels of ionizing radiation has been shown to be harmful to the health of laboratory personnel and to potentially cause hematological disorders.[8,20] In investigating the damage produced by radiation, blood cell count can serve as a biological indicator.[21] Therefore, the aim of this study was to investigate the effects of long-term low X-ray exposure on the blood cells of radiology staff.

The demographic characteristics, including sex, occupation, educational status, and marital status, among participants in this study were consistent with those in studies by Nureddin et al. (2016), Shafiee et al. (2016), and Joudoh et al. (2018). Fewer female than male participants were studied; the minimum education was a diploma; and most participants were married and lived in the city.[9,22,23]

Because other parameters beyond radiation might also affect the relationship between blood cells and radiation, we investigated the relationship between blood cells and the place of work, as well as the sex of radiation workers. The mean RBC, hemoglobin, MCV, and HCT were higher in men than women, whereas the mean PLT and PCT were higher in women than men. These findings were consistent with those reported by Davoudi et al. (2012) and Ryu et al. (2013), but not Tavakoli et al. (2012).[24−26] Physiological differences in the mean blood test parameters were observed between men and women, possibly because of the small volume of sample sizes, because work history was associated with the length radiation exposure, or because of underlying diseases. Further studies are necessary to resolve these ambiguities.

In this study, the percentage of no smokers was much higher than that of non-smokers and alcohol consumers. The mean WBC in non-smokers was higher than that in the other groups, in agreement with findings reported by Guo et al. (2020).[27] The mean number of lymphocytes in smokers was higher than that in other groups. Surniyantoro et al. (2019)[28] have reported that the percentage of non-smokers was higher, and, in general, the mean lymphocytes were lower, contrary to our findings. Cigarette smoke has been reported to damage artery walls, impair leukocyte and PLT function, and have immediate effects on endothelial cells.[29,30] Pedersen et al. (2019) have demonstrated that smoking increases neutrophils, lymphocytes, and other leukocytes in the blood.[31] Given these contradictory findings, more studies must be conducted.

Table 7: Comparison of CBC (mean ± SD) between men and women by number of years working at the radiology unit.

Blood parameters	Work experience							
	Male				Female			
	10 years or fewer	10–20 years	21 years or more	P-value[a]	10 years or fewer	10–20 years	21 years or more	P-value[a]
	Mean ± SD	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	Mean ± SD	
WBC × 10^9/l	6.90 ± 1.70	6.50 ± 1.30	700 ± 1.80	0.49	6.90 ± 1.70	7.00 ± 1.70	5.90 ± 1.00	0.102
Neutrophils × 10^9/l (Neu %)	61.60 ± 12.60	58.80 ± 12.90	58.20 ± 10.40	0.633	61.90 ± 10.10	61.60 ± 10.40	54.20 ± 10.30	0.119
Lymphocytes × 10^9/l (Lym %)	32.90 ± 10.90	36.80 ± 9.50	33.40 ± 9.70	0.145	29.10 ± 10.30	31.70 ± 9.50	60.50 ± 86.90	0.008
Monocytes × 10^9/l (mon %)	7.10 ± 2.20	5.50 ± 2.30	6.50 ± 2.10	0.063	6.40 ± 2.70	6.20 ± 2.80	6.60 ± 2.20	0.925
Eosinophils × 10^9/l (Eos %)	2.40 ± 2.20	2.50 ± 2.00	2.50 ± 1.80	0.977	2.10 ± 1.40	1.70 ± 1.70	1.90 ± 1.20	0.565
Basophils × 10^9/l (Bas %)	0.70 ± 0.50	0.40 ± 0.40	0.40 ± 0.20	0.176	0.70 ± 0.40	0.40 ± 0.30	0.40 ± 0.20	0.056
RBCs × 10^{12}/l	5.20 ± 0.60	5.20 ± 0.60	5.10 ± 0.60	0.914	4.80 ± 0.50	5.00 ± 0.50	4.70 ± 0.50	0.20
Hb (g/dl)	14.50 ± 1.70	14.40 ± 1.70	14.70 ± 1.60	0.762	13.30 ± 1.50	13.50 ± 1.40	12.80 ± 1.90	0.438
HCT %	44.00 ± 5.00	42.20 ± 4.20	43.30 ± 4.30	0.158	40.10 ± 4.40	40.70 ± 3.40	39.30 ± 5.00	0.57
MCV (fl)	82.80 ± 9.90	82.40 ± 8.20	84.80 ± 4.20	0.649	80.7 ± 10.50	80.8 ± 11.00	75.3 ± 17.80	0.305
MCH (pg)	29.70 ± 8.10	29.20 ± 9.80	31.60 ± 13.60	0.663	29.9 ± 10.30	28.0 ± 2.30	27.3 ± 2.30	0.398
MCHC (g/dl)	32.80 ± 3.20	33.80 ± 1.90	33.60 ± 1.80	0.156	33.4 ± 1.20	33.2 ± 1.80	31.1 ± 8.60	0.088
RDW-CV	13.20 ± 4.60	13.00 ± 1.90	12.90 ± 1.20	0.9.3	13.0 ± 1.30	13.5 ± 2.50	13.3 ± 1.40	0.441
RDW-SD	47.30 ± 9.50	46.80 ± 9.90	46.60 ± 8.00	0.933	49.1 ± 6.20	47.6 ± 9.40	46.3 ± 6.00	0.452
PLT × 10^9/l	243.10 ± 53.4	241.8 ± 46.6	242.7 ± 33.7	0.991	257.8 ± 51.7	265.8 ± 76.9	258.5 ± 40.5	0.831
MPV	8.50 ± 1.30	8.40 ± 0.80	8.10 ± 0.90	0.45	8.80 ± 1.70	8.50 ± 1.10	8.70 ± 0.60	0.581
PDW	10.80 ± 1.60	11.00 ± 1.70	16.20 ± 23.90	0.04	11.10 ± 1.20	34.2 ± 135.7	11.3 ± 1.30	0.438
PCT	0.20 ± 0.10	0.20 ± 0.00	0.20 ± 0.00	0.965	0.20 ± 0.10	0.20 ± 0.10	0.20 ± 0.00	0.899
P-LCR	24.60 ± 10.80	23.00 ± 8.20	23.50 ± 7.20	0.704	26.60 ± 10.4	25.30 ± 11.0	29.4 ± 6.40	0.494
P-LCC	60.90 ± 19.30	67.80 ± 42.90	59.80 ± 19.30	0.558	63.80 ± 16.3	63.40 ± 20.0	79.6 ± 16.20	0.031

[a] ANOVA, $P < 0.05$.

The mean RDW-CV and RDW-SD were significantly higher in radiologists than in radiographers and people with other professions. However, in a study by Khorrami et al. (2015), the changes in the mean RDW were not noticeable and were not statistically significant.[32] Güngördü et al. (2022) have observed to note a notable rise in RDW. These discrepancies might be due to laboratory errors.[33] In addition, because the blood factor MCV is used in the calculation of RDW, errors in MCV measurement might lead to errors in the calculation of RDW. Therefore, more studies with greater accuracy and fewer errors are required.

The mean WBC among people who never consumed alcohol was higher than those among current drinkers and former drinkers. Haag et al. (2022) have reported that alcohol consumption immediately affects the function and number of leukocytes, and causes immune changes associated with diminished innate immune cell function.[34] These findings have been confirmed by Pasala et al. (2015).[35]

The comparison of mean CBC values between men and women according to the number of working hours per day indicated that the mean WBC, basophil, and PLT in men, and the mean WBC, MCV, RDW-SD. In women, the P-LCC exhibited noteworthy alterations. Mohamed et al. (2021), in a study in Libya, have reported differences in WBC, MCV, and MCHC between workers with versus without radiation exposure. In addition, in an investigation of the effects of radiation hematology according to employee sex, only the hematology parameters of HCT, PLT, and MCH showed significant changes in men and women.[36]

Examination of the changes in CBC parameters among men and women according to the number of years of work or work experience indicated that the mean PDW in men significantly increased with increasing work experience. In women, the mean lymphocytes increased, and the mean basophils and P-LCC also showed significant changes with increasing work experience. These results were consistent with those reported by Güngördü et al. (2022), individuals exposed to ionizing radiation for less than 10 years were found to have reduced counts of white blood cells and neutrophils. In individuals exposed to ionizing radiation for 10 years or longer, there was a decrease in levels of white blood cells, neutrophils, and hemoglobin, while RDW increased. Among the group of workers exposed to radiation, a notable rise in RDW was observed and lymphocyte levels was observed with increasing work experience. In addition, according to the findings of the aforementioned study and the present study, the effects of ionizing radiation on blood parameters are associated with the frequency and duration of the radiation dose.[33]

Talab et al. (2018) have investigated the effects of low-dose radiology radiation on blood factors among radiologists working in radiology departments. Radiation and occupational exposure did not affect blood parameters, in agreement with our findings of no differences in blood

Table 8: Comparison of CBC (mean ± SD) between men and women according to the number of patients attending the radiology unit.

Blood parameters	Number of patients/day									
	Male					Female				
	10 patients or fewer	10–20 patients	21–30 patients	31 patients or more	P-value[a]	10 patients or fewer	10–20 patients	21–30 patients	31 patients or more	P-value[a]
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
WBCs × 10^9/l	6.8 ± 2.0	7.1 ± 1.5	6.7 ± 1.6	6.6 ± 1.5	0.61	6.4 ± 2.0	7.5 ± 1.5	6.6 ± 1.5	6.5 ± 1.1	0.12
Neutrophils × 10^9/l (Neu %)	70.2 ± 14.4	60.1 ± 10.5	61.0 ± 12.6	49.0 ± 7.2	0.07	65.2 ± 9.9	60.4 ± 10.4	59.3 ± 11.2	54.2 ± 5.9	0.13
Lymphocytes × 10^9/l (Lym %)	29.8 ± 14.7	34.4 ± 11.4	33.4 ± 9.3	38.6 ± 6.9	0.08	26.0 ± 11.1	30.4 ± 8.8	32.4 ± 9.9	78.5 ± 10.9	0.001
Monocytes × 10^9/l (mon %)	8.3 ± 1.6	6.8 ± 1.5	6.4 ± 2.7	6.5 ± 1.4	0.33	7.5 ± 2.4	6.3 ± 4.0	6.0 ± 1.8	4.9 ± 1.1	0.13
Eosinophils × 10^9/l (Eos %)	1.6 ± 0.6	3.4 ± 2.8	2.1 ± 1.6	1.5 ± 0.9	0.06	2.3 ± 1.7	1.4 ± 0.9	2.0 ± 1.7	1.7 ± 0.8	0.50
Basophils × 10^9/l (Bas %)	0.7 ± 0.3	0.8 ± 0.6	0.4 ± 0.3	0.5 ± 0.2	0.06	0.8 ± 0.5	0.5 ± 0.3	0.4 ± 0.3	0.5 ± 0.2	0.05
RBCs × 10^{12}/l	5.2 ± 0.6	5.3 ± 0.7	5.1 ± 0.6	5.2 ± 0.4	0.33	4.7 ± 0.5	4.9 ± 0.5	4.9 ± 0.5	4.9 ± 0.4	0.49
Hb (g/dl)	14.4 ± 2.1	14.6 ± 1.7	14.3 ± 1.7	15.0 ± 1.1	0.41	13.4 ± 1.9	13.0 ± 1.5	13.4 ± 1.4	13.4 ± 1.6	0.84
HCT %	43.9 ± 6.1	43.7 ± 4.0	42.8 ± 5.2	44.7 ± 3.0	0.40	40.4 ± 4.5	39.7 ± 4.2	40.4 ± 3.9	40.2 ± 5.0	0.14
MCV (fl)	84.9 ± 8.3	82.9 ± 5.7	81.8 ± 11.3	85.4 ± 4.1	0.33	81.4 ± 11.7	79.7 ± 11.7	81.1 ± 8.9	70.9 ± 21.8	0.14
MCH (pg)	27.9 ± 2.7	29.4 ± 9.0	30.4 ± 11.3	29.9 ± 4.4	0.78	30.6 ± 10.7	28.0 ± 2.1	28.8 ± 8.3	27.3 ± 2.0	0.61
MCHC (g/dl)	32.7 ± 0.9	32.6 ± 4.9	33.5 ± 1.4	33.7 ± 1.0	0.34	33.4 ± 1.4	32.9 ± 1.1	33.6 ± 1.9	29.3 ± 10.5	0.01
RDW-CV	12.5 ± 1.5	14.0 ± 6.6	13.1 ± 1.6	11.9 ± 0.9	0.19	13.3 ± 1.2	13.5 ± 2.6	13.1 ± 1.7	12.9 ± 1.2	0.82
RDW-SD	49.5 ± 10.9	47.1 ± 9.8	47.6 ± 8.5	43.4 ± 9.7	0.24	50.7 ± 6.9	49.4 ± 7.5	46.7 ± 8.0	45.2 ± 4.2	0.13
PLT × 10^9/l	232 ± 40.3	251.8 ± 50.3	245 ± 53.9	224.7 ± 31.7	0.17	245.6 ± 55.8	285.3 ± 55.7	254.5 ± 63.7	266.5 ± 52.5	0.12
MPV	8.4 ± 0.7	8.6 ± 1.4	8.5 ± 1.0	8.0 ± 0.8	0.29	9.4 ± 2.2	8.3 ± 0.9	8.6 ± 0.9	8.2 ± 1.0	0.04
PDW	10.8 ± 1.3	10.7 ± 1.7	12.5 ± 11.9	10.2 ± 1.4	0.58	11.3 ± 1.6	10.5 ± 1.0	11.2 ± 1.3	109.9 ± 279.7	0.01
PCT	0.2 ± 0.00	0.20 ± 0.1	0.2 ± 0.00	0.2 ± 0.00	0.08	0.20 ± 0.1	0.20 ± 0.1	0.20 ± 0.1	0.3 ± 0.00	0.7
P-LCR	25.4 ± 9.5	23.9 ± 8.6	25.2 ± 10.7	18.7 ± 8.1	0.08	29.8 ± 12.1	22.6 ± 6.7	26.9 ± 10.5	26.3 ± 8.8	0.14
P-LCC	48.3 ± 13.0	70.6 ± 38.6	63.8 ± 23.3	50.2 ± 16.1	0.09	54.7 ± 14.6	71.2 ± 21.2	68.1 ± 16.3	81.1 ± 16.3	0.01

[a] ANOVA, $P < 0.05$.

parameters according to the number of patients seen per day among men exposed to low doses of radiation.[37]

Limitations

The limitations of this study included the lack of comparison of radiology department employees with other employees as witnesses, as well as examination of the duration of exposure to ionizing radiation. Selection bias due to some participants' ineligibility to participate in the study might have occurred. Biased information is possible when some participants do not provide reliable information about their drinking and smoking habits due to cultural and religious reasons, which may cause shame for others who come across this information.

Conclusion

On the basis of the results of this study, we concluded that changes in the parameters of RDW-CV and RDW-SD, white blood cells, platelets, hematocrit percentage, red blood cells, and other blood parameters. Our findings also indicated the importance of paying attention to the factors of sex, alcohol, and smoking, as well as job type—an indicator of the duration of exposure to ionizing radiation. Managers must focus on the personal dosimetry devices used by employees in the radiology department to consistently monitor the radiation exposure levels of employees and track the amount of radiation they are exposed to and consider the factors of sex, alcohol consumption, and smoking in the duration of monitoring. Moreover, employees should be educated regarding blood complications and their relationships with occupation, sex, smoking, and alcohol consumption. Radiology staff should undergo routine examinations yearly to determine the complete blood count, and the government should make policies regarding this issue.

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Conflict of interest

We have no conflicts of interest to declare.

Ethical approval

The researchers proceeded with the study after receiving the required licenses from the research facility and hospital authorities (IRB). Additionally, the study protocol was revised and approved by the ethical committee of the College of Health and Medical Technology, Sulaimani Polytechnic University, Sulaimaniyah, Iraq, under approval No. CH00038 on June 2, 2021.

Authors contributions

The author contributions to the paper are as follows: **SQ** designed the study, collected the data, performed the statistical analysis, and wrote the results and methods sections. **BK** wrote the discussion section, revised the article for linguistic evaluation, and provided critical feedback. **TA** wrote the conclusion and abstract, revised the article for scientific evaluation, provided valuable input, and approved the final text. All authors have critically reviewed and approved the final draft, and are responsible for the content and similarity index of the manuscript.

Data availability

The authors will ensure provision of the research data to other researchers on request.

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