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wjpmr, 2021,7(5), 18-27

SJIF Impact Factor: 5.922

WORLD JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.wjpmr.com

Research Article

ISSN 2455-3301

WJPMR

THE EFFECTS OF RADIATION ON HAEMATOLOGICAL PARAMETERS OF THE TECHNICIANS IN X-RAY DEPARTMENTS OF DIFFERENT HOSPITALS IN BENGHAZI-LIBYA

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Article Received on 24/02/2021 **Article Revised on 16/03/2021** **Article Accepted on 06/04/2021**

ABSTRACT

Background: X-ray is a type of ionized radiation. Long exposure leads to serious hazard to workers. This study aimed to evaluate the effects of radiation on the workers' blood parameters and determine its correlations with age, gender, qualification levels and years of experience. **Methods:** a cross sectional study carried out in 5 Hospitals in Benghazi City from February to May 2018. A total of 76 individuals divided into two groups; 50 exposed workers (group A) and 27 non-exposed (group B). Demographic data collected by using a multiple-choice questionnaire. Blood samples were collected to investigate complete blood counts (CBC) for the participants. **Results:** There was a decrease in neutrophils (NEU) and haematocrit (HCT) values and an increase in MCHC and lymphocytes (LYM) levels. In addition, there were significant differences between two groups in white blood cells (WBC), mean corpuscular haemoglobin concentration (MCHC), and mean corpuscular volume (MCV) (P=0.04, 0.02, and 0.02, respectively). On the other hand, the values of WBC, platelets (PLT) and mean corpuscular haemoglobin (MCH) were controversial among workers; there was elevations in some workers and reduction in others. Moreover, there were a positive relationship between age and years of experience with MCHC counts. However, the level of worker's education did not have any association with effects of x-ray radiation on workers' blood. Conversely, there is association between workers' gender and MCT, PLT and MCH. **Conclusion:** exposure to x-ray causes haematological disturbances on the exposed group which may lead subsequently to several health hazards including anaemia and cancer.

KEYWORDS: Radiation, Blood, Technicians, X-ray.

INTRODUCTION

Recently, workers are exposed to several hazards in the workplace. These hazards can affect several systems in the human body (WHO, 2001). In this respect, many hazards are affecting the blood components of the workers (OSHA, 2012; Mohamed, 2018), and one of these hazards is the ionizing radiation. In fact, X-ray is a form of ionizing radiation (Clarke and Dux, 2011), which is an invisible electromagnetic radiation. It has short wave length and high energy with high penetration ability. Its wavelength range lies between 0.05 and 0.01 nm. In reality, X-ray can penetrate through the object more deeply due to their high energy compared to other radiations types (Langland et al., 2002).

In medical field, X-ray is used in different technologies and techniques by radiographs to identify several spectrum of pathologies and to create images of human body in particular bones. This is because they have a higher electron density than soft tissues, so that, they absorb most of the X-ray photons by photoelectric processes (Burattini & Ballerna, 1994). They are including computed tomography (CT scan), fluoroscopy and radiography ("conventional X-ray" including mammography) (Hall & Brenner, 2008). They are used in examining bones, soft tissue. In addition, it used in combination with contrast fluid to examine blood vessels and certain organs such as Barium swallow that is used to help in diagnoses the upper digestive system problems (Health Service Executive, 2017).

There are two different ways of radiation exposure; internal and external. Internal exposure to ionizing radiation happens when human inhales, ingests radionuclide. In addition, it can be entering to the human bloods' though wounds or injection (WHO, 2016). On the other hand, External exposure occurs when ionizing radiation carried by dust, liquid and aerosol and deposited on the human skin or clothes. Furthermore, patient and technicians can be exposed to this radiation from external source through using radiation equipment that used in diagnosis and treatment in hospitals (WHO, 2016).

Workers, who are over-exposed to x-ray radiations dose, are prone to develop life-threatening diseases, since it can penetrate the living tissues and can destroy living cells or make them functionally abnormal (Baker, 1990).

X-rays has enough energy to attack and destroy the body cells by removing electrons from the atoms. Therefore, it leads to chemical changes in the cell and produce active free radicals (Nureddin & Alatta, 2016; Rozaj et al, 1999). Subsequently, these radicals can cause either damage to the cells, which is called as somatic effect or cause inheritable changes, which is known as mutations or genetic damage effects (Masumura et al., 2002).

Clinically, the health effects of ionizing radiation exposure are divided into two categories; somatic and genetic (Shaban et al., 2005). The Somatic effects include damage to any component of the human body except the reproductive organs. Actually, irradiated bone marrow can lead to anaemia, also, fatigue and muscle weakness. In addition, irradiated gastrointestinal tract causes mala-absorption of nutrients from the bowl. Furthermore, ionizing radiation causes loss of hair and skin dryness. Over time, it can cause skin cancer as well as cataracts on the lenses of the eyes (Canadian Cancer Society, 2009).

In literature, radiation can harm the reproductive organs directly and can genetically causes a damage to genes and chromosomes, which pass on to future generations. In this respect, radiation leads to stillbirths, miscarriages, and infant deaths. In addition, it leads to leukaemia of these children or it causes microcephaly and birth defects (limbs missing, large growths) or mental impairments (Canadian Cancer Society, 2009).

Recently, National cancer institute (NCI) added medical x-ray to human carcinogenic list (International Agency for Research on Cancer, 2015). In reality, exposure to radiation leads to bone marrow depression, and that leads to preventing all blood cells composition, and it causes decrease in the WBCs, PLTs and RBCs counts (Meo, 2004). Pathologically, radiation can produce free radicals that break chemical bonds of the molecules and damage DNA (Rozaj et al., 1999).

Up to date, there is no data available about the effect of X-ray radiation on haematological parameters of technician workers in Libya. Hence, the aim of this study is to identify the effects of X-ray radiation on haematological parameters of X-ray technicians in five different hospitals in Benghazi, Libya.

2. MATERIAL AND METHODS

Study Site: This study was conducted in five different hospitals in Benghazi, which are Benghazi Medical Center (BMC), Al-hwari Kidney Services Centre, Al Hawari General Hospital, Benghazi Cardiac Center, and Aljala Hospital.

Study Design: The study design was descriptive that adopts a quantitative and cross- sectional approach.

Method of Data Collection: The data was collected by two ways; first way is using a multiple choice questionnaire and the second way is blood collection for investigating Complete Blood Counts test (CBC). This data was collected between February and May 2018.

Questionnaire Design: demographic data did involve eight multiple choice questions about Technician's gender, age, level of education, years of experience, work shift, work exposed hours and wearing Personal Protective Equipment (PPE) in the department of radiology, and health status before starting work in this field.

Blood Samples: blood samples were collected from exposed and non- exposed persons to compare the haematological parameters between the two groups. The samples were collected by using vacuum with EDTA containing containers, then blood samples analysed by using Sysmex xp-300 device for testing complete blood counts.

Nine CBC parameters were taken into account in this test: Haemoglobin (Hb), Haematocrit (HCT), Red Blood Cells (RBC), Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration (MCHC), Platelet count (PLT), White Blood Cells (WBC), Neutrophils (NEUT) and Lymphocytes (LYM).

Target Population and Sample Size: The total number of participants was 76 persons divided into two groups. Group A includes 50 technicians who were exposed to radiation in the department of Radiology in the five selected hospitals (17 workers in BMC, 14 in ALhawari General Hospital, 9 in Aljala Hospital, 6 in Benghazi Cardiac Center BCC (alhawari) and 4 in Al-hwari Kidney Services Centre (Alhawari). On the other hand, group B involved 26 individuals who were not exposed to radiation hazards.

Statistical Analysis: The study uses Statistical package for social sciences (SPSS) version 22 software to analyze the collected data. It calculated the Frequency and percentage of demographic information. In addition, Chi square and ANOVA tests were calculated to test the relationships between some variables between the two groups.

Ethical Consideration: This study was conducted after getting permission letter from radiology department of the 5 Hospitals. The permission was obtained after sending preliminary request letter from the University of Benghazi to these hospitals. Subsequently, all participants were asked to sign of a consent form if they wanted to participate after full explanation of the protocol of the study.

3. RESULTS

Descriptive Analysis

Our work results are divided into two main parts; descriptive and inferential results. This part represents the descriptive analysis. **Figure (3.1)** shows that the 64.9% of the sample population was at group A while 35.1 % of the sample population represents group B.

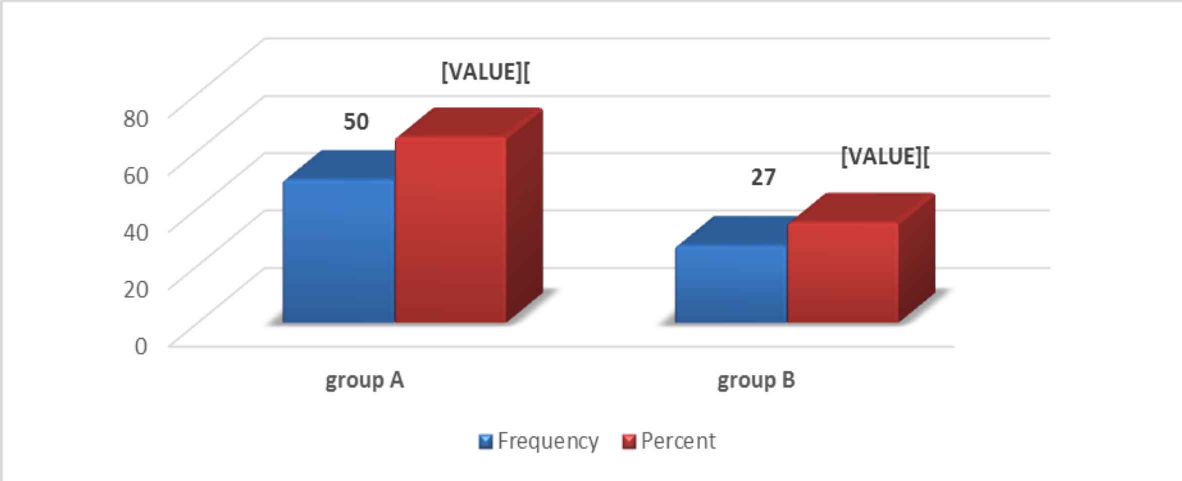

Figure 3.1: proportions of participants in x-ray exposed group and control group.

Considering the worker's distribution among different hospitals, the highest percentage of exposed sample were BMC workers (34 %), followed by Alhawari general hospital, Aljala hospital, Benghazi Cardiac Center and Al-hwari Kidney Services Centre **(figure 3.2).**

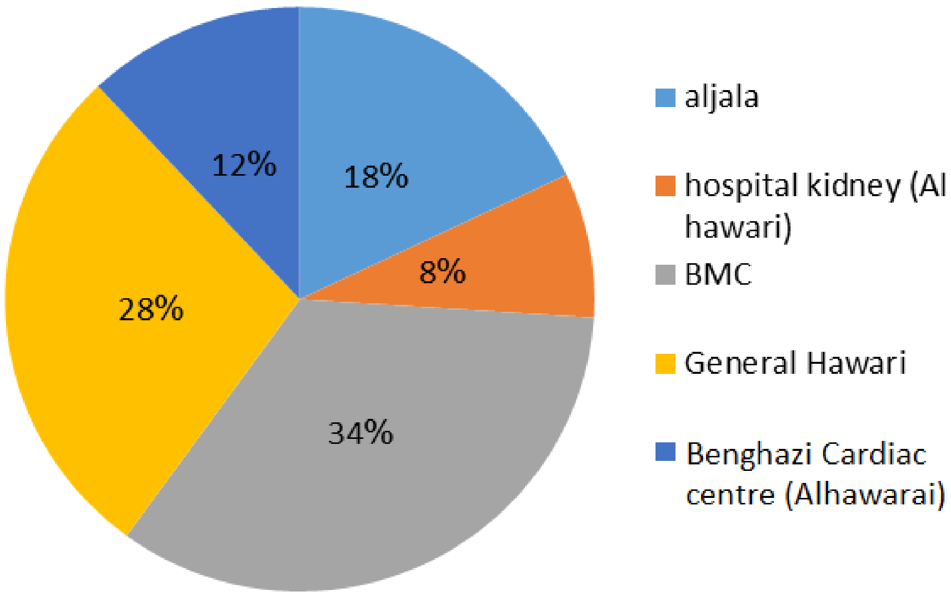

Figure 3.2: Proportion of exposed group in radiology department of five different hospitals.

Regarding gender, it is clear from **figure 3.3** that male gender represents the vast majority of participants of the x-ray exposed group (group A) 37 individuals (equal to 74% of group A) and there are 13 female participants (equal to 26% of group A), while the control group includes 17 female persons (62.96%) and 10 male participants (37.037 %).

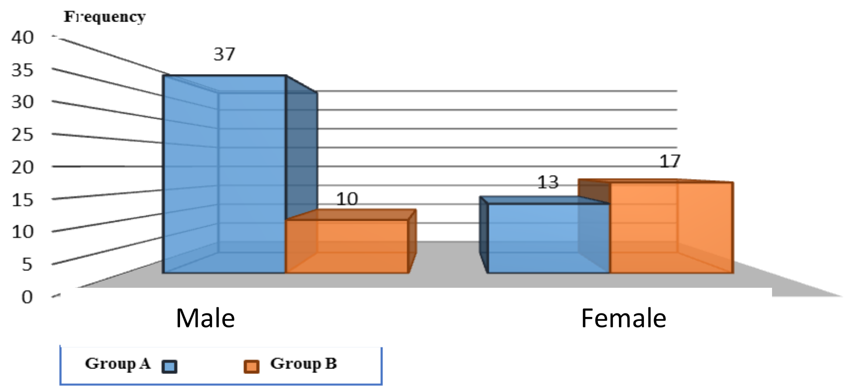

Figure 3.3: Participants' Frequency and Percentage Distribution, (according to gender).

Furthermore, the highest number of participants of group A were allocated among ages group from 28 to 32 years, while the highest number were assigned in group B ranges from 42 years and more (**figure 3.4**).

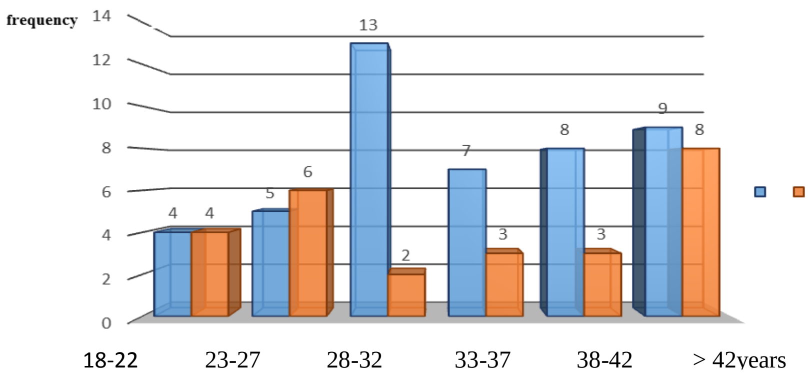

Figure 3.4: Participants' Frequency and Percentage Distribution, (according to age), where blue colour represents group A and brown represents group B.

Regarding the level of education of exposed group, Figure **(3.5)** demonstrated that the highest portion of exposed sample holds Diploma level followed by the high Diploma and the lowest percentage of the participants are the Bachler holders.

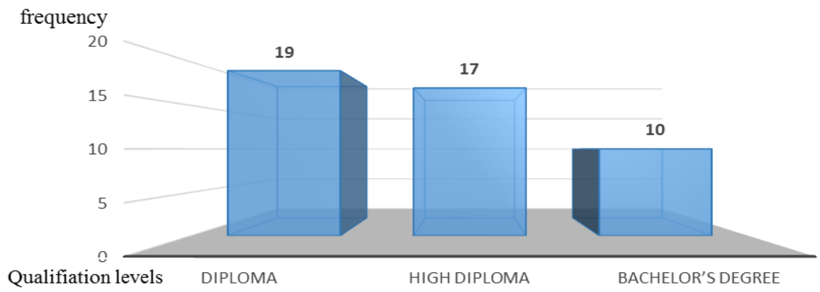

Figure 3.5: Radiation exposed participants' Frequency and Percentage Distribution, (according to level of education).

On the other hand, **figure (3.6)** shows that the highest percent (31%) of group A were exposed to radiation for five years or less and a considerable percent (22%) exposed form six years up to ten years. While the highest period of exposure (more than 26 years) represented by 15% of the exposed group.

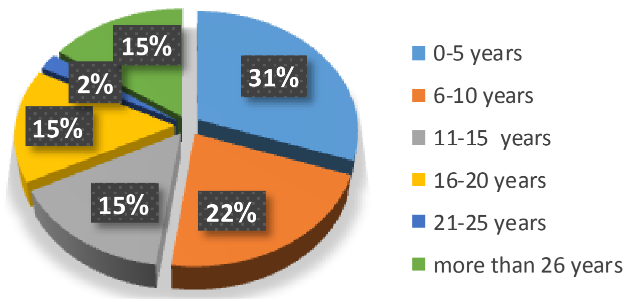

Figure 3.6: Radiation exposed participants' Frequency and Percentage Distribution, (according to years of experience).

Furthermore, the highest percentage of x-ray workers (70%) exposed daily to x-ray radiation in their workplace, while 11% exposed once a week **(figure 3.7)**.

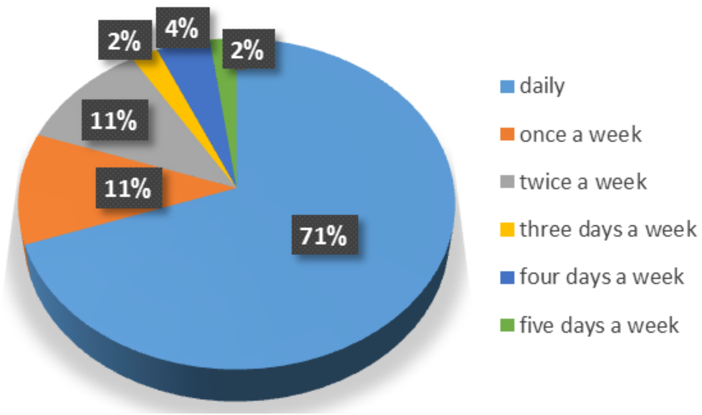

Figure 3.7: Frequency and Percentage Distribution of group A working hours.

Regarding the hours of exposure, **figure 3.8** shows that 86% of technicians expose to radiation for 4-8 hours in radiology department (figure 3.8).

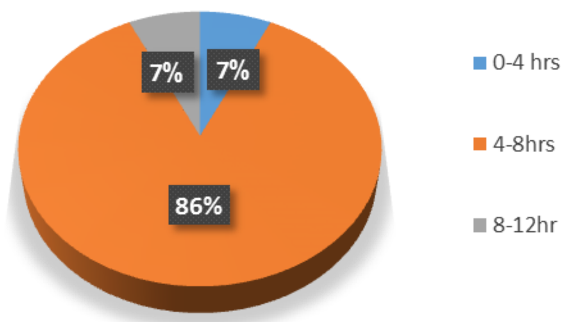

Figure 3.8: Frequency and distribution of exposed technicians' working hours in radiology department in five different hospitals.

Moreover, results of exposed technicians showed that 80% of sample did not wear PPE during the work and only 20% wear the PPE during the working hours **(figure 3.9)**.

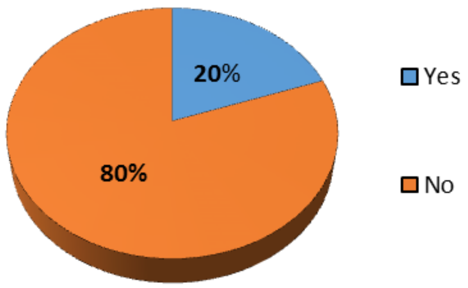

Figure 3.9: Wearing PPE during work in radiology department in five different hospitals.

Quantitative and inferential result

There were a significant difference in WBC, MCV and MCHC between the two groups (P = less than 0.05) **(table 3.1)**. Furthermore, there was a reduction in the levels of NEU and HCT of exposed workers below the normal values (normal values of NEUT are 60-70% and HCT are 40-50% for men and 37-47% for women).

On the other hands, there were an increase in the levels of MCHC and LYM of exposed workers (normal level of MCHC is 33.4-35.5g/dl and LYM is 1000-4800mm^3 (25-40%).

Table 3.1: Haematological parameters of exposed and non-exposed group.

Blood parameters	Category	Frequency and percentage of group A	Frequency and percentage of group B	P value
RBC	Below normal	1 (2%)	0 (0%)	0.57
	Normal	48 (96%)	27 (100%)	
	Above normal	1 (2%)	0 (0%)	
WBC	Below normal	7 (14%)	0 (0%)	0.04
	Normal	37 (74%)	26 (96%)	
	Above normal	6 (12%)	1 (3.7%)	
HCT	Below normal	14 (28%)	4 (16%)	0.31
	Normal	34 (68%)	20 (83.3%)	
	Above normal	2 (4%)	0 (0%)	
Hb	Below normal	9 (18%)	1 (4.2%)	0.26
	Normal	39 (78%)	22 (91.7%)	
	Above normal	2 (4%)	1 (4.2%)	
PLT	Below normal	5 (10%)	0 (0%)	0.20
	Normal	42 (84%)	26 (96%)	
	Above normal	3 (6%)	1 (3.7%)	
MCV	Below normal	20 (40%)	4 (14.8%)	0.02
	Normal	27 (54%)	23 (85.2%)	
	Above normal	3 (6%)	0 (0%)	
MCH	Below normal	6 (13%)	3 (11.1%)	0.26
	Normal	36 (78.3%)	24 (88.9%)	
	Above normal	4 (8.7%)	0 (0%)	
MCHC	Below normal	4 (8.7%)	4 (14.8%)	0.02
	Normal	18 (41.9%)	4 (57.1%)	
	Above normal	2 (4.7%)	1 (14.3%)	
LYM	Below normal	5 (11.1%)	3 (20%)	0.57
	Normal	30 (66.7%)	10 (66.7%)	
	Above normal	10 (22.2%)	12 (20%)	
NEUT	Below normal	23 (53.5%)	2 (28.6%)	0.36
	Normal	18 (41.9%)	4 (57.1%)	
	Above normal	2 (4.7%)	1 (14.3%)	

In addition, there is discrepancy in values of WBC, PLT and MCH between exposed workers; these parameters were increased in some workers, while they were decreased in others.

Concerning the most affected group among studied Hospitals, the results demonstrated that the BM technicians and Alhawari General Hospital were at the top list. In both groups, there were a decrease in NEUT, HCT and MCV. Moreover, there were elevation in the counts of LYPH and MCHC **(table 3.2)**.

Table 3.2: haematological parameters of exposed group in five different Hospitals.

Blood parameters	Category	Aljala Hospital	Kidney Hospital	BMC	Al hawari General Hospital	BCC
RBC	Below normal	0	0	0	1	0
	Normal	8	4	17	13	6
	Above normal	1	0	0	0	0
WBC	Below normal	2	0	1	3	1
	Normal	6	4	12	10	5
	Above normal	1	0	4	1	0
HCT	Below normal	1	1	3	6	3
	Normal	7	3	13	8	3
	Above normal	1	0	1	0	0
Hb	Below normal	2	1	1	4	1
	Normal	6	3	16	9	5
	Above normal	1	0	0	1	0
PLT	Below normal	1	0	3	1	0
	Normal	7	4	14	11	6
	Above normal	1	0	0	2	0
MCV	Below normal	0	2	3	10	5
	Normal	9	2	11	4	1
	Above normal	0	0	3	0	0
MCH	Below normal	1	-	0	3	2
	Normal	9	-	13	11	4
	Above normal	0	-	4	0	0
MCHC	Below normal	1	-	1	2	0
	Normal	8	-	11	4	2
	Above normal	0	-	5	8	4
LYM	Below normal	1	-	4	0	0
	Normal	8	-	10	8	4
	Above normal	0	-	2	6	2
NEUT	Below normal	4	-	2	11	6
	Normal	3	-	12	3	0
	Above normal	1	-	1	0	0

Additionally, there was a significant association using an ANOVA test between gender and effects of radiation on HCT, PLT and MCH **(table 3.3)**.

Table 3.3: Association between haematological effects of radiation and workers' gender.

Blood parameters	Mean Square	F	Sig.
RBC	.055	2.105	.151
HGB	.012	.068	.795
WBC	.000	.000	1.000
HCT	1.010	4.683	.034
PLT	.627	5.629	.020
MCV	.076	.270	.605
MCH	.881	5.310	.024
MCHC	.360	1.022	.316
LYM	.026	.078	.782
NEUT	.376	1.005	.321

Furthermore, there was a positive relationship between the workers' age and effects of radiation of MCHC **(table 3.4)**.

Table 3.4: Association between haematological effects of radiation and workers' age.

Blood parameters	Df	Mean Square	F	Sig.
RBC	5	.036	1.320	.267
HGB	5	.093	.531	.752
WBC	5	.392	2.344	.051
HCT	5	.280	1.231	.305
PLT	5	.096	.743	.594
MCV	5	.424	1.671	.154
MCH	5	.268	1.472	.212
MCHC	5	.987	3.125	.014
LYM	5	.691	2.248	.064
NEUT	5	.284	.716	.615

According to **table 3.5**, there was no correlation between the qualification level of workers and haematological effects of radiation.

3.5 Association between haematological parameters and workers' qualification levels.

Blood parameters	Mean Square	F	Sig
RBC	.000	.000	1.000
HGB	.100	.475	.625
WBC	.212	.794	.458
HCT	.299	1.092	.345
PLT	.074	.411	.666
MCH	.565	2.512	.094
MCHC	.227	.549	.582
LYM	.125	.356	.703
NEUT	.265	.721	.493

Moreover, **table 3.6** reported a positive relationship between workers' years of experience and effects of radiation on MCHC.

3.6 Correlation of haematological parameters and years of experience of the workers.

Blood parameters	Mean Square	F	Sig.
RBC	.000	.000	1.000
HGB	.129	.603	.698
WBC	.188	.687	.636
HCT	.097	.326	.895
PLT	.203	1.175	.339
MCV	.568	1.877	.120
MCH	.196	.797	.535
MCHC	1.049	3.136	.026
LYM	.188	.527	.717
NEUT	.333	.913	.467

DISCUSSION

Based on our results, the exposure to x-ray radiation causes adverse effects on hematologic parameters of the workers in radiology departments. In this context, there was a significant correlation between exposure to x-ray and its effects on WBC, MCV and MCHC. In addition, there was a decrease in NEU, HCT, PLT and HCT counts of exposed workers as well as increases in MCHC and LYM. Moreover, lack of Personal Protective Equipment (PPE) and/or lack of protective strategies to inforce the x-ray workers to wear the PPEs inside the departments of radiology in Libya, these factors extravagate the negative effect of x-ray exposure upon the health status as well as the haematological parameters.

These results are in agreement with a study conducted in 2012 in Iran which showed a decrease in WBC and PLT counts (Davoudi et al., 2012). In literature, another study was carried out in 2004 reported that exposure to x-ray leads to decrease in PLT count, however, it did not observe any differences in WBC and RBC (Meo, 2004). Alongside this, another study conducted in Sudan indicated that x-ray exposure leads to decline NEU count. In contrast, it found an increase in LYM count (Waggiallah, 2013).

On the other hands, Khorrami and Riahi-Zanjani (2015) found no differences in WBC,RBS, HCT, Hb, PLT, MCH, MCHC, MCV, NEU and LYM among individuals exposed to x-ray. However, they found a statistical difference in Platelet Disruption Width (PDW) and Platelet Large Cell Ratio (PLCR) between exposed and non-exposed groups (Khorrami & Riahi-Zanjani, 2015). Additionally, Mohammed et al. (2014) reported that exposure to x-ray leads to changes in the lymphocyte counts, this finding is in accordance with the current study which found a significant increase in the lymphocytes among exposed group. While no differences in RBC, WBC and PLT between two groups. In addition, it indicated that there was a positive relationship between work duration and the counts of lymphocytes of the x-ray technicians (Mohammed et al., 2014).

Considering an association between gender and effects of radiation on haematological parameters, this study presented association between gender and PLT, HCT, MCH. These finding are in agreement with Alnahhal1 et al. (2017) who found a significant association between gender and the effects of ionizing radiation on RBC and Hb of x-ray workers. Moreover, Shafiee et al (2016) found a clear association between gender and ionizing radiation effects on RBC of exposed workers, however, they did not find any association between gender and the other blood parameters (Shafiee et al., 2016).

According to the present study, there is a significant association between age and effects of x-ray on WBC and MCHC of exposed group. However, up to our knowledge there is no study available up-to-date have had tested this correlation.

The findings of the present study didn't demonstrate any relationship between the qualification level of the workers and subsequent effects of x-ray on haematologic parameters. Furthermore, there has been no published research studied this relationship according to our search and knowledge.

This study showed a significant association between years of experience and radiation effects on MCHC of exposed group. These findings are consistent with the results of Shahid et al. (2014). In fact, Shahid et al showed that the long-term exposure to ionizing radiation have a negative impacts on blood parameter (Shahid et al., 2014). Specifically, they found a significant association between exposure to x-ray and MCHC, as long term exposure leads to a decrease in its count (Shahid et al., 2014). Alongside this, Nureddin et al. conducted a study in Tripoli in 2016; they reported that the duration of exposure had a positive correlation with changes of exposed workers blood cells (Nureddin & Alatta, 2016). Similarly, Shafiee et al. (2016) found a significant relationship, which increases the duration of x ray exposure leads to increase the its effect of RBC (Shafiee et al., 2016).

Moreover, Khorrami and Riahi-Zanjani (2015) suggested that chronic X-ray exposure had a negative effect on thrombocytopenia and coagulation function (Khorrami & Riahi-Zanjani, 2015). In contrast, Alnahhal1 et al. (2017) did not indicate any association between the duration of radiation exposure and haematological parameters of exposed workers (Alnahhal1 et al., 2017).

This study has faced number of limitations. Firstly, there was a short time for collecting blood samples from five different hospitals. Secondly, some of the Technicians have refused to withdrawing sample. Thirdly, some hospitals did not allow the authors to test samples outside their own laboratory, and that cause problems since the CBC test did not include 9 parameters that are studied in this search.

CONCLUSION

The results of this study demonstrated that the Long-term exposure to X-ray might cause a negative impact on the workers' blood. In fact, the results of this work indicated that there is an impact of x-ray exposure on the haematological parameters which subsequently needs an interventional occupational health strategy in order to protect the workers by providing the PPE and inforce the workers to use them. Moreover, the results of this work indicated that age, gender and duration of exposure seems to have an associated relationship with their impact effects on haematological parameters.

REFERENCES

1. Alnahhal, M, Alajeramy, Y, Mostafa, SA, Shab, KA, Jaber S and Najim, A. Assessment of Hematological parameters among medical radiographers at governmental hospitals, Gaza strip. *Am J Med Med Sci*, 2017; *7*(6): 238-41.
2. Baker N. Exposure to ionizing-radiation from X-rays in the intensive therapy unit St. Vincent's Hospital. *Nursing monograph*, 1990; *1*: 19-26.
3. Canadian Cancer Society. Health and Physics: A Grade 12 Manitoba Physics Resource for Health and Radiation Physics. Canada. The Manitoba Division of the Canadian Cancer Society and the Government of Manitoba, 2009.
4. Clarke C and Dux A, chest x-rays for medical students. John wile and sons, 2011.
5. Davoudi, M., Keikhaei, B., Tahmasebi, M. and Rahim, F., Hematological profile change in radiation field workers. *Apadana Journal of Clinical Research*, 2012; *1*(1): 38-44.
6. Burattini E and Ballerna A, "Preface". Biomedical Applications of Synchrotron Radiation: Proceedings of the 128th Course at the International School of Physics -Enrico Fermi, Varenna, Italy. IOS Press, 1994.
7. Hall EJ and Brenner DJ, Cancer risks from diagnostic radiology. *The British journal of radiology*, 2008; *81*(965): 362-378.
8. Health Service Executive, X-ray "what is used for". Available from https://www.hse.ie /eng/health/az/x/x-ray/, 2017.
9. International Agency for Research on Cancer (IARC), Agents Classified by the IARC Monographs, 2015; 1 – 114.
10. Khorrami, MB and Riahi-Zanjani B, Hematological profile of healthy workers exposed to low dose radiation. *Pharmacol Online*, 2015; *2*: 138-141.

11. Langland OE, Langlais RP and Preece JW. *Principles of dental imaging*. Lippincott Williams & Wilkins, 2002.
12. Masumura KI, Kuniya K, Kurobe T, Fukuoka M, Yatagai F and Nohmi T. Heavy-ion-induced mutations in the gpt delta transgenic mouse: Comparison of mutation spectra induced by heavy-ion, X-ray, and γ-ray radiation. *Environmental and molecular mutagenesis*, 2002; *40*(3): 207-215.
13. Mohamed H, Swani MA, Alaghib MI, Abdeljawad AI, Alkezza M and Alobaidy M, Hematological Assessment of Benzene Exposure among Employees in Brega Oil Marketing Company (BOMC), Benghazi. International Blood Research & Reviews, 2018; 1-7.
14. Mohammed MR, Abdulateef SM, Dawood NA, Taher MG, Jabur SA, Alwain AH. Effects of radiation on the Hematological parameters in X-ray technicians: a case-control study. *Journal of Pioneering Medical Sciences*, 2014; *4*(2): 85-88.
15. Meo SA, Hematological findings in male x-ray technicians. *Saudi medical journal*, 2004; *25*(7): 852-856.
16. Nureddin AS and Alatta NO, Effects of long-term exposure to low X-ray on the blood consists of Radiology Department staff of health centers in Libya. *Age (year)*, 2016; *37*: 1-60.
17. OSHA, 2012. Health Hazards in Construction Workbook. Available online at https://www.osha.gov/sites/default/files/2019-03/health_hazards_workbook.pdf.
18. Rozgaj R, Kašuba V, Šentija K and Prlić I, Radiation-induced chromosomal aberrations and haematological alterations in hospital workers. *Occupational medicine*, 1999; *49*(6): 353-360.
19. Shahid S, Mahmood N, Chaudhry MN, Sheikh S and Ahmad N, Assessment of impacts of hematological parameters of chronic ionizing radiation exposed workers in hospitals. *FUUAST Journal of Biology*, 2014; *4*(2): 135.
20. Shafiee M, Hoseinnezhad E, Vafapour H, Borzoueisileh S, Ghorbani M and Rashidfar R, Hematological findings in medical professionals involved at intraoperative fluoroscopy. *Global Journal of Health Science*
21. Shabon MH, Sayed ZS, EL-gawish, MA, Mahdy EME and Shosha WG, 2005. Effect of single or fractionated dose exposures to gamma radiation on hemopoietic system. *Isotope and Radiation Research*, 2016; *37*(2): 617-624.
22. Waggiallah H, The Effect of X-Ray Radiationon Hematopoietic Tissue Among Radiology Technologists, 2013.
23. WHO, Occupational health A manual for primary health care workers, 2001.
24. WHO, Ionizing radiation, health effects and protective measures. https://www.who.int/news-room/fact-sheets/detail/ionizing-radiation-health-effects-and-protective-measures, 2016.