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Abstract

Background: Long-term exposure to low doses of ionizing radiation adversely affect human cells and tissues of medical imaging technologists, especially hematological parameters.

Aim: The aim of the present study to assess the effect of low dose radiation on the hematological parameters among MITs of Dhamar City Hospitals, Yemen.

Method: A cases-control study with 100 participants in the period two months (from 1- March to 30 April 2021) of Dhamar City was carried out. Out of them 60 were radiation exposed and 40 were controls. Hematological parameters were analyzed using Sysmex XN-350. Data was entered and analyzed using SPSS version 25 P. values ≤ 0.05 were considered statistically significant.

Results: In this study the Monocyte, Basophil, RBCs, HGB, HCT and RDW-SD were higher while MCHC and RDW-CV were lower in the exposed group. Significantly increased blood parameters (RBCs, HGB, HCT and lymphocyte) were statically increased significant among both exposure groups work less or equal six years and work more than six years compared to control group. Also, Neutrophil show statically decrease significant ($P<0.05$) with exposure group who work more than six years.

Conclusion: Low dose of ionizing radiations can alter CBC parameters of radiation technician medical imaging technologists. Effect of radiation increased with long term of exposure.

We recommended using appropriate personal protective measures for medical imaging technologists. Furthermore, performing a research order to have a clearer image of the effects of ionizing radiation.

Keywords: Low dose radiation, hematological parameters, medical technologists, Dhamar City, Yemen.

Introduction:

Radiation is energy in the form of waves or stream of particles. It can come from unstable atoms or it can be produced by machines, travels from its source in the form of energy waves or energized particles (1). Radiation may be classified as ionizing or non-ionizing, depending on its ability to ionize matter (2). Exposure to ionizing radiation (IR) is inherent in daily life and the average worldwide exposure from all sources approximately ~3 Millisievert (mSv)/year. Natural background radiation exposure contributes to ~2.4 mSv/year, (3). Medical imaging and the largest man made source of exposure and contributes to ~0.6 mSv/year. Diagnostic imaging and have substantially improved health care services and patient outcomes over the years (4).

IR are widely used in the diagnosis and treatment of patients. Radiation workers have the direct responsibility of performing the tests in the radiology, computed tomography (CT), nuclear medicine, and radiotherapy departments since they are frequently exposed to radiation (5 & 6). Hematopoietic cells (HPCs) considered the most sensitive cells to radiation therefore IR exposure directly damages HPCs and alters the capacity of bone marrow stromal elements to support and/or maintain hematopoiesis in vivo and in vitro. Exposure to IR induces dose-dependent declines in circulating hematopoietic cells not only through reduced bone marrow production, but also by redistribution and apoptosis of mature formed elements of the blood (7 & 8). Generally, exposure to IR including X-rays and gamma rays will lead to abnormal hematological findings, cancer including leukemia, birth defects in the future children of exposed parents, and cataracts. This risk associated with each imaging procedure is extremely low but, does slowly increase with the increasing number of exposure medical imaging techniques. Accordingly, blood cell count can be used as a biological indicator in the investigation of the damage caused by radiation (9). Diagnostic X-rays are the largest man-made sources of radiation exposure to the general population, contributing about 14% of the total annual exposure worldwide from all sources. Although diagnostic X-rays provide great benefits, their use involves some small risk of developing cancer is generally accepted (10 & 11).

Because application of IR increases continuously in medicine therefore the number of diagnostic technicians also increases. Diagnostic technicians (DT) may expose chronically to low doses of X-ray during their work especially those whom they do not use radiation protection tools. Some studies have demonstrated the negative effect of

LDR on hematological parameters while others detect the change at genetic analysis level only. No published study is available from our country. Thus, this study has recruited X-ray technicians as they are continuously exposed to occupational IR typically X-ray.

Therefor this study to assess the effect of low dose radiation (LDR) on the hematological parameters of medical imaging technologists (MITs) of Dhamar City Hospitals.

Materials and Methods

Study design

A cases – control study was conducted to assess effects in the hematological profile of MITs in Dhamar City Hospitals, Yemen.

Study area

The study was conducted on MITs, the samples collected within two months of Dhamar City hospitals and its suburbs from 1-March to 30 April 2021.

Study population

MITs Dhamar City Hospitals who voluntarily participated in the study and sign for consent. Healthy controls, with the same range of age, sex, and area residence with the exposed workers were taken.

Inclusion and exclusion criteria

Inclusion criteria

All apparently healthy workers with work experience of one year (1year) and above were included.

Exclusion criteria

Participants, both exposed and unexposed, with gross anemia, known history of diabetes mellitus, cardiopulmonary disease, acute or chronic infection, autoimmune disease, malignancy, those who have taken radiotherapy or chemotherapy and those who are taking any drug during the study period were all excluded.

Sample size determination

Sample size was determined by taking all MITs of Dhamar City Hospitals available through the data collection period who are fulfilling the explained criteria and who are volunteers to participate by giving their informed consent. In this study 100 participants were recruited. A total of 60 apparently healthy occupational radiation exposed workers and a total of 40 apparently healthy and unexposed controls were included.

Data collection procedure

Details of the socio-demographic background, occupational and medical history regarding work-related exposure to mutagenic agents, safety measures taken, duration of exposure, use of therapeutic drugs and smoking was obtained from a questionnaire that was completed by each study participant. The information was used to include or exclude participants.

Sample Collection and Processing

About 3 ml of venous blood was collected from volunteer participants, who have fulfilled the

criteria, into lavender Ethylene diamine tetracetic acid (EDTA) tube for complete blood count and blood cell morphology tests. In this collection process a 23-gauge needle was used in order to avoid clotting or hemolysis. For proper mixture of blood and anticoagulant, collected specimen was mixed by inverting the tubes 8-10 times. Each specimen was checked for the presence of clots prior to labeling and analysis. Standard venous blood collection procedure was followed to ensure the quality of specimen. CBC was performed within to one hour of collection (12).

Data analysis

Data was analyzed using SPSS Version 25. To conduct analysis, Quantitative variables were expressed Percentage as well as Mean ± standard deviation (SD), Independent t-test used to comparison hematological parameters of MITs and control. Chi-squire used to show percentage of hematological parameters among MITs and control. One-way ANOVA was used to Comparison of hematological parameters among exposed groups and unexposed groups depend on duration of work in medical imaging. P. value of <0.05 was regarded as significant.

Ethical Consideration

Approval for this study was taken from the department of chemistry of applied science collage in Thamar University. Informed consent was obtained from the study subjects before data collection and blood sampling were carried out. Study participants were told that they have the right to quit the study any time they decided and that data is confidential and it will be used only for the study.

Results and Discussion

Exposure of cells to IR induces damage in various cellular compartments and results in complex biological responses (13). It has been described that blood cell counts immediately drop soon after irradiation with low doses of IR (14).

This study has analyzed blood samples of the exposed workers for CBC and compared it with controls.

Demographic characteristic distribution

Results showed that sixty 60 healthy medical radiation workers were precipitate in this study. Their age ranged from 20 to 60 years the mean of age was 28 years. The result reveal that mean of duration of work experience was 6 years, mean of work per day 10 hours. Medical radiation workers were control to forty 40 healthy non-radiation exposure.

Table 1: Demographic characteristic distribution.

Demographic characteristic	Medical Radiation Workers group n=60 (100%)
Age **≤28** **>28**	 **38 (63.3%)** **22 (36.7%)**
Duration of work **≤ 6 years** **>6 years**	 **35 (58.3%)** **25 (41.7%)**
Work per day **≤ 10hours** **>10 hours**	 **38 (63.3%)** **22 (36.7%)**

Hematological parameters analysis among MITs and control group

Table 2 revealed that a number of the CBC parameters are affected in the radiation exposed workers as compared to workers who were not exposed to radiation.

Blood parameters (Monocyte, Basophil, RBCs, HGB, HCT and RDW- SD) were statically increased significant (P<0.05), while (MCHC and RDW-CV) were statically decrease significant (P<0.05) between Control Group compared to Exposure Group, Whereas other blood parameters WBC, Neutrophil, Eosinophil, Lymphocyte, MCV, MCH and Plts) show difference in mean compared to control but this difference have no statically significant (P < 0.05).

Increased significant of Monocyte and RBCs agreed with findings by Surniyantoro *et al.*, 2019(15), in Indonesia which reported that RBCs and monocyte counts were significantly higher in radiation-exposed workers compared to controls. Significant of RBCs, Monocyte and MCHC smellier to finding by Joudoh *et al.,* 2018 (16). In Iraq Significant differences were noted in hematological parameters in RBCs. Highly significant differences were noted in Monocyte and MCHC. Our study finding approved with study by Shahid *et al.,* 2015 (17). in Pakistan which noted Significant differences were found HGB, WBCs, MCH, MCHC, HCT, and Lymphocyte by the t-test between radiation exposed and unexposed individuals.

Our study show disagrees finding to several recent studies conducted in Iran, Iraq and Egypt which reported some variations in the basic hematological parameters with no statistically significant (18 - 20**).**

Table2: Hematological parameters of MITs compared with the control group using independent t- test:

Parameters	Control Group n=40 Mean± SD	Exposure Group n=60 Mean± SD	P Value
WBCs	**6.02±1.5**	**6.04±1.6**	**0.971**
Neutrophil	**3.2±1.4**	**2.8±1.2**	**0.086**
Eosinophil	**0.24±0.23**	**0.22±0.20**	**0.808**
Basophil	**0.02±0.02**	**0.04±0.02**	**0.003**
Lymphocyte	**2.2±0.7**	**2.247±0.63**	**0.079**
Monocyte	**0.34± 0.2**	**0.49 ± 0.12**	**0.000**
RBCs	**5.2± 0.58**	**5.7 ± 0.61**	**0.000**
HBG	**14.8 ±1.6**	**15.8±2.00**	**0.019**
Plts	**262 ±62**	**287 ±68**	**0.057**
HCV	**44.2 ±4.8**	**46 ±4.8**	**0.036**
MCV	**83 ±12**	**80 ±13**	**0.218**
MCH	**28±2**	**28 ±3.14**	**0.257**
MCHC	**76.5 ±11**	**33.7 ± 4**	**0.002**
RDW-SD	**41.7 ±9**	**51.5 ±61.8**	**0.039**
RDW-CV	**14.8 ±6.3**	**13.6 ±3.7**	**0.000**

The frequency and percentage of Hematological parameters abnormalities among MITs compared with the control group as seen in table 3. The current study showed the higher prevalence of Hematological parameters (Neutrophil, Eosinophil, Basophil, Monocyte, RBCs, HGB and Plts) abnormalities among MITs compared with the control group.

The result show that 16 (26.7%) of MITs had abnormalities value of Neutrophil compared to control 5 (11.9%). Although Monocyte was higher abnormality among MITs 15 (25.3%), control showed 5 (11.9%). The result reveal that RBCs reach highest abnormalities among DT 23 (38.3%) compared to control 6 (14.3%). The results of the present work revealed that hematological parameters abnormalities had been more altered among MITs compared with a non-workers control group. This may be due to Long-term exposure to low doses of IR may adversely affect human cells and tissues of hospital radiation workers, especially in peripheral blood cells count (*21)*. The possible reason higher prevalence increased among MITs exposure of their erythropoietin system during maturation of erythrocytes in the circulation *(*22*)*. The present results also showed a decrease in

neutrophil values among MITs compared with control group as well as an elevation of both lymphocytes and monocytes among MR workers compared with control group. This result is in agreement with Joudoh *et al.*, 2018 (23). Who found decrease in neutrophil values among MITs compared with non-workers as well as an elevation of both lymphocytes and monocytes among workers compared with nonworkers control group.

Table 3: Prevalence of hematological parameters abnormalities among MITs and control group using Chai-squire test

HPS	Control Group	Exposure Group
WBCs	4 (9.5%)	3 (5%)↓
Neutrophil*	5 (11.9%)	16 (26.7%) ↓
Eosinophil	6 (14.3%)	8 (13.3%) ↑
Basophil	2 (4.8%)	7 (11.7%)↑
Lymphocyte	7 (16.3%)	7 (11.7%)↑
Monocyte	5 (11.9%)	15 (25.3%) ↑
RBCs*	6 (14.3%)	23 (38.3%) ↑
HBG	2 (4.8%)	7 (11.7%) ↑
Plts	4 (9.5%)	9 (15%)↑

The arrow ↓ mean that value was under normal rang, while ↑ arrow mean that value was higher than normal rang.

Complete Blood Count values according to duration of working

Our study finding in figure.1 Show that the RBCs, HGB, HCT and lymphocyte were statically increased significant ($P<0.05$) between control group and both exposure groups, Also neutrophil show statically decrease significant.

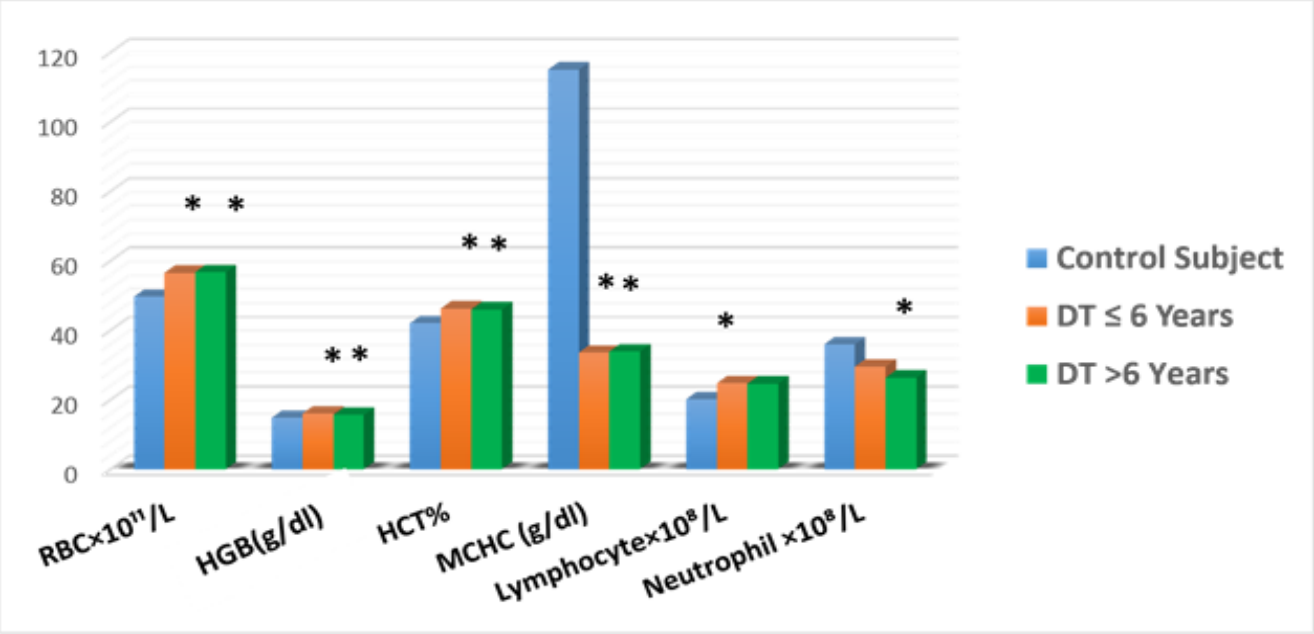

Figure 1: Mean Complete Blood Count values of medical imaging technologists according to duration of working, compared with their controls groups.

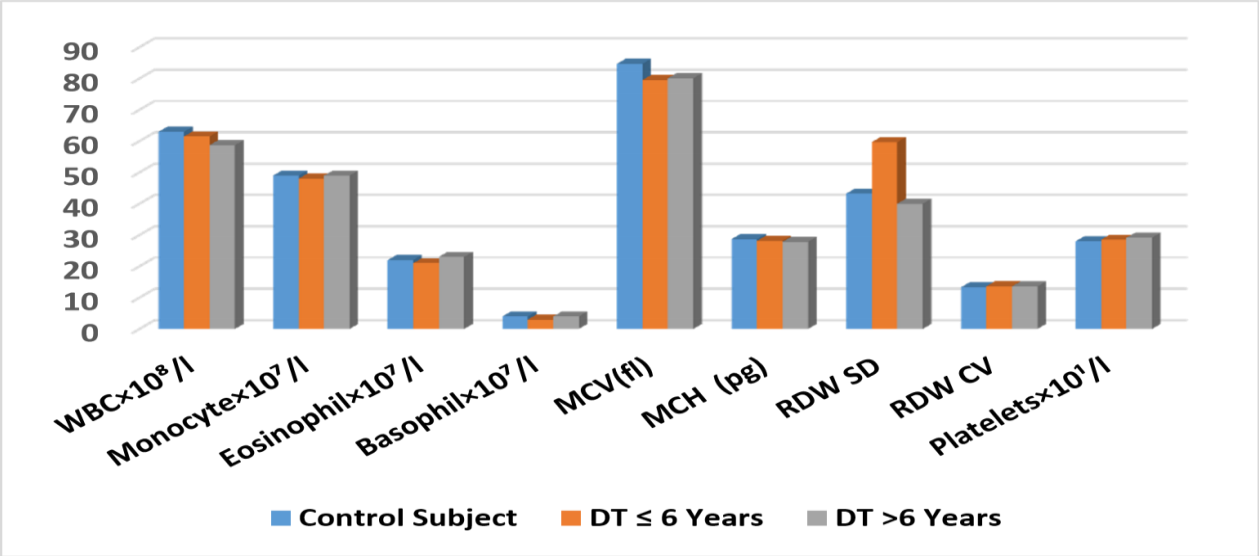

Figure 2: Mean Complete Blood Count values of medical imaging technologists according to duration of working, compared with their controls groups and significance level using ANOVA test:

However the significantly increased of blood meters in our study result were approved in some parameters differ in the parameters to recent study conducted in Iraq done by (24) studied the effects of occupational exposure of x-Ray on hematological parameters of DT .Which observed that the lymphocytes, RBCs, HGB and HCT significantly (P<0.05) increased.

In another study done by Meo S. A. (25), showed the reduction of mean value of Plts in X-ray technicians but he observed no significant difference in RBCs and WBCs with the control groups. However, recent studies conducted in Poland and Pakistan, Sudan, Sudia Arabia Kingdom found statistically significant difference between exposed and non-exposed subjects regarding to lymphocytes count (26).

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 (27). Similarly, Shafiee *et al.* (2016) found a significant relationship, which increases the duration of X-ray exposure leads to increase the its effect of RBCs (28).

In this study we observed most of the CBC parameters in X-ray technicians were altered compared with the controls, this alteration may be due to overexposure of the technicians to low dose during their daily work since they do not use any radiation protection tools and not have personal dosimeters to record the absorbed energy. The majority of the technicians have not enough information about risk of low dose of X-ray using in the machines (29).

Complete Blood Count (CBC) according to age of working.

Our study finding in fig 3 showed that RBCs, HBG, HCT and Lymphocytes were statically increased significant ($P<0.05$) between control group and both of age exposure groups, While Lymphocyte increased significantly ($P<0.05$) with exposure group who work less or equal 28 years.

However Our study finding in fig..4 revealed that the WBC, Neutrophil, Monocyte, Eosinophil, Basophil, MCV, MCH, RDW-SD, RDW-CV and Plts in MIT showed difference in mean compared with control but this difference have no statically significant ($P >0.05$). Our finding similar with another study reported by Younis et al., noted positive relationship between age with MCHC counts (30). Another study was conducted by Sabagh and Chaparian, 2019 (31), showed that the number of RBCs, HGB, and HCT had a positive poor correlation with age ($P<0.01$).

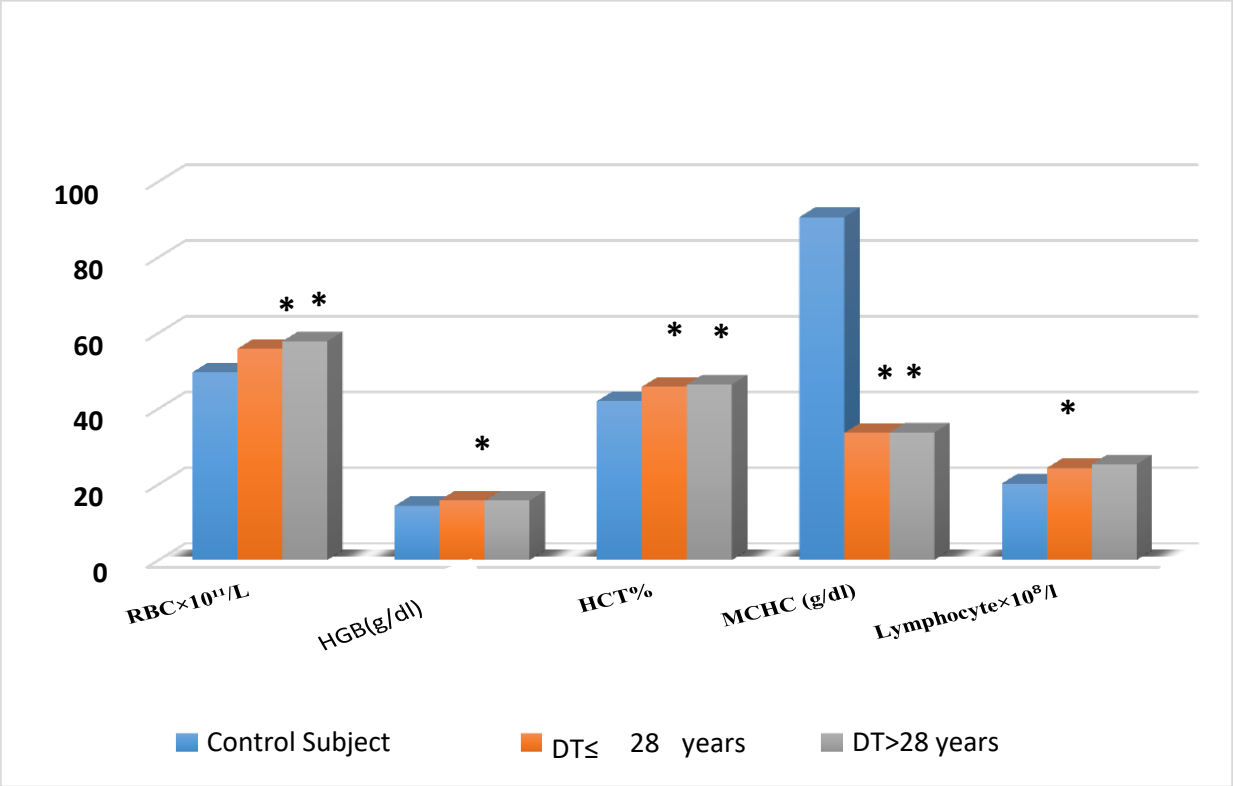

Figure 3: Mean Complete Blood Count (CBC) values of medical imaging technologists according to age. *Mean there is statically significant at (P<0.05), compared controls groups.

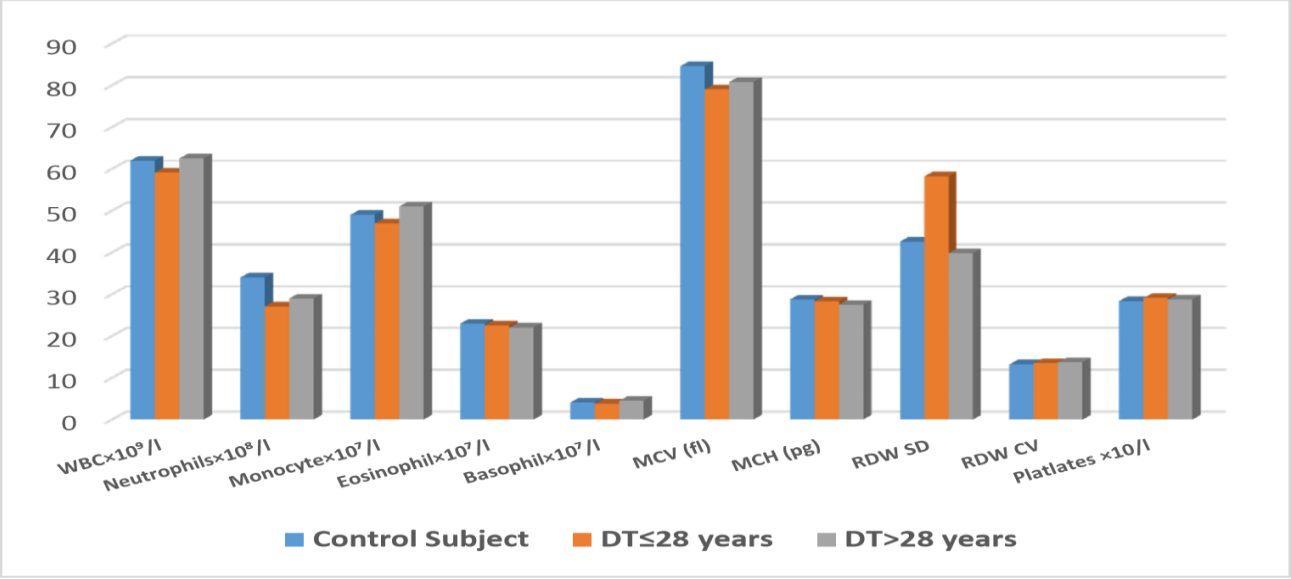

Figure 4: Mean Complete Blood Count values of medical imaging technologists according to age. *Mean there is statically significant at (P<0.05), compared controls groups.

Conclusions

Depending on our results, we can conclude that low X-ray doses use for diagnosis from x-ray machine has an effect on the CBC parameters of medical imaging technologists. RBCs, HBG, Monocyte, Basophil, HCT and RDW-SD, MCHC and RDW-CV were significant difference between exposed and non-exposed groups. That is, the mean Monocyte, Basophil, RBCs, HBG, HCT and RDW-SD were higher while MCHC and RDW-CV were lower in the exposed group.

We recorded the CBC parameters (Neutrophil, Eosinophil, Basophil, Monocyte, RBCs, HBG and Plts) higher abnormal value out of normal range among medical imaging technologists compared to control group.

Significantly increased blood parameters (RBCs, HBG, HCT and lymphocyte were statically increased significant among both exposure groups work less or equal six years and work more than six years compared to control group., Neutrophil show statically decrease significant ($P<0.05$) with exposure group who work more than six years.

Training and courses about hazard of IR should be organized to enhance the healthcare quality of the technicians and to improve their knowledge about benefit of radiation protection tools such as lead apparel, lead goggles, thyroid shield etc. to protect themselves from any overexposure during the daily life.

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References

1. Strang, Brian, and CGP CNSC. "Practice Analysis of Nutrition Support Professionals: Evidence-Based Multidisciplinary Nutrition Support Certification Examination." (2012).
2. Kuchay MS, Krishan S, Mishra SK, Farooqui KJ, Singh MK, Wasir JS, Bansal B, Kaur P, Jevalikar G, Gill HK, Choudhary NS. Effect of empagliflozin on liver fat in patients with type 2 diabetes and nonalcoholic fatty liver disease: a randomized controlled trial (E-LIFT Trial). Diabetes care. 2018 Aug 1;41(8):1801-8.
3. Zivuku, Munyaradzi. *Radionuclides and heavy metals concentrations in particulate matter around uranium and gold mining towns of Erongo region, Namibia*. Diss. North-West University (South Africa), 2020.
4. Kim, Sung Eun, et al. "Ultrasmall nanoparticles induce ferroptosis in nutrient-deprived cancer cells and suppress tumour growth." *Nature nanotechnology* 11.11 (2016): 977-985.

5. Jabeen S, Shah MT, Khan S, Hayat MQ. Determination of major and trace elements in ten important folk therapeutic plants of Haripur basin, Pakistan. Journal of Medicinal Plants Research. 2010 Apr 4;4(7):559-66.
6. Masood A, Ali Al-Jumaily A. Computer aided diagnostic support system for skin cancer: a review of techniques and algorithms. International journal of biomedical imaging. 2013 Oct 30;2013.
7. Du J, Liu Y, Meline B, Kong G, Tan LX, Lo JC, Wang J, Ranheim E, Zhang L, Chang YI, Ryu MJ. Loss of CD44 attenuates aberrant GM-CSF signaling in Kras G12D hematopoietic progenitor/precursor cells and prolongs the survival of diseased animals. Leukemia. 2013 Mar;27(3):754-7.
8. Dainiak N. Hematologic consequences of exposure to ionizing radiation. Experimental hematology. 2002 Jun 1;30(6):513-28.
9. Fachin AL, Mello SS, Sandrin-Garcia P, Junta CM, Ghilardi-Netto T, Donadi EA, da Silva Passos GA, Sakamoto-Hojo ET. Gene expression profiles in radiation workers occupationally exposed to ionizing radiation. Journal of radiation research. 2009;50(1):61-71.
10. de Gonzalez AB, Darby S. Risk of cancer from diagnostic X-rays: estimates for the UK and 14 other countries. The lancet. 2004 Jan 31;363(9406):345-51.
11. Sabagh M, Chaparian A. Evaluation of Blood Parameters of the Medical Radiation Workers. Iranian Journal of Medical Physics. 2019 Nov 1;16(6):439-43.
12. Cheesbrough M. District laboratory practice in tropical countries, part 2. Cambridge university press; 2005.
13. Amundson SA, Bittner M, Fornace AJ. Functional genomics as a window on radiation stress signaling. Oncogene. 2003 Sep;22(37):5828-33.
14. Zachariah B, Jacob SS, Gwede C, Cantor A, Patil J, Casey L, Zachariah AB. Effect of fractionated regional external beam radiotherapy on peripheral blood cell count. International Journal of Radiation Oncology* Biology* Physics. 2001 Jun 1;50(2):465-72.
15. Harry Nugroho Eko S, Tur R, Yanti L, Nastiti R, Sadewa S, Hastuti H, Hiroyuki D. Assessment of Ionizing Radiation Effects on the Hematological Parameters of Radiation-Exposed Workers. Atom Indonesia. 2019 Jun 1;45(2):123-9.
16. Joudoh HJ, Al-Kaysi AM, Kadhim NF. Effects of external radiation exposure on some hematological parameters of hospitals workers staff. Biol Appl Environ Res. 2018;2:171-9.
17. Shahid S. Review of hematological indices of cancer patients receiving combined chemotherapy & radiotherapy or receiving radiotherapy alone. Critical Reviews in Oncology/Hematology. 2016 Sep 1;105:145-55.
18. Shafiee M, Hoseinnezhad E, Vafapour H, Borzoueisileh S, Ghorbani M, Rashidfar R. Hematological findings in medical professionals involved at intraoperative fluoroscopy. Global Journal of Health Science. 2016.
19. Khorrami MB, Riahi-Zanjani B. Hematological profile of healthy workers exposed to low dose radiation. Pharmacol Online. 2015 Aug 30;2:138-41.
20. Hogan MC, Abebe K, Torres VE, Chapman AB, Bae KT, Tao C, Sun H, Perrone RD, Steinman TI, Braun W, Winklhofer FT. Liver involvement in early autosomal-dominant polycystic

kidney disease. Clinical gastroenterology and hepatology. 2015 Jan 1;13(1):155-64.
21. Alnahhal M, Alajeramy Y, Mostafa SA, Shab KA, Jaber S, Najim A. Assessment of Hematological parameters among medical radiographers at governmental hospitals, Gaza strip. Am J Med Med Sci. 2017;7(6):238-41.
22. Shahid S, Mahmood N, Chaudhry MN, Sheikh S, Ahmad N. Assessment of impacts of hematological parameters of chronic ionizing radiation exposed workers in hospitals. FUUAST Journal of Biology. 2014 Dec 1;4(2):135.
23. Joudoh HJ, Al-Kaysi AM, Kadhim NF. Effects of external radiation exposure on some hematological parameters of hospitals workers staff. Biol Appl Environ Res. 2018;2:171-9.
24. Taqi AH, Zaynal S, Said J, Hameed A. Effects of high doses of X-Ray on hematological parameters and morphology of red blood cells in human blood. Iranian journal of medical physics. 2019;16(1):112-9.
25. Meo SA. Hematological findings in male x-ray technicians. Saudi medical journal. 2004 Jul 1;25(7):852-6.
26. Alnahhal M, Alajeramy Y, Mostafa SA, Shab KA, Jaber S, Najim A. Assessment of Hematological parameters among medical radiographers at governmental hospitals, Gaza strip. Am J Med Med Sci. 2017;7(6):238-41.
27. Nureddin AS, 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 Sep 22;37(1.60).
28. Gheisari Y, Vasei M, Shafiee A, Soleimani M, Seyedjafari E, Omidkhoda A, Langroudi L, Ahmadbeigi N. A three-dimensional scaffold-based system for modeling the bone marrow tissue. Stem Cells and Development. 2016 Mar 15;25(6):492-8.
29. Reinwald M, Spiess B, Heinz WJ, Vehreschild JJ, Lass-Flörl C, Kiehl M, Schultheis B, Krause SW, Wolf HH, Bertz H, Maschmeyer G. Diagnosing pulmonary aspergillosis in patients with hematological malignancies: a multicenter prospective evaluation of an A spergillus PCR assay and a galactomannan ELISA in bronchoalveolar lavage samples. European journal of haematology. 2012 Aug;89(2):120-7.
30. Abdel-Warith AW, Younis EM, Al-Asgah NA, Gewaily MS, El-Tonoby SM, Dawood MA. Role of fucoidan on the growth behavior and blood metabolites and toxic effects of atrazine in Nile tilapia Oreochromis niloticus (linnaeus, 1758). Animals. 2021 May;11(5):1448.
31. Sabagh M, Chaparian A. Evaluation of Blood Parameters of the Medical Radiation Workers. Iranian Journal of Medical Physics. 2019 Nov 1;16(6):439-43.