

## Radiologic technologists in Saudi Arabia. *Does long-term exposure to radiation increase the risk of hematological disorders?*

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### ABSTRACT

**Objectives:** To determine the influence of prolonged exposure to radiation based on dosimeter readings on hematological parameters among radiologic technologists (RTs) in Saudi Arabia.

**Methods:** The study was specifically conducted on selected RTs with experience of more than 10 years and the highest thermoluminescent dosimeter (TLD) readings among all RTs in the Radiological Department, Sabya General Hospital, Ministry of Health, Saudi Arabia from August to October 2020. The RTs group was compared with a control group of non-irradiated participants. Blood samples were collected for hematological and coagulation profile evaluation.

**Results:** The acquired radiation dose analysis revealed that the average accumulated dose in 10 years is 7.6 mSv. The medians of prothrombin time (PT) and activated partial thromboplastin time (APTT) of the RTs group were significantly lower when compared to the control group. In addition, RTs group exhibited a significant reduction in neutrophil count and an elevation in lymphocyte count.

**Conclusion:** Chronic exposure to radiation revealed a significant change in blood tests and may reflect an effect on RTs tissues, leading to serious health problems. However, further investigation in a large cohort to study the association between alteration in hematological parameters and chronic radiation exposure is required.

**Keywords:** ionizing radiation, radiation dosage, radiation exposure, hematological tests, coagulation tests

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Radiologic technologists (RTs) are exposed to chronic ionizing radiation (IR) while performing their duties. Ionizing radiation has more energy than non-ionizing, and its effects on human body tissues

at low doses remain controversial. Ionizing radiation can penetrate human tissues, which leads to tissue damage through ionization of the atoms and molecules of the tissues.<sup>1</sup> Investigating the association of chronic exposure to radiation with human illnesses is thus of interest, and particularly among medical RTs.

Maintaining the various blood cell types at a persistent level is the main role of the hematopoietic system. Ionizing radiation can interrupt this system, leading to radiation-induced pathophysiology.<sup>2</sup> Radiation exposure also causes a significant reduction of peripheral blood cells because of associated high rates of cellular division.<sup>3</sup> These cells are necessary for the renewal of hematopoietic cells and have been shown to be highly sensitive to IR.<sup>4</sup> Moreover, the reduction of peripheral blood cells can accompany and contribute to physiological symptoms including nausea, vomiting, and fatigue.<sup>3</sup> The effect of radiation on peripheral blood cells can be quantitative, qualitative, or both. Two factors play a role in this type of effect: the amount of the absorbed dose and the type of cell irradiated. A reduction in white blood cell count was seen following a dose of radiation using a radiation-exposed mouse model.<sup>5</sup> Murine lymphocytes and platelets similarly exhibited reduction following irradiation, but the decline of platelets was noted as slow compared to that of lymphocytes.<sup>6</sup> Hematological parameters are widely used to assist in the evaluation of different hematological and non-hematological disorders. These parameters assist physicians in defining a person's health status. The current study is designed to examine possible changes in hematological parameters in RTs, who are chronically exposed to various types of radiation, in relation to their personal dosimeter readings.

**Methods.** The study was carried out in the Department of Radiology, Sabya General Hospital, Jazan, Saudi Arabia from August to October 2020. The association of cumulative radiation dose and health concerns has been previously determined using several methods; however, the criteria designed for this study are distinct and unique, particularly in Saudi Arabia. The study was approved by the Ethical Committee of Scientific Research at King Khalid University with approval number (ECM#2020-3201)-(HAPO-06-B-001).

The current study enrolled 38 RTs from the department of radiology at Sabya hospital; however, after conducting a small questionnaire, only 10 RTs consisted of 5 male and 5 female met the study's criteria, reducing the planned sample size. The inclusion criteria for the selection of RTs were as follows: those who

are adults aged between 30-45 years; have worked in the radiology field for more than 10 years; have only worked at Sabya General Hospital, Jazan, Saudi Arabia for the mentioned period; have the highest thermoluminescent dosimeter (TLD) readings (235.85 to 323.72 uSv) among all TLD measured volunteers. The exclusion criteria for the selection of RTs were as follows: those who are alcoholics, smokers, or have a history of hypertension or diabetes. The control group consisted of non-irradiated healthy adults who were non-alcoholic and non-smokers, did not have a history of hypertension or diabetes, and did not work in a medical radiology department.

The presented analysis examines the effect of absorbed radiation on radiologic technologists who have been exposed to various occupational doses between 2009 and 2019. Thermoluminescent dosimeter was used to obtain participants having the highest cumulative doses. The study aims to concentrate on the association between dose cumulation and possible changes in hematological parameters.

The following equation was applied for the calculation of cumulative radiation dose:

$$D = \sum_{i=1}^n X_i$$

where D is the cumulative radiation dose (mSv) and  $X_i$  is the radiation dose in the first year (i).

Blood samples were collected from all participants by vein puncture and placed in tubes containing either ethylenediamine tetra-acetic acid (EDTA) for complete blood count assessments or trisodium citrate for coagulation profile evaluation. A hematology analyzer (Sysmex XN550) was used to assess various hematological parameters. For coagulation studies, blood was withdrawn from participants and immediately centrifuged at 900 rpm for 15 minutes at room temperature. Coagulation profiles were assessed by an automated coagulation analyzer (Stago Satellite).

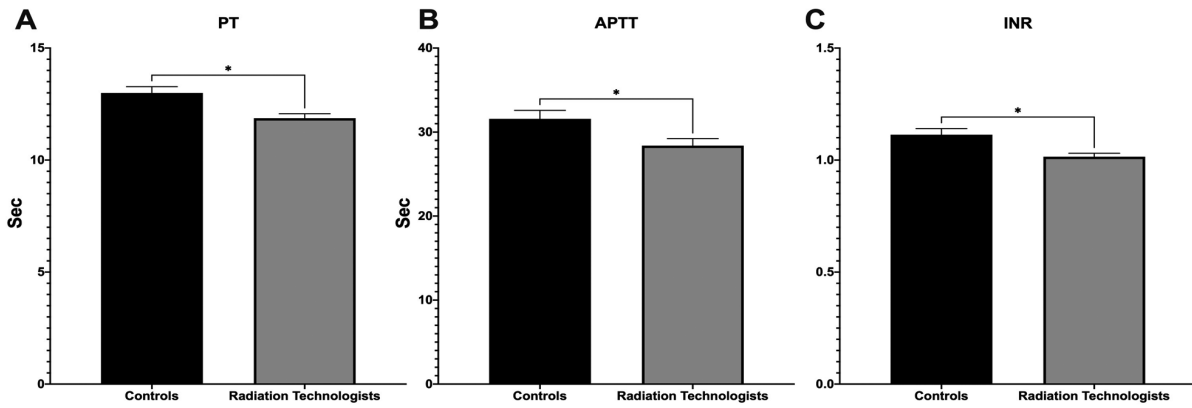
**Statistical analysis.** GraphPad Prism was used for analyses (GraphPad Prism version 9.00 for Mac, GraphPad Software, San Diego, CA, USA). The Mann-Whitney U test was used to compare irradiated participants with non-irradiated controls. To evaluate the degree of association between 2 variables, Spearman's

correlation was used. A *p*-value less than 0.05 was statistically considered as significant.

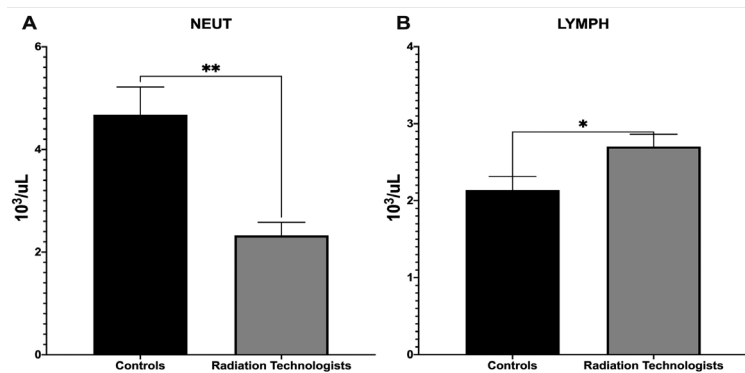
**Results.** The total sample of 35 consisted of 25 controls and 10 RTs. The interest was in determining a significant median difference between these 2 groups in terms of prothrombin time (PT) (Figure 1A). As such, a Mann-Whitney U test ( $\alpha=0.05$ ) was used to compare the medians. The results were significant, with  $Z$ -score=2.4920,  $p=0.0127$ . The conclusion is that the control group scores (median=13.00, SD=1.28) are greater than RT scores (median=12.00, SD=0.62). The median activated partial thromboplastin time (APTT) for the control group and the RTs group was also statistically compared (Figure 1B). The results suggest that the median control group scores (median=32.20, SD=4.59) are significantly greater than the median RT scores (median=28.10, SD=2.66), with  $Z$ -score=2.0315,  $p=0.0422$ . The results also suggest that the median international normalized ratio (INR) is significantly greater for the control group (median=1.11, SD=0.12) than for the RTs (median=1.02, SD=0.04), with  $Z$ -score=2.2635,  $p=0.0236$  as shown in Figure 1C. Moreover, neutrophil and lymphocyte levels exhibited significant variation as shown in Figures 2A & 2B, respectively. Radiologic technologists group exhibited a significant reduction in neutrophil count (median=2.67, SD=0.67) compared to the control group (median=3.75, SD=2.92), with  $Z$ -score=2.6563,  $p=0.0079$ . Conversely, lymphocyte levels in RTs group (median=2.61, SD=0.42) showed a significant elevation compared to the control group (median=2.01, SD=0.97) with  $Z$ -score=2.1165,  $p=0.0343$ . Other hematological parameters including white blood cell count, red blood cell count, hemoglobin, hematocrit, mean cell volume, mean cell hemoglobin, platelet count, red cell distribution width-SD, red cell distribution width-CV, platelet distribution width, mean platelet volume, platelet-large cell ratio, procalcitonin, monocyte, eosinophil, basophil, and immunoglobulins were not statistically different between the control and RT groups (Table 1).

**Discussion.** Chronic radiation exposure in RTs may influence the function and count of blood cells. This concern has led researchers to study the possible direct outcomes of chronic exposure to IR on human body tissues. Health status was shown to be influenced by IR, and the effect varied due to the amount of absorbed dose and the type of cell.<sup>7</sup> Long-term radiation

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**Figure 1** - Effect of radiation exposure on coagulation profiles among radiologic technologists (RTs), including A) prothrombin time (PT), B) activated partial thromboplastin time (APTT), and C) international normalized ratio (INR). The total sample of 35 consisted of 25 controls and 10 RTs. \* $p < 0.05$



**Figure 2** - Effect of radiation exposure on A) neutrophil (NEUT) and B) lymphocyte (LYMPH) levels among radiologic technologists (RTs). The total sample of 35 consisted of 25 controls and 10 RTs. \* $p < 0.05$ , \*\* $p < 0.01$

**Table 1** - Effect of radiation exposure on hematological parameters among radiologic technologists (RTs). The total sample of 35 consisted of 25 controls and 10 RTs.

Hematological parameters	Control group			RTs group			Z-score (P-value)
	1st Quartile	Median	3rd Quartile	1st Quartile	Median	3rd Quartile	
White blood cell count (10 <sup>3</sup> /μL)	4.25	6.81	10.38	4.81	5.88	6.50	1.1060 (0.2687)
Red blood cell count (10 <sup>6</sup> /μL)	4.51	4.68	5.35	4.62	4.85	5.42	0.8569 (0.3915)
Hemoglobin (g/dL)	10.98	11.55	13.00	10.42	11.80	12.75	0.3306 (0.7409)
Hematocrit (%)	32.50	34.80	41.08	34.25	37.17	39.69	0.3924 (0.6947)
Mean cell volume (fL)	69.20	73.20	82.28	68.66	74.45	78.67	0.1921 (0.8476)
Mean cell hemoglobin (pg)	22.80	24.70	26.20	20.95	22.82	25.19	1.5817 (0.1137)
Platelet count (10 <sup>3</sup> /μL)	221.00	282.00	370.50	217.80	308.60	349.30	0.0001 (0.9999)
Red cell distribution width-SD (fL)	36.03	41.10	45.50	34.56	38.23	45.21	0.4846 (0.6279)
Red cell distribution width-CV (%)	13.53	15.35	17.38	12.76	15.97	17.83	0.0076 (0.9939)
Platelet distribution width (fL)	10.20	11.95	13.83	10.44	11.80	14.42	0.1692 (0.8656)
Mean platelet volume (fL)	9.38	10.45	11.25	9.53	10.17	11.67	0.1892 (0.8499)
Platelet-large cell ratio (%)	19.20	28.00	34.95	21.18	26.05	37.94	0.0001 (0.9999)
Procalcitonin (%)	0.24	0.31	0.35	0.29	0.32	0.37	0.6901 (0.4901)
Monocyte (10 <sup>3</sup> /μL)	0.50	0.59	0.96	0.49	0.52	0.62	1.1554 (0.2479)
Eosinophil (10 <sup>3</sup> /μL)	0.03	0.10	0.23	0.15	0.20	0.36	1.6262 (0.1039)
Basophil (10 <sup>3</sup> /μL)	0.02	0.03	0.05	0.02	0.04	0.04	0.8694 (0.3846)
Immunoglobulins (103/μL)	0.01	0.02	0.03	0.01	0.01	0.01	1.4033 (0.1605)

exposure in humans was demonstrated to disrupt the immune system and led to the potential development of hematological disorders.<sup>8</sup> The existing study studied hematological parameter alterations prompted by chronic exposure to radiation of a selected group of RTs in the radiology department.

Screening of coagulation profiles is used to evaluate the ability of platelets and coagulation factors to stop bleeding. Our results showed a reduction in all coagulation profiles including prothrombin time (PT), INR, and APTT in the selected RTs, although platelet count assessment showed no statistical variation between RTs and the control group. Platelets may not be affected, as the interaction between platelets and subendothelium matrix content, including collagen and tissue factors, may not be stimulated by radiation. However, the interaction between the coagulation cascade and coagulation factors in secondary hemostasis might be evoked by chronic exposure to radiation. The amount of radiation absorbed by RTs probably has a direct impact on plasma rather than platelets, as plasma contains coagulation factors. Our findings were consistent with the previous reports that suggested a potential effect of radiation on the coagulation system.<sup>9,10</sup> However, one report showed an increase in clotting time, our results reveal a significant reduction among the RTs group.<sup>9</sup> The discrepancy in this reported data may occur as a consequence of the type of radiation used and the absorbed dose, which may interfere with the coagulation system in diverse ways. Meanwhile, reductions in the PT and APTT consistent with our observations were reported in leukoreduced fresh-frozen plasma following radiation.<sup>10</sup>

In investigating the hematological parameters of RTs, our data revealed dramatic changes including absolute neutrophils and lymphocyte counts. Neutrophils are the body's first line of protection against infection. They act against the dissemination of organisms via phagocytosis, degranulation, and the formation of neutrophil extracellular traps (NETs).<sup>11</sup> The present data showed a significant decrease in the neutrophil absolute counts of RTs compared to the healthy group. Radiation has been shown to induce neutrophil cell killing, leading to the formation of neutrophil NETs, which in turn led to coagulation cascade activation and thrombus growth formation.<sup>12</sup>

Additionally, lymphocytes are another type of immune cells that play a crucial role against infections. It has been reported that experienced medical RTs show significant increases in their lymphocyte counts.<sup>13</sup> In line with that previous study, our data revealed a substantial increase in lymphocyte number in the RTs.<sup>13</sup>

A study carried out on a group of terrestrial radiation-exposed individuals revealed decreases in most hematological parameters, including some red blood indices, hemoglobin, hematocrit, neutrophils, and platelets, while increases were observed in red blood cells and lymphocytes.<sup>14</sup> Our findings for neutrophils, lymphocytes, and mean cell hemoglobin concentration were within the same range as the earlier report,<sup>14</sup> therefore confirming that chronic exposure to any source of radiation even at a low level may lead to significant adverse impacts on human health and the development of diseases. Defective lymphoid organs and ineffective hematopoiesis were shown in the literature to depend on the absorbed doses of radiation by tissues.<sup>15</sup>

**Study limitations.** The primary limitation of this study was its small sample size and the need to recruit more participants fit for the current inclusion criteria, including long work experience at the radiology department. Further studies on a larger participant cohort may improve our knowledge of the association between chronic radiation exposure and health parameters.

In conclusion, this study aimed to examine if radiation may have a negative impact on hematological parameters and coagulation profiles in RTs. Long exposure to different doses of radiation revealed a dramatic variation in the hematological examinations. This variation may lead to development of serious hematological diseases. Despite the limited number of participants in this study, our data may contribute to provide preliminary information to address RTs' concerns and provide biomarkers for the risks associated with prolonged radiation exposure. Further analysis is required to examine the contribution of radiation to coagulopathies by conducting more sophisticated tests.

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