Research Article

Investigating the Effect of Ionizing Radiation on Hematological Parameters of Catheterization Laboratory Technicians: A Multilayer Perceptron Modeling

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Abstract

Background: The present study aims was to investigate the effects of low and continuous radiation on hematological parameters and morphology in human blood tests. Besides, we know that machine learning methods can be utilized to evaluate the effect of dose absorbed by individual's overtime on hematological parameters. In these methods, using available data, a model is designed to predict the desired variable and the accuracy of the model is assessed. Designing a meticulous prediction model signifies the relevance of available data and the desired variable. Therefore, this study explores the identified relationships using multi-layer perceptron modeling. **Methods:** This is a cross-sectional study in which subjects with more than 2-year experience of working in Cath Lab who have been exposed to continuous radiation are included in the study. **Results:** More than 58% of participants were female with a mean age of 39.8 ± 6.6 years and the rest were male with a mean age of 41.41 ± 7.98 years. In the initial studies and also the modeling of regression, no correlation was found between the exposure dose and the MCHC parameter, but neural network modeling indicated a nonlinear relationship. Also, despite initial studies that exhibited a relationship between the RBC parameter and the data analyzed, the regression model was not accurate for this parameter; however, the accuracy of the multi-layered perceptron model was desirable. This indicates a nonlinear relationship between the exposure doses of subjects and the RBC parameter. **Conclusion:** According to the results of the study, hematological parameters are not reliable tests for assessing biological risks in long-term exposure. Therefore, for more accurate results, studies with larger sample size and longer duration are required.

Keywords: Hematological parameters; Absorbed dose; Ionizing radiation

Introduction

The effects of ionizing radiation on humans can appear in low or high doses. The interaction of radiation with cell DNA may lead to the production of free radicals in the water in the cell. [1] The penetration of radiation into cells may transmit radiant energy to biological hazards. Absorbed energy can form reactive oxygen species, chemical bond breaking, ionization of various biologically essential macromolecules such as DNA, lipid concentration and proteins. The DNA damage induced by irradiation involves strand breaking or chromosomal abnormality that can lead to mutation. [2] The dose of radiation to sensitive organs such as ovaries, testicles, and thyroid can lead to genetic effects or cancers. [3] Non-random effects refer to acute exposure and immediate health effects at a specific dose below which no harm is generated. On the other hand, random effects are generated by chronic exposures in which there is no threshold. The probability of these effects is not commensurate with absorption dose. [4] However, the effects of low doses of ionizing radiation are still controversial and challenging. Effect of ionizing radiation on pulmonary function tests, skin lesions, orthopedic strains, cataract, hypertension, hypercholesterolemia, and thyroid function has been described. [5-8] The effects depend on several factors such as age, sex, and duration of exposure. Taqi et al. [9] stated that chronic exposure could significantly change hematological parameters in human blood while Talab [10] suggested that prolonged exposure could not alter the level of blood factors. However, they report that white blood cell counts dropped at old age following persistent work. The life span of red blood cells is 110-120 days. [11] Macrophages collect

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damaged RBCs from the liver, spleen, and bone marrow. [12] The mechanical properties of healthy RBCs depend on several factors such as their shape, spherical surface, membrane flexibility, and cytoplasm viscosity. Any change in these factors can affect the membrane and cytoskeletal structure. [13] Elevated hemoglobin released from RBCs as well as decreased hemoglobin concentration is associated with higher doses. Besides, there is evidence of aggravated cell membrane damage following radiation. With this background, the present study aims to investigate the effects of low and continuous radiation on hematological parameters and morphology in human blood tests. Besides, we know that machine learning methods can be utilized to evaluate the effect of dose absorbed by individual's overtime on hematological parameters. In these methods, using available data, a model is designed to predict the selected variable and the accuracy of the model is assessed. Designing a meticulous prediction model signifies the relevance of available data and the desired variable. Therefore, this study explores the identified relationships using multi-layer perceptron modeling.

Research Methodology

This is a cross-sectional study in which subjects with more than 2-years' experience of working in Cath Lab who have been exposed to continuous radiation are included in the study. The dosimetric values of these subjects were extracted from the results of their film badge for at least two years. Since they are required to perform dosimetry and hematological test every three months in compliance with the Atomic Energy Organization (the authorized official for ionizing radiation surveillance and safety in Iran,) the results of these tests were obtained. Then, the collected data was encoded and their descriptive statistics were evaluated using SPSS software. Further, the correlation of CBC results and urine tests with the obtained dosage were assessed using the regression test. Changes in hematological parameters were also evaluated during this period by the time series test. So, the study consists of data about doses absorbed by subjects over the past two years, which were used to predict hematological parameters. In fact, in this study, each hematological variable was considered as the predicted variable, and a model was constructed for predicting each of these variables, separately. Given the continuous nature of the hematological parameters, numerical prediction methods should be employed. For this reason, regression modeling and multi-layer perceptron model was adopted in this study. This allowed us to address the possible low accuracy of the model to predict parameters of the modeling using the regression test. The multilayer perceptron method is used to investigate nonlinear relationships. [14,15] This method recruits an artificial neural network inspired by the neural network of the human brain. This structure consists of one input layer, one or more hidden layers and one output layer. Each of these layers contains nerve nodes called neurons that forge the link between layers. [14] The structure of a simple three-layer neural network is shown in Figure 1. The input layer of the depicted network consists of four neurons, the hidden layer contains three neurons and the output layer has one neuron.

In this study, to predict any of the hematological parameters, a specific parameter model (with different layers and neurons) was developed. In these models, the absorption values of subjects over the past two years were incorporated in the network as inputs and after carrying out operations in the hidden layers, the parameter values are predicted. The structure of the three-layer neural network is represented by I-H-O, in which I represent the number of input neurons, H indicates the number of hidden layer neurons and O shows the number of neurons in the output. As can be seen, when a hidden layer is added, the letters increase. To evaluate the model, the data is divided into two parts: training and test data. As the name implies, the training data is used to construct and train the model, and the test data are utilized to assess the prediction accuracy of the model. [15] For a more accurate assessment, leave-one-out cross-validation method was employed. In this method, which is repeated in fitting with the number of samples, a sample of data is considered as test data each time and the model is trained using other data. The overall accuracy of the model is the average of accuracies obtained at the end of each stage. In this study, the model evaluation was carried out using the root mean square error (RMSE) criterion.

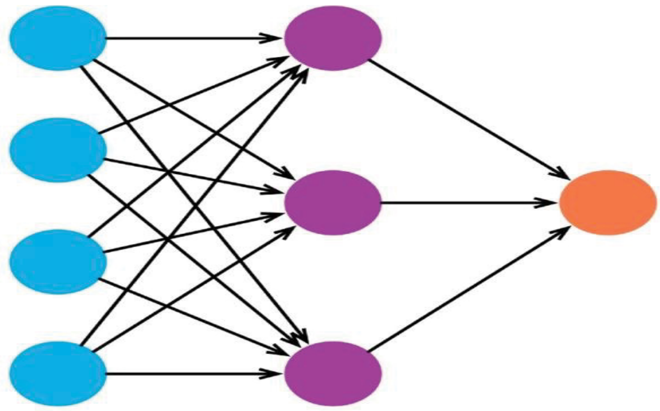

Figure 1: The structure of a simple three-layer neural network.

Results

This study aimed to investigate changes in hematologic factors of the Cath Lab technicians in the Razavi general hospital, who had worked in the Lab for at least two years. 58% of participants were female with a mean age of 39.8 ± 6.6 years and the rest were male with a mean age of 41.41 ± 7.98 years. To evaluate variations in the absorbed dose of technicians over three months, a time series test was recruited. The results did not show a significant difference in three-monthly exposure dose over three years. ($p>0.05$). The time series test for the evaluation of hematological parameters also did not reveal any significant difference between variations of MCV, WBC, HB, MCH as well as platelet, monocyte, eosinophil, and basophil, and TSH. ($p<0.05$) over three years [Table 1].

The results of the regression test in each year did not suggest any significant correlation between effective absorbed dose and hematologic parameters of the subjects ($p> 0.05$). Given that time series test exhibited a significant difference between hematological parameters such as RBC and other cases, and the regression test did not demonstrate its association with absorbed dose, to discover the exact cause of changes, modeling, and structure of neural network model was adopted. Table 2 illustrates the modeling results and the structure of the neural network model for each parameter. The modeling was performed using the R software. There were 12 input neurons in all models (the number of doses absorbed over two years) and 1 output neuron (the predicted value of the desired parameter). It should be noted that different values were assigned to the number of hidden layers and the number of neurons in the study. The results were also evaluated and finally, the best outcomes for the best model were reported, as shown in the following table.

As can be seen, the model constructed using multilayer perceptron method (except for the model related to the RBC and MCHC parameters) is not as accurate as regression modeling, which indicates the absence of an association between data studied and hematological parameters. The point that should be considered here is the accuracy of the model in predicting the RBC and MCHC parameters. In the initial studies and also the modeling of regression, no correlation was found between the absorbed dose and the MCHC parameter, but neural network modeling indicated a nonlinear relationship. Also, despite initial studies that exhibited a relationship between the RBC parameter and the data analyzed, the regression model was not accurate for this parameter; however, the accuracy of the multi-layered perceptron model was desirable. This indicates a nonlinear relationship between the absorbed doses of subjects and the RBC parameter.

Table 1: The results of the time series test for hematological factors over three years.

Variables	p-value
TSH	0.188
Neutrophils	0.03
Basophils	0.222
Eosinophil	0.159
Monocytes	0.066
Lymphocytes	0.045
Platelets	0.106
MCHC	0.02
MCH	0.117
MVC	0.096
HTC	0.05
HB	0.07
RBC	0.04
WBC	0.07

Table 2: The results of modeling of the neural network model for each parameter.

Hematological parameters	Model structure		Evaluation criterion (RMSE)
	Number of layers	Number of neurons	
WBC	1	12-8-1	1.489042
RBC	1	12-10-1	0.9278558
Hb	2	12-10-8-1	1.707962
HTC	2	12-8-4-1	3.560246
MVC	1	12-10-1	3.97951
MCH	2	12-10-8-1	1.699247
MCHC	2	12-10-8-1	0.7486565
Platelets	1	12-8-1	52.65453
Neutrophils	2	12-8-4-1	8.47004
Lymphocytes	2	12-10-8-1	6.585334
Monocytes	2	12-10-8-1	2.61869
Eosinophil	1	12-4-1	1.526469
Basophils	1	12-4-1	1.996618
TSH	1	12-4-1	3.362384
WBC Urin	1	12-4-1	3.65513
RBC Urin	1	12-4-1	3.65513

Discussion

Long-term exposure to the low dose of ionizing radiation affects the hematological system. The effect of irradiation on the immune and hematologic system in the long-term has been shown to disrupt human immunity by suppressing or stimulating the immune system, which may give rise to various hematological disorders. [16] There is an abundance of studies about ionizing radiation exposure and hematologic consequences. *In vitro* studies such as Taqi et al. reported morphologic changes in RBCs exposed to high dose X-ray exposure. [12] Effects of X ray exposure on human hematopoietic system have been studied in multiple studies. [17-25] In some of them occupational exposure to X ray was attributed to change in hematologic consequences. [8,17-20,22-25] In some others objectively measured X-ray absorption was studied and related to hematologic changes was described. [7,21,22] Different studies have shown the diversity of hematologic changes. RBC count was not different in X-ray exposed personal and controls. [21,24,25] WBC count was lower in some studies. [17,18] and had no changes in some others. [19,21,24,25] Platelet count was lower. [17,18,22,25] and was not different in other studies. [21,24] Platelet distribution width (PDW) is reported to be higher in X-ray exposure. [17,23] Mean corpuscular hemoglobin (MCH) and hematocrit and red cell distribution width (RDW) values are reported to be lower [17,22] or higher [19,21] in X-ray exposure. Lymphocyte and granulocyte count tends to be lower in X-ray workers [17,19,22] while the granulocyte count was higher in another study. [19,22] In one study sex difference in hematologic consequences, change was reported in X-ray workers. [20] The radiobiological effects of the hematopoietic system are related to total absorbed dose and the dose or frequency of repeated exposure. [26-28] The data regarding the effects of variables on dosage and the accumulated dosage is sparse. In general, a significant reduction has been reported in red blood cell counts after dose-dependent ionizing radiation. [29] Some studies have indicated that red blood cells tend to recover several days or weeks after radiation, and signs of improved hematopoietic repair after chronic radiation have been registered. [27] They assert that when exposed to radiation, the blood cell count begins to drop and then rebound. The animal studies do not demonstrate a significant difference in variations of WBC, platelet, and RBC in low doses. The present study showed that variations in hematological parameters were all in the normal range and there was no significant difference over time. According to Table 1, no association was found between hematologic changes and absorbed dose and there was only a link between the absorbed dose and RBC and MCHC. The nearest work for our study is the Shafiee et al. article. In line with our study, Shafiee also showed that most of the hematological parameters were within the normal range, recording changes in HTC and MCHC and MCH.[26] Using the neuron model is unique to the present study. Since, in our CBCs, values of MPV, PDW, RDW, PLCR was not included so they did not enter the analysis. The participant X-ray absorbed doses in this study were in the normal range. So there is a possibility that hematologic indices are a more sensitive marker of X-ray exposure in overdosed workers than those in the normal range. However, given the results of this study and contradictory results reported in various studies, it is recommended to undertake studies with larger sample size and longer duration.

Conclusion

According to the results of the study, hematological parameters are not reliable tests for assessing biological risks in long-term exposure. Therefore, for more accurate results, studies with larger sample size and longer duration are required.

Competing Interest

The authors declare that they have no competing interests.

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