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The Effect of X-Ray on Plasma and Erythrocyte Concentration of Zn and Cu in Radiology Staff of Tehran Oil Hospital

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Abstract**—**Introduction: Some parameters should be considered to investigate the chronic effects of radiation absorption in radiation workers. Trace elements are parameters which small changes in them can cause significant effects on live systems. The role of trace element concentration in human health is significant. These elements play an important role in the developing and functioning of the immune system, cellular respiration, and oxidation processes. Considering the importance and necessity of this issue and few studies, measurements of concentration changes of these elements due to the absorbed dose are important. Purpose: This study aimed to determine the biological effects of occupational dose absorption on plasma and erythrocyte concentration of Zn and Cu in the radiology staff of Tehran Oil Hospital. Material and methods: In this analytical-comparative study, 72 people have entered. 36 people (18 males and 18 females) were selected as radiology staff in the diagnostic and therapeutic departments of Tehran Oil Hospital. And 36 people (18 males and 18 females) were selected as general section staff in the same hospital as a control group. Radiology and control groups' age and sex were matched. 10 ml of venous blood was taken from all people. An atomic absorption spectrometer was used to obtain zinc and copper plasma concentrations. Levine test was used to compare these results validity. Results: The mean concentrations of copper and zinc were measured as 0.951 and 0.754 mg/L in the plasma phase and 3.2 and 0.401 mg/L in the RBC phase for the radiology group. Copper and zinc average concentrations, respectively 0.976 and 0.813 mg/L in the plasma phase and 2.906 and 0.476 mg/L in the RBC phase, were measured for the control group. These elements Concentrations in the plasma phase were significantly different from that of the control group, but the concentrations in the red blood cell phase did not show a significant difference compared to the control group. In comparison, a separate comparison between men and women in the experimental and control groups showed a significant difference in the values of the elements mentioned. With a significant increase in samples, a better justification than the available statistical results can be extracted. Conclusions: Within this study results, chronic occupational probabilistic absorption destructive effects (even within the permitted range) on blood trace element concentration have been confirmed.

Keywords**—**Chronic absorption, atomic absorption spectrometry, radiology staff, trace element concentration.

I. Introduction

OVER the past few decades, several reports on ionizing radiation biological effects and high dose radiation absorption effects are known. But there are less information and more unknown factors on the effects of low absorption doses. Achieving comprehensive information in this area requires extensive research. The extensive and comprehensive application of X-ray to imaging has exposed the general public, and especially radiation workers, to potential radiation effects. Based on personal dosimetry results, the hospital staff radiation exposure was much lower than permissible limits set by the International Commission on Radiological Protection. But additional chronic or accidental exposure can cause destructive effects.

Recent studies on people occupational radiation absorption, such as nuclear power plant staff, radiologists, and radiology technologists, highlight various aspects of the effects of radiation, such as immunological parameters, cancer incidence, mortality rates. And changes in very small arteries have been studied [14], [15]. Many studies have been conducted on habitual or adaptive body responses, as well as hormones, which will bring new perspectives [16]. Low-dose chronic X-ray absorption has different destructive effects on trace elements concentration variation [17], [18]. These elements' concentration change (by chronic low dose x-rays) can cause significant impacts on the human body [19], [20]. Some reports have been presented on the effect of low X-ray absorbance rates on the amount of blood-borne metals and changes in the structure of hair and nails in radiology staff. Trace elements, including zinc and copper, play a vital role in many vital processes [21], [22]. Some of the important functions of these two trace elements are defense against free radicals, preservation of the integrity, and health of the cell membrane. On the other hand, their acceptable range to maintain the physiological function of the body is very limited; changes in the concentration of these ions are important and reflect the important changes in the physiology of these elements [23].

The purpose of this study was a comparison between Zn and Cu concentration levels in radiology and control groups for finding chronic low dose absorption effects.

II. Literature Review

Occupational radiation absorption includes two groups. The first group includes people who absorbed radiation through their works (radiographers). And the second group includes people who work in other sections and are not directly under radiation absorption (control group).

Cells sensitivity against radiation is different. Studies have

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shown that immune cells, including lymphocytes, are the most susceptible cells in the body. Studies also show that the average number of white blood cells and monocytes, and plasma lymphocytes of immunoglobulins, is lower in the blood of exposed staff than in the control group [1]. The atomic absorption method was introduced in the mid-1950s by Alan Walsh, although the basic principles of atomic absorption spectra were established in the years prior to 1860 [2]. The amount of absorbed radiation by radiology workers in the workplace is usually less than the criteria determined by the International Commission on Radiation Protection (ICRP) as an acceptable level of absorbed dose [3]. By believing that the effects are non-threshold, the ICRP does not recognize any radiation from the beam without danger. In contrast, many researchers believe that low and chronic radiation absorption produces adrenal responses called Hormesis. Therefore, there is little information about the biological effects of low absorption of ionization radiation. This subject requires extensive research. With regard to this issue, parameters which small changes in them can make important changes to the living systems must be studied [4]. One of these variables is the trace elements of the body that play a vital role for all critical processes and, with the advancement of measurement methods, their significance becomes clearer day by day [5]. Studies have shown that low doses (less than 1 cGy) and chronic X-rays can significantly alter the number of trace elements of rat tissues [6]. Studies, done on radiologists mainly performed using hair samples, have shown significant changes in the number of low levels of this tissue [7]. These two elements play a significant role in the immune system, counteracting free radicals, oxidation, and inflammatory reactions, and their metabolism in the body is controlled by homeostasis system and in maintaining the structural and functional tissues act in a very narrow range [8]. Dede et al. studied the effects of antioxidant and mineral supplements on zinc and copper concentrations in rabbit's red blood cells after X-rays absorption [9]. Zargan et al. compared blood parameters in the blood of 30 radiologists and 30 non-radiologists, which were matched for interventional variables. The mean of blood test indexes including red blood cells, platelets, white blood cells, subpopulations, and hematocrits did not show any significant difference in the case group compared to the control group. Also, the results of this study have shown that blood indices in ionizing radiation absorption of radiologists may not predict the amount of radiation received or reflect its effects [10]. Minerals are essential for normal growth, and acute infections change metabolism and increase the risk of infectious diseases in premature infants. Vissonskaya et al., in a study of blood serum test, used a total-fluorescence method to measure low levels of zinc and copper. The ratio of copper to zinc is dependent on pregnancy age. Based on the results obtained in CP patients, serum zinc levels are reduced and these changes can be used as biomarkers for early infection detection [11]. Niha et al. studied the changes in trace elements in radiology staff. Measuring blood serum level by atomic absorption spectrophotometer has shown that zinc was high in the control group compared to the radiation group. Increasing exposure time can reduce the amount of blood zinc concentration. Although there is no significant difference in copper concentration levels, chronic X-Ray absorption can also affect the level of copper concentration in the blood. Also, there was no difference in the mean serum levels of manganese and selenium concentrations between the two groups based on exposure time. Changes in serum zinc and copper concentrations levels may be due to the formation of forms of oxidative effects and losses caused by gamma rays [12]. Also, the general reflection of X-ray fluorescence radiation is a new and comparable method for measuring small quantities of minerals in biological samples. Jeffrey et al. showed a new method of total reflection X-ray fluorescence compared to atomic absorption in measuring low levels of zinc, copper, and selenium in full blood, which may be better responsive to patients [13].

III. Material and Methods

In this analytical-comparative study, after register, initial information about volunteers, including 36 imaging, CT scan, CT angiography and angiography workers who were only involved in X-ray activity sampling were done.

The volunteers included 18 men and 18 women aged 30 to 45 years with a history of continuous exposure of 5 to 20 years old and working in the Tehran Central Oil Hospital located in Tehran Centrale. The monthly working hours of these people ranged from 132 to 162 hours in one to three turns with devices ranging from 40 to 120 kvp and 20 to 3,000 mA. This group radiation absorption is controlled by the Iranian Atomic Energy Organization by the Baj film. According to reports [24], [25] from the Iranian Atomic Energy Organization, the absorbed dose for each person was less than or equal to 0.05 milliseconds every two months. Also, 36 other experts from the same hospital (Tehran Central Oil Hospital) without any occupational exposure included 18 males and 18 females. Samples' age was similar to radiology group sample in the range of 30 to 45 years old. Control group economic and social classification as the same radiology group was selected. Each of the groups did not have a special diet, like vegetarianism, and used common and almost identical foods and they ate at least one meal of food at the hospital. These samples have not been exposed to imaging tests in the past few months and lack any acute or chronic illness. None of the women were pregnant.

Blood sampling was performed at the emergency department of the Tehran Oil Hospital. After the blood sampling, all volunteers were given a simple and nourishing snack. Blood sampling was done using disposable syringes, connected plastic vacuum tubes, and CBC kit. Sampling was done by an experienced nurse to avoid problems with blood sampling. After blood sampling, the samples were shaken in the sterile plastic tubes several times and placed in the base of the tube retainer. Samples were stored in the refrigerator and then prepared by centrifugation of plasma and RBC separation.

A. Plasma and Red Blood Cell Separation Method

The stages of plasma and red blood cell separation are as follows:

1. Blood samples were centrifuged for 5 minutes at 4000 rpm.
2. The upper layer plasma, using the Sampler, is removed as far as possible.
3. The remaining content, which contains blood cells, was washed at 0.9% salt serum for 3 steps at 1000 rpm for 10 minutes.
4. After washing, the upper layer of the solution was discarded and again, using the salt serum for 2 other times, this procedure was repeated, and each sample was washed for half an hour in three 10-minute steps.
5. The remaining product, which only contains blood cells without plasma, is transmitted to new tubes using Sampler.
6. 300 µl of the blood cells obtained in the previous step were removed by Sampler and were dispensed in a 10cc Marcano solution. By Sampler, the invert movements (shaking) of the test tube were mixed with one hand. Error to results ratio is calculated about 30:1.
7. After the blood cells were poured into the Marcano solution, the red blood cell wall was lysed, and its contents contain all the elements, including copper and zinc. Due to the release of iron from the blood cells, the color of the solution turns reddish-purple. At this stage, Neobar lam microscope is filled by one or two drops of solution. If all the red blood cells were lysed, there was no lesion in the lamb, and in reverse, all white blood cells, including neutrophils, are healthy and visible.
8. After ensuring that no red blood cells were present, the resulting solution was centrifuged for 5 minutes, to allow all white blood cells and other healthy cells to precipitate.
9. The upper layer solution was removed using Sampler and stored as a final product in 15cc flasks or test tubes at -4 °C and stored up to an atomic absorption spectrometer. In all the above steps, the marking and encoding of the samples were performed to prevent manual error on pipes and falcons.

IV. Results

The results were analyzed in general form. Data were collected from both radiology and control groups. Then, using tables and graphs, a descriptive description of the index status and the research hypotheses were presented. Then, to reject or confirm the hypotheses, the research hypotheses were tested based on the results of the examination of the questions using inferential statistics.

The obtained results are descriptive statistics of the research variables. Zinc and copper concentrations, in sample persons red blood cells and plasma of radiology and control group, have been tested.

One of the strongest and most appropriate methods of analysis in research is the analysis of variables. In order to examine the difference between the mean of the research samples in the two groups, the mean comparison test of the two independent groups was used. To test the equation between the mean of two independent sample groups, it is necessary to first check whether the variance of the two groups was equal. In other words, the equality of variances was tested before the mean equation test. Considering that the equality of variances was preceded by the averaging test, the Levine test results were used to test the equality of variances in the two sample groups. The assumption of variances equality was confirmed. Therefore, concerning the equality of variances, the numbers of the first row of the table should be used to compare the mean between zinc element and the red blood cell copper element of the radiograph and control group. According to Table I, it can be concluded that the mean difference between the zinc element and the copper element of the red blood cell, radiology group, and control group was significant.

In Table I, the mean concentrations of Zn and Cu in red blood cells and plasma in women and men in mg/L unit were summarized.

TABLE I
AVERAGE CONCENTRATION OF ZINC AND COPPER IN THE RED BLOOD CELL AND PLASMA OF RADIOGRAPHERS AND CONTROL GROUP (MG / L)

Red blood	Men	Zinc	Control group	0.5825
			Radiographer group	0.4189
		Copper	Control group	3.2556
			Radiographer group	2.9389
	Women	Zinc	Control group	0.3689
			Radiographer group	0.3817
		Copper	Control group	2.5565
			Radiographer group	3.4611
plasma	Men	Zinc	Control group	0.8258
			Radiographer group	0.7376
		Copper	Control group	1.1131
			Radiographer group	0.9927
	Women	Zinc	Control group	0.7992
			Radiographer group	0.7701
		Copper	Control group	0.8375
			Radiographer group	0.9081

As it mentioned in Table I, In “Red Blood Cell” the concentration of Zinc and Cooper, in “men” samples, in “Radiographer group” in comparison with “Control group” has reduced more than 28% and 9% respectively. In “Red Blood Cell” the concentration of Zinc and Cooper, in “women” samples, in “Radiographer group” in comparison with “Control group” has increased more than 3% and 35% respectively. In “Plasma” the concentration of Zinc and Cooper, in “men” samples, in “Radiographer group” in comparison with “Control group” has reduced more than 10% and 10% respectively. In “Plasma” the concentration of Zinc and Cooper, in “women” samples, in “Radiographer group” in comparison with “Control group” has reduced more than 3% and increased more than 8% respectively.

According to Table I, for men, trace elements’ concentration reductions caused by chronic exposure can cause immune system defection. According to Table I, for women, trace elements’ concentration unspecified meaningful changes can be caused by lack of sample numbers or intrinsic variation. Despite this issue, changes happen, so reduction and increase in concentration trends can cause immunity defection and poisoning effects, respectively.

V. Validation

For validation purpose, the comparison between the results of Nia et al. [2] and the results obtained in this study have been studied. This research was conducted on the concentration of trace elements, zinc, and copper in the blood plasma, women and men radiology and control, which are two different groups of samples.

TABLE II
COMPARISON BETWEEN ZINC AND COPPER CONCENTRATION REPORTED IN [2] AND THIS STUDY

Elements	Mean concentrations (mg/l) (in [2])				Mean concentrations (mg/l) (in this research)			
	Control group		Radiographer group		Control group		Radiographer group	
	men	women	Men	Women	Men	Women	Men	women
Zinc	0.905	0.840	0.826	0.710	0.799	0.826	0.77	0.738
Copper	0.847	0.959	1.060	1.104	0.838	1.113	0.908	0.993

As mentioned in Table II, the maximum difference between [2] and this research is 6%. This amount of error is tolerable. This difference can be solved by increasing the sample number.

VI. Conclusion

An atomic absorption spectroscopy method is a simple and high-precision method for measuring the concentration of metal elements based on the absorption of the sample passing through the sample when the desired element is atomic. Because of the high precision of this method, it can be used to measure toxic elements in drinking water, and to determine the therapeutic levels of drugs such as lithium in the blood, and also to determine the iron density in the workplace environment. In this analytical-comparative study, after the initial information of the volunteers, the imaging area radiographers including radiology, CT scan, CT angiography and angiography who participated only in X-ray imaging activities were selected and sampling was done. The volunteers consisted of a number of men and women with a history of continuous exposure in the Tehran Central Oil Hospital radiography section located in Tehran Centrale. Their monthly work hours were one to three shifts. Their occupational absorbed dose was controlled by the Atomic Energy Agency of Iran, with a film badge that reportedly received an absorbed dose of less than 0.05 millisieverts every two months. Hospital staff is divided in same numbers of males and females. They are divided in two groups with no occupational radiation absorption, and with occupational radiation absorption. Samples in both groups were not under special diets and they used common and almost identical foods. These subjects have not been exposed to imaging tests in the past few months and lack any acute or chronic illness. The ladies were not pregnant.

Blood sampling has been done using disposable syringes and vacuum tubes.

Results have shown incredible destructive effects of chronic absorption on radiology staff. As it is mentioned in Table I, these effects on men staff were significantly great than women staff.

As it is mentioned in Table I, sensible trace element concentration reduction caused by chronic exposure happened in men sample. And in women sample, changes happened but have not any meaningful trend.

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