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Occupational Exposure of Diagnostic Technicians to X-Ray May Change Some Liver Functions and Proteins

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ABSTRACT

Introduction: The most common impact of X-ray is the induction of cancer after chronic exposure. The current study was conducted to investigate the effects of low X-ray doses on some liver functions and proteins among diagnostic technicians working at Kirkuk hospitals, Kirkuk, Iraq. To this purpose, the parameters, such aspartate aminotransferase (AST), alanine aminotransferase (ALT), total protein, albumin, globulin, serum ferritin (s.ferritin), malondialdehyde (MDA), and glutathione (GSH) were measured in this study.

Material and Methods: In total, 20 male diagnostic technicians with a mean age of 39.55±10.02 years participated in this study. On the other hand, 20 male healthy controls with a mean age of 39.9±10.29 years were selected from outside of the hospitals. Five ml of blood was taken from each individual (technicians and controls). All parameters were measured with their own techniques.

Results: According to the results, significant increase ($p<0.001$) was observed in the levels AST, ALT, and s.ferritin; however, there were remarkable decreases in the values of MDA, total protein, albumin, globulin, and GSH ($p<0.001$) among diagnostic technicians, compared to the control group.

Conclusion: Based on the results, it was revealed that chronic exposure to low X-rays doses from conventional X-ray machine may change significantly the values of ALT, AST, s. ferritin, MDA, total protein, albumin, globulin, and GSH in diagnostic technicians who are exposed to an overdose at their workplace. It is importance to utilize radiation protection tools, hold training courses, and follow up the technicians to reduce the effect of radiation on these individuals.

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Introduction

People are exposed to physical, chemical, and biological agents. Through the physical agents, ionizing radiations can produce damage to molecular systems [1]. Moreover, early and late effects on normal tissues and organs are induced by ionizing radiation [2, 3], which is commonly used in therapy against diseases and in diagnosis for detecting abnormality in human body. Ionizing radiations has an important role in modern medicine [4].

The X-ray has been widely used in medicine to create images using different techniques such as computed tomography scan, fluoroscopy and radiography. The most common impact of X-ray is the induction of cancer after chronic exposure [5-7]. Georgieva S. et al.(2013) showed that ionizing radiations could form reactive oxygen species (ROS) and damage cellular components including proteins, lipids and DNA by direct or indirect mechanisms[8,9]. The X-ray interacts indirectly through water radiolysis mechanisms producing free radicals which cause oxidative stress [10]. The ionizing radiation gives rise to produce large amounts of ROS in the body and the imbalance between the production of ROS and antioxidant defense can result in oxidative stress [11].

Diagnostic technicians may be exposed to soft X-ray during their daily life especially those who do not apply radiation protection rules as it is observed during this study. It has been proved that there is an association between ionizing radiation and malignant diseases [12, 13], including various hepatic diseases presenting with tender hepatomegaly, hyperbilirubinemia and ascites [14, 15]. It has also been proved that ionizing radiation can induce hepatic dysfunction or liver cancer in patients without hepatic diseases who undergo radiotherapy [16-19]. The high doses of ionizing radiation can induce liver damage; however, the effects of chronic exposure to low doses of radiation on liver damage are not clear [20]. Bakshi, M.V. et al. (2015) showed that liver inflammation in male mice increased after being exposed to a single dose ranging from 0.02 to 1.0 Gy[21]. Although the liver was once believed to be relatively radio-resistant, hepatic morphologic and functional alterations have been observed after radiation therapy [22, 23]. Furthermore, the studies revealed that soluble enzymes of rat liver were affected by X and gamma (Co-60) radiations [24]. A number of investigators reported alterations in the serum

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proteins of animals exposed to whole-body irradiation [25, 26]. Serum ferritin (s.ferritin) is one of the measured parameters in this study which is an iron (**Fe**) molecules stored as a porous protein capsule and plays a major role in iron storage in the liver, spleen and bone marrow.[27]. The accumulation or diminution of iron is associated the incidence of several diseases [28].

The other two measured parameters in the present study include malondialdehyde (MDA) and intracellular glutathione (GSH). The MDA is the last product of peroxidation and a major aldehyde product that is mutagenic in cells and could be used to assess cell damages [29, 30]. Moreover, GSH is a common antioxidant in the human body participating in the human defense system against oxidative damage. It has been reported that GSH level can be reduced by oxidative stress [31].

There are still controversies regarding the effects of low doses of ionizing radiation; as a result, the majority of our studies are focused on this field. In our previous studies it was found that ionizing radiations led to DNA damage and apoptosis. Furthermore, in our recently published, it was revealed that some hematological parameters in diagnostic technicians altered significantly after being exposed to low doses of X-ray [32, 33]. Accordingly, this study focuses on other molecules such as proteins, enzymes and antioxidants. With this background in mind, the current study aimed to investigate the effects of occupational exposure to X –ray on liver functions and proteins among diagnostic technicians who work at the department of radiology in Kirkuk hospitals, Kirkuk, Iraq through measuring alanine aminotransferase (ALT), aspartate aminotransferase (AST), total proteins, albumin, globulin, s.ferritin, MDA, and GSH.

Materials and Methods

This study was conducted from August to September 2018. In total, 20 male diagnostic technicians with the mean age of 39.55±10.02 years participated in this study. On the other hand, 20 male healthy individuals with a mean age of 39.9±10.29 years were selected from outside of the hospitals and considered as the control group. Initially, the research objectives were explained to all participants, and they were informed of the voluntary participation in the study. Subsequently, 5 ml of blood was taken from each subject in two groups. The participates were non-smokers, had no disease, and consumed no medications before and during the study. Table 1 tabulated some characteristics of the technicians. All technicians had experiences of working with conventional X-ray machines which used a low X-ray dose for imaging.

The AST, ALT, total protein, and albumin were measured by a technique according to the instructions of manufacturer company kit Randox (Biolabo kits, France), whereas s.ferritin was measured using an enzyme-linked immunosorbent assay technique. Moreover, globulin was determined using the following equation:

Globulin= total proteins - albumin

The MDA was measured based on the colorimetric reaction with thiobarbituric acid using spectrophotometer (Unico company, USA) [34].

Table1. Technician Characteristics

ID	Age	Working hours/day	No. of servicing years	No. of patients diagnosed / day	Smoking	Presences of other diseases
1	30	8	5	10	no	-
2	45	8	22	13	no	-
3	24	8	3	5	yes	-
4	50	8	8	20	no	-
5	25	6	3	10	no	-
6	31	6	6	7	no	Hyper tension
7	40	6	12	10	no	-
8	46	3	17	10	no	-
9	37	6	10	10	no	-
10	28	4	6	8	no	-
11	51	3	21	7	no	Hyper tension
12	38	6	14	10	no	-
13	31	6	8	15	yes	-
14	53	4	23	5	no	-
15	46	4	17	10	no	-
16	37	6	12	10	no	-
17	29	6	9	13	yes	-
18	55	4	25	15	no	-
19	42	6	14	15	no	-
20	53	3	19	8	no	-

Furthermore, the GSH level was estimated by mixing a 2.3 ml buffer (phosphate buffer, H_2O_2 buffer) with 0.2ml of the sample. Subsequently, 0.5 ml of 5, 5-dithio-bis-(2-nitrobenzoic acid) was added and the mixture was analyzed using spectrophotometer [35].

The data were analyzed using a statistical Minitab program (Minitab 17, Minitab Company, and USA). One way analysis of variance was used to evaluate the statistical difference among the means values of the two groups. A P values less than 0.05 was considered statistically significant.

Results

Effects of occupational exposure to X-ray on Alanine aminotransferase, Aspartate aminotransferase, and s.ferritin

The results obtained from the evaluation of AST, ALT and s.ferritin in two groups (i.e, diagnostic technicians and control) are shown in Table 2 and Figure1. According to the results, there is an increase in the values of the three parameters under study ($p<0.001$). Moreover, the mean values of AST, ALT and s.ferritin were 56.2±16.73U/L, 64.27±15.27U/L, and 62.46 ± 9.01ng/L in the diagnostic technician group, whereas the corresponding values were obtained at 15.75±3.13 U/L, 15.5±2.81U/L, and 44.07±3.01 ng/L in the control group respectively.

Table 2. Measured values of Aspartate aminotransferase, Alanine aminotransferase, and S.ferritin in two groups

Groups / Parameters	Control Mean ± SD	Diagnostic technicians Mean ± SD	P-Value
Aspartate aminotransferase (U/L)	15.75±3.13	56.2±16.73*	<0.001
Alanine aminotransferase (U/L)	15.5±2.81	64.27±15.27*	<0.001
S.ferritin (ng/L)	44.07±3.01	62.46 ± 9.01*	<0.001

* Significant difference p<0.001

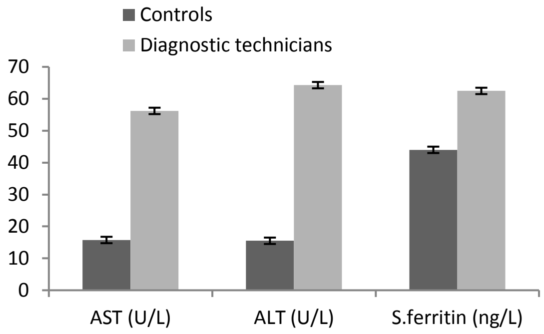

Figure1. Aspartate aminotransferase, Alanine aminotransferase, and S.ferritin values in two groups

Effects of occupational exposure to X-ray on total proteins, albumin, and globulin

As can be seen in Table 3, there is a significant decrease ($p<0.001$) in the amounts of proteins, albumin and globulin a. The mean values of total protein, albumin and globulin were 5.93±0.53, 2.71±0.32, and 3.19 ± 0.25 mg/dl for the technicians group, respectively. Moreover, the corresponding values in the control group were estimated at and the values for the control were 7.33±0.27, 3.53±0.16, and 3.78±0.13mg/dl Figure2.

Table 3. Total protein, Albumin, and Globulin values in two groups

Groups / Parameters	Control Mean ± SD	Diagnostic technicians Mean ± SD	P-Value
Total protein (mg/dl)	7.33±0.27	5.93±0.53*	<0.001
Albumin (mg/dl)	3.53±0.16	2.71±0.32*	<0.001
Globulin (mg/dl)	3.78±0.13	3.19 ± 0.25*	<0.001

* Significant difference P<0.001

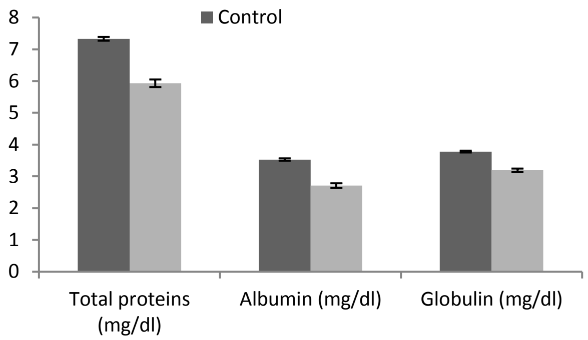

Figure 2. Total protein, albumin, and globulin values in two groups

Effects of occupational exposure to X-ray on the values of Malondialdehyde and Glutathione

Table 4 summarizes the values of MDA and GSH in the two groups. The MDA levels increased significantly ($p<0.001$) followed by a remarkable reduction in the GSH values ($p<0.001$). The mean values of MDA and GSH were estimated at 1.77±0.27 and 1.24±0.071 mol/l as well as 0.386±0.028 and 0.442±0.055 mol/l in the technicians and control groups, respectively. Figure3 represents the values of MDA and GSH in two groups.

Table 4. Malondialdehyde and Glutathione values in two groups

Groups / Parameters	Control Mean ±SD	Diagnostic Technicians Mean ±SD	P-Value
Malondialdehyde (mol/l)	1.24±0.071	1.77±0.271*	<0.001
Glutathione (mol/l)	0.442±0.055	0.386±0.028*	<0.001

* Significant difference P<0.001

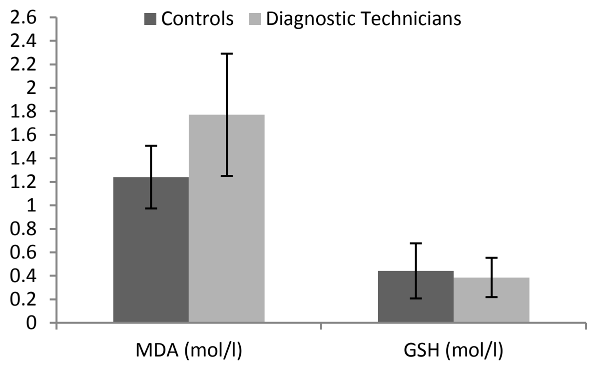

Figure 3. Malondialdehyde and Glutathione values in two groups

Discussion

The X-ray is vastly used for therapy and diagnostic purposes in medicine. Diagnostic technicians may be excessively exposed to low doses of X-ray during their professional life more than other people especially those who do not apply radiation protection rules as it was observed during this study. Since there is a dearth of research on the effects of low doses of ionizing radiation on liver functions, the present study aimed to investigate the risk of long term of X-ray on liver functions using ALT and AST measurements. According to the results both ALT and AST levels elevated significantly in the diagnostic technician group, compared with the control group. It was also showed that chronic exposure to radiation was a risk factor for liver injury; however, there was no association between accumulative radiation dose and hepatic injury [36]. CR Nwokocha et al. (2012) showed that the values of ALT and AST elevated significantly with increasing radiations after total body irradiations of rats to 1.27 Gy/minute as cumulative doses [37]. Furthermore Wei Cheng et al. (2015) observed that the levels of AST and ALT were elevated after irradiation of rats for 2 weeks [38].

The third measured parameter in the present study was s. ferritin. It has been shown that many diseases are correlated with iron overload or iron deficiency. S. ferritin has been described as a risk factor for veno-occlusive disease [39]. Similarly Zhe Feng et al. (2015) revealed a significant association between s. ferritin and colorectal cancer [40]. The determination of ferritin has been considered a suitable method for ascertaining the iron metabolism situation which provides a representative measure of body's iron reserves [28]. The diagnostic technicians obtained a significant increase in s.ferritin compared with the control group in this study. This increase may be due to oxidative stress and enzyme activity affected by the radiation. It has been reported that an increase in hepatitis and the direct effect of different inflammatory mediators such as acute-phase cytokines led to the changes in ferritin subunits [41-44].

Diagnostically, total serum protein measurement is remarkably important in assessing of state of an organism, and an increase in this parameter led to inflammatory processes and tissue dysfunction [37]. A significant decrease in total protein, albumin and globulin was observed in the present study. In a study conducted by Jorn Ditzel (1962), after 1500 rad and 1000 rad of total-body X-irradiation of golden hamster the albumin fraction decreased; however, αl-, α2-, and β-globulin fractions increased [45]. In the same line E. S. Goranson et al. (1960) observed that animal exposure to supra-lethal total-body irradiation produced changes in a number of the serum components. The most striking change was the increase in the a-globulin component (Fα2) [46]. The results of the current study were inconsistent with the findings of the two previous studies, which may be due to the differences in the amount of the absorbed dose. CR Nwokocha et al. (2012) also showed that serum proteins increased significantly with increasing radiation; moreover, serum levels of albumins increased significantly ($p < 0.05$) with the first to third radiation exposures followed by a reduction at the fourth cumulative dose exposure [37] which was in line with the results of the present study.

Oxidative stress induced by radiation may increase MDA, which is interesting for researchers, and the intracellular concentration of GSH can be used as an indicator of oxidative stress [47]. The results of this study showed alteration in both MDA and GSH. The value of MDA increased significantly, whereas there was a remarkable decrease in GSH level in the diagnostic technician group, compared to the control group. Decreased levels of GSH can be attributed to low dose of radiation which can induce oxidative stress. According to a study carried out by Meydan D.B. et al. (2011), ROS led to negative effects on the antioxidant defense by depleting the intracellular concentration of GSH [48]. In a similar vein Deger Y. et al. 2003 showed increased and decreased levels of MDA and GSH, respectively, after the irradiation of mice to 550 rad X-ray [49]. Based on the results of a study performed by Haitian Zhao et al. (2012), the levels of MDA increased followed by a reduction in the values of GSH in liver tissues of mice after irradiation to 5Gy of Co-60 [50]. The results of these two studies were in line with the finding of the present study. Oxidant damage to the mitochondria and myocyte membranes that could promote cell death due to membrane damage, which is termed ″radiation induced apoptosis″, may be due to a high level of MDA [51]. Liren et al 2010 showed an increase in the levels of MDA in the cardiac tissue of mice irradiated by gamma rays [52].

Conclusion

This study revealed that chronic exposure to low X-ray doses in diagnostic technicians who are exposed to radiation at their workplace may change significantly the values of ALT, AST, s. ferritin, MDA, total protein, albumin, globulin and GSH. The results also revealed significant associations between the aforementioned parameters and hepatic diseases. Since there is little evidence on the effects of low doses of ionizing radiation on these parameters, more studies are required to confirm the results. Moreover, it is recommended to utilize radiation protection tools, hold training courses and follow up the technicians to reduce the effect of radiation on these individuals.

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References

1. Prise K. M. New advances in radiation biology, Occupational Medicine 2006; 56:156-161.
2. Cullings, H.M. Impact on the Japanese Atomic Bomb Survivors of Radiation Received From the Bombs. Health Phys. 2014; 106: 281‑293.
3. Dorr W. Radiobiology of tissue reactions. Ann. ICRP. 2015;44: 58‑68.
4. Srinivasan M, Devipriya N, Kalpana KB, Menon VP. Lycopene: an antioxidant and radioprotector against γ-radiation-induced cellular damages in cultured human lymphocytes. Toxicology. 2009;262(1):43-9.
5. Hall EJ, Brenner DJ. Cancer risks from diagnostic radiology. Br J Radiol.2008; 81:362-78.
6. Brenner DJ.Should we be concerned about the rapid increase in CT usage? Rev Environ Health.2010; 25:63-8.
7. De Santis M, Cesari E, Nobili E, Straface G, Cavaliere AF, Caruso A. Radiation effects on development. Birth Defects Research Part C: Embryo Today: Reviews. 2007;81(3):177-82.
8. Georgieva S, Popov B, Bonev G. Radioprotective effect of Haberlea rhodopensis (Friv.) leaf extract on-radiation-induced DNA damage, lipid peroxidation and antioxidant levels in rabbit blood Indian J. Exp. Biol. 2013; 51: 29-36.
9. Kıvrak EG, Yurt KK, Kaplan AA, Alkan I, Altun G. Effects of electromagnetic fields exposure on the antioxidant defense system. Journal of microscopy and ultrastructure. 2017;5(4):167-76.
10. Azab KS, Bashandy M, Salem M, Ahmed O, Tawfik Z, Helal H. Royal jelly modulates oxidative stress and tissue injury in gamma irradiated male Wister Albino rats. North American journal of medical sciences. 2011;3(6):268.
11. Yoshino F, Yoshida A, Okada E, Okada Y, Maehata Y, Miyamoto C, et al. Dental resin curing blue light induced oxidative stress with reactive oxygen species production. Journal of Photochemistry and Photobiology B: Biology. 2012; 114:73-8.
12. Pierce DA, Preston DL. Radiation-related cancer risks at low doses among atomic bomb survivors. Radiat Res. 2000; 154: 178‑186.
13. Ochs A. Acute hepatic vascular complications. Der Internist. 2011;52(7):795-6.
14. Lawrence TS, Robertson JM, Anscher MS, Jirtle RL, Ensminger WD, Fajardo LF. Hepatic toxicity resulting from cancer treatment. International Journal of Radiation Oncology* Biology* Physics. 1995;31(5):1237-48
15. Helmy A. Review article: updates in the pathogenesis and therapy of hepatic sinusoidal obstruction syndrome. Aliment Pharmacol Ther 2006; 23: 11−25.
16. Walsh L, Grosche B, Schnelzer M, Tschense A, Sogl M, Kreuzer M. A review of the results from the German Wismut uranium miners cohort. Radiation protection dosimetry. 2015;164(1-2):147-53.
17. Ozasa K, Shimizu Y, Suyama A, Kasagi F, Soda M, Grant EJ, et al. Studies of the mortality of atomic bomb survivors, Report 14, 1950‑2003: an overview of cancer and noncancer diseases. Radiation research. 2012;177(3):229-43.
18. Pan CC, Kavanagh BD, Dawson LA, Li XA, Das SK, Miften M, et al. Radiation-associated liver injury. International Journal of Radiation Oncology* Biology* Physics. 2010;76(3):S94-100.
19. Zielinski JM, Garner MJ, Band PR, Krewski D, Shilnikova NS, Jiang H, et al. Health outcomes of low-dose ionizing radiation exposure among medical workers: a cohort study of the Canadian national dose registry of radiation workers. International journal of occupational medicine and environmental health. 2009;22(2):149.
20. Sun Q, Mao W, Jiang H, Zhang X, Xiao J, Lian Y. The Effect of Protracted Exposure to Radiation on Liver Injury: A Cohort Study of Industrial Radiographers in Xinjiang, China. International journal of environmental research and public health. 2018;15(1):71.
21. Bakshi MV, Azimzadeh O, Barjaktarovic Z, Kempf SJ, Merl-Pham J, Hauck SM, et al. Total body exposure to low-dose ionizing radiation induces long-term alterations to the liver proteome of neonatally exposed mice. Journal of proteome research. 2015;14(1):366-73.
22. Tai A, Erickson B, Allen X. Extrapolation of normal tissue complication probability for different fractionations in liver irradiation. Int J Radiation Oncology Biol Phys. 2008;74(1) : 283-9.
23. Gore RM, Levine MS. High-yield imaging: gastrointestinal. Elsevier Health Sciences; 2010.
24. Catravas G. N.. Effect of x ray and Co-60 gamma rays on the liver enzyme responsible for fatty acid synthesis, armed forces radiobiology research institute, Defense Atomic Support Agency, Bethesda, Maryland. 1969.
25. Fischer MA, Magee MZ, Coulter EP. Studies on the serum proteins of the X-irradiated rat. Archives of biochemistry and biophysics. 1955;56(1):66-75.
26. Hohne G, Kunkel HA, Anger R. Serum proteins of the rat after whole-body irradiation with 3000 r. Klin. Wochschr. 1955;33:284
27. Clegg GA, Fitton JE, Harrison PM, Treffry A. Ferritin: molecular structure and iron-storage mechanisms. Progress in biophysics and molecular biology. 1981;36:53-86.
28. Jacobs A, Hodgetts J, Hoy T.Ferritins and isoferritins as biochemical markers. Amsterdam: Elsevier science publisher.1984; 113‑27.
29. Marnett L J.Oxy radicals, lipid peroxidation and DNA damage. Toxicology.2002; 181-182:219-222.
30. Dalle-Donne I, Rossi R, Colombo R, Giustarini D, Milzani A. Biomarkers of oxidative damage in human disease. Clinical chemistry. 2006;52(4):601-23.
31. Sener G, Kabasakal L, Atasoy BM, Erzik C, Velioglu-Ogunc A, Cetinel S, et al. Propylthiouracil-induced hypothyroidism protects ionizing radiation-

induced multiple organ damage in rats. Journal of endocrinology. 2006;189(2):257-69.
32. Taqi AH, Faraj KA, Zaynal SA, Hameed AM, Mahmood AA. Effects of occupational exposure of x-ray on hematological parameters of diagnostic technicians. Radiation Physics and Chemistry. 2018; 147:45-52.
33. Faraj K, Mohammed S. Effects of chronic exposure of X-ray on hematological parameters in human blood. Comparative Clinical Pathology. 2018;27(1):31-6.
34. Rao B, Soufir JC, Martin M, David G. Lipid peroxidation in human spermatozoa as relatd to midpiece abnormalities and motility. Gamete research. 1989;24(2):127-34.
35. Moron MS, Depierre JW, Mannervik B. Levels of glutathione, glutathione reductase and glutathione S-transferase activities in rat lung and liver. Biochimica et biophysica acta (BBA)-general subjects. 1979;582(1):67-78.
36. Sun Q, Mao W, Jiang H, Zhang X, Xiao J, Lian Y. The Effect of Protracted Exposure to Radiation on Liver Injury: A Cohort Study of Industrial Radiographers in Xinjiang, China. International journal of environmental research and public health. 2018;15(1):71.
37. Nwokocha CR, Nwokocha M, Mounmbegna P, Orhue J, Onyezuligbo O, Olu-Osifo EH, et al. Proteins and liver function changes in rats following cumulative total body irradiations. West Indian Medical Journal. 2012;61(8).
38. Cheng W, Xiao L, Ainiwaer A, Wang Y, Wu G, Mao R, et al. Molecular responses of radiation-induced liver damage in rats. Molecular medicine reports. 2015;11(4):2592-600.
39. Morado M, Ojeda E, Garcia-Bustos J, Aguado MJ, Arrieta R, Quevedo E, et al. Serum ferritin as risk factor for veno-occlusive disease of the liver. Prospective cohort study. Hematology. 1999;4(6):505-12.
40. Feng Z, Chen JW, Feng JH, Shen F, Cai WS, Cao J, et al. The association between serum ferritin with colorectal cancer. International journal of clinical and experimental medicine. 2015;8(12):22293
41. Naz N, Moriconi F, Ahmad S, Amanzada A, Khan S, Mihm S, et al. Ferritin L is the sole serum ferritin constituent and a positive hepatic acute-phase protein. Shock. 2013;39(6):520-6.
42. Sheikh N, Batusic DS, Dudas J, Tron K, Neubauer K, Saile B, et al. Hepcidin and hemojuvelin gene expression in rat liver damage: in vivo and in vitro studies. American Journal of Physiology-Gastrointestinal and Liver Physiology. 2006;291(3):G482-90.
43. Muntané-Relat J, Ourlin JC, Domergue J, Maurel P. Differential effects of cytokines on the inducible expression of CYP1A1, CYP1A2, and CYP3A4 in human hepatocytes in primary culture. Hepatology. 1995 Oct 1;22(4):1143-53.
44. Torti SV, Kwak EL, Miller SC, Miller LL, Ringold GM, Myambo KB, et al. The molecular cloning and characterization of murine ferritin heavy chain, a tumor necrosis factor-inducible gene. Journal of Biological Chemistry. 1988;263(25):12638-44.
45. Ditzel J. The effect of total-body x-irradiation on serum proteins in the hamster. Radiation research. 1962;17(5):694-702.
46. Goranson ES, McCULLOCH EA, Cinits EA. The Effect of Whole-Body X-irradiation on an Alpha Globulin Component in the Serum of C3Hf/HeHa Mice, Radiation Research 1960;12: 560-6.
47. Mohamed MI, Mohammad MK, Zakaria AM, Ghazali N, Isa MM, Razak HR, et al. Induction of oxidative stress following low dose ionizing radiation in ICR mice. World Journal of Medical Sciences. 2014;10(2):198-203.
48. Meydan D, Gursel B, Bilgici B, Can B, Ozbek N. Protective effect of lycopene against radiation-induced hepatic toxicity in rats. Journal of International Medical Research. 2011 Aug;39(4):1239-52.
49. Deger Y, Dede S, Belge A, Mert N, Kahraman T, Alkan M. Effects of X-ray radiation on lipid peroxidation and antioxidant systems in rabbits treated with antioxidant compounds. Biological trace element research. 2003;94(2):149-56.
50. Zhao H, Wang Z, Ma F, Yang X, Cheng C, Yao L. Protective effect of anthocyanin from Lonicera caerulea var. edulis on radiation-induced damage in mice. International journal of molecular sciences. 2012;13(9):11773-82
51. Robson B, Aline AB, BrunoTR. Effect of black grape juice against heart damage from acute gamma TBI in rats. Molecules 2013; 18:12154-67.
52. Liren Q, Jianliang S. The potential cardio protective eff ects of hydrogenin irradiated mice. Radiation research 2010;51:741-7.