Original Article

Evaluation of the effects of radiation doses from computed tomography on the biochemical parameters of the hepatorenal organs of albino rats

Emeka Kevin Mgbe, Kenneth Chiedozie Ogbanya[1], Emmanuel Obinna Modebe, Iniobong Gabriel Abah[2], Theophilus Okafor Nnaji[1]

Department of Radiation Medicine, University of Nigeria Teaching Hospital, Ituku/Ozalla, Enugu, [1]Department of Veterinary Surgery and Radiology, University of Nigeria, Nsukka, [2]Department of Radiology, University of Uyo, Uyo, Akwa Ibom, Nigeria

Abstract

Background/Aims: Computed tomography (CT) uses X-rays which are ionizing radiation. Interaction of ionizing radiation with the body may result in harmful effects on the organism depending on the radiation dose. This study aimed to evaluate the impact of different doses of CT radiation on the hepatorenal organs of male albino rats using biochemical parameters as the pathological response of the organs to radiation.

Materials and Methods: Thirty healthy male Wistar albino rats weighing 180–200 g were assigned into five groups of six rats each. Rats in groups B, C, D, and E underwent noncontrast helical total body CT irradiation and received varying doses of CT radiation while group A received sham irradiation and served as control. At 72 h postirradiation, blood was collected using conventional methods, and serum was harvested for the determination of alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), total bilirubin (TB), total protein (TP), albumin (Alb), urea, uric acid, and creatinine.

Results: The mean serum levels of TP in the control (group A) and in the irradiated groups B, C, D, and E were 8.21 ± 0.34, 6.08 ± 0.30, 5.86 ± 0.42, 5.22 ± 0.30, and 4.72 ± 0.16, respectively. The mean values of TP in the irradiated groups decreased significantly in a dose-dependent manner compared to the control. The mean serum levels of ALP in the group A and in the irradiated groups B, C, D, and E were 75.20 ± 3.14, 111.60 ± 1.60, 117.60 ± 1.12, 124.40 ± 2.48, and 133.60 ± 2.46, respectively. The mean serum levels of AST in the group A and in the irradiated groups B, C, D, and E were 33.80 ± 0.58, 54.40 ± 2.29, 52.60 ± 1.78, 58.60 ± 2.64, and 63.60 ± 0.81, respectively. The mean serum levels of ALT in the group A and in the irradiated groups B, C, D, and E were 21.20 ± 0.86, 36.00 ± 0.84, 40.40 ± 1.17, 37.40 ± 0.93, and 41.60 ± 1.03, respectively. The mean serum levels of TB in the group A and in the irradiated groups B, C, D, and E were 2.78 ± 0.28, 3.70 ± 0.18, 4.77 ± 0.40, 5.88 ± 0.11, and 6.34 ± 0.04, respectively. The mean serum levels of Alb in the group A and in the irradiated groups B, C, D, and E were 3.68 ± 0.16, 5.96 ± 0.21, 6.65 ± 0.26, 8.15 ± 0.23, and 8.91 ± 0.17, respectively. The mean serum levels of urea in the group A and in the irradiated groups B, C, D, and E were 42.40 ± 0.17, 54.40 ± 1.33, 56.00 ± 1.76, 54.60 ± 1.72, and 57.80 ± 1.39, respectively. The mean serum levels of uric acid in the group A and in the irradiated groups B, C, D, and E

Address for correspondence: Dr. Kenneth Chiedozie Ogbanya, Veterinary Surgery and Radiology, University of Nigeria, Nsukka, Nigeria.
E-mail: kenneth.ogbanya@unn.edu.ng

Submitted: 11-Jan-2024 **Revised:** 27-Mar-2024 **Accepted:** 02-May-2024 **Published:** 05-Aug-2024

Access this article online	
Quick Response Code:	Website: https://journals.lww.com/wajr
	DOI: 10.4103/wajr.wajr_3_24

How to cite this article: Mgbe EK, Ogbanya KC, Modebe EO, Abah IG, Nnaji TO. Evaluation of the effects of radiation doses from computed tomography on the biochemical parameters of the hepatorenal organs of albino rats. West Afr J Radiol 2023;30:41-6.

were 5.65 ± 0.36, 8.32 ± 0.46, 8.87 ± 1.11, 9.13 ± 0.29, and 9.91 ± 0.29, respectively. The mean serum levels of creatinine in the group A and in the irradiated groups B, C, D, and E were 2.05 ± 0.13, 4.44 ± 0.32, 5.81 ± 1.17, 6.31 ± 0.03, and 6.63 ± 0.40, respectively. The mean values of ALP, AST, ALT, TB, Alb, urea, uric acid, and creatinine increased significantly in the irradiated groups compared to the control group.

Conclusion: From the lowest to the highest doses of CT irradiation in the study, alterations in the biochemical parameters were evident and significant. Moreover, this suggests a possible deleterious biological effect of CT radiation on the hepatorenal organs probably due to the effects of radiation-induced free radicals which adversely affected the hepatorenal organs.

Keywords: Computed tomography, ionizing radiation, kidney, liver, radiation dose, X-rays

INTRODUCTION

Progressive development in all fields of science and technology in the world has predisposed both humans and animals to a huge number of various sources of radiation. These include space exploration, mobile communications, computed tomography (CT), digital X-ray, fluoroscopy, gamma radiation, and nuclear weapons.[1,2] CT uses X-rays which are ionizing radiation. Interaction of ionizing radiation with the body results in harmful effects on the organism due to its direct and indirect effects. X-rays and gamma rays are classified as ionizing radiations. Exposure of organisms to high doses of these radiations can cause considerable cell damage, which may eventually even lead to cell death.[3] Ionizing radiation is used in getting rid of unwanted cells within a living system and has emerged as one of the successful strategies in cancer treatment by way of radiotherapy (RT).[4] Radiation-induced liver diseases have been reported in humans with normal liver function, causing hepatomegaly and a mild increase in alkaline phosphatase (ALP) concentration and this may develop fibrosis, cirrhosis, and finally liver failure.[5]

Biochemical mechanisms that are triggered on exposure of a liver cell to ionizing radiations include the generation of oxygen-derived free radicals, namely hydroxyl radical, superoxide radical, hydronium ion, alkoxy-radical, peroxy-radical, and oxides of nitrogen.[6] Injury caused by these free radicals is well advocated by their fatal interactions with lipids, proteins, DNA, and RNA of cell membranes and organelles.[7,8] The kidneys are essential organs that regulate the organism's fluids, electrolytes, and acid-base metabolism. Kidneys excrete waste metabolites, modulate blood pressure, and produce erythropoietin to stimulate erythropoiesis and activate Vitamin D.[9]

Radiation nephropathy is a kidney injury induced by ionizing radiation. In a clinical setting, ionizing radiation is used in RT. Ionizing radiation causes double-strand breaks in the DNA, followed by cell death including apoptosis and necrosis of renal endothelial, tubular, and glomerular cells.[10] Following radiation injury, kidney dysfunction leads to anemia, hypertension, and osteodystrophy. Toxic waste metabolites accumulate and cause uremia, electrolyte disorders such as hyperkalemia, hyperphosphatemia, hypocalcemia, and ultimately chronic renal failure.[11] Irradiation of both kidneys to a modest dose of about 30 Gy gamma radiation in 2 Gy fractions (3000 rad in 200-rad fractions) has resulted in nephropathy with arterial hypertension and anemia and the radiation damage develops slowly and may not become evident for months.[12] Dilatation of Bowman's capsule, degeneration of tubular epithelium, and congestion of renal blood vessels were the significant findings that described the acute gamma radiation effects in rats exposed to a single dose of 20 Gy whole-body irradiation.[13] Alterations in the levels of mRNA after chronic low-dose-rate gamma exposure have been observed in the liver, kidney, and testis of male C57Bl/6 mice.[14] So also, many of the genes in the kidneys and testes of mice were differentially expressed after long-term irradiation with low-dose-rate gamma rays as determined through microarray analysis.[15] Exposure of rats to a single dose of gamma radiation (6 Gy) has been shown to cause a significant rise in the activities of plasma alanine aminotransferase (ALT), aspartate aminotransferase (AST), ALP, and the levels of bilirubin.[16] Hanafy and Kandil reported significant elevation of plasma creatinine, uric acid, and urea levels in response to whole-body gamma irradiation of albino rats.[17] Most of the earlier studies have reported the effects of different doses of gamma radiation in the body but there is a scarcity of information on the effects of different doses of CT radiation in the body. Lowe *et al*.,[18] stated that despite decades of research to understand the biological effects of ionizing radiation, there is still much uncertainty over the role of dose rate. To the best of knowledge, no previous studies have investigated the effects of different doses of CT radiation-induced biochemical changes either in humans or animals. This study, therefore, emphasizes the biochemical alteration of

the hepatorenal organs of Wistar albino rats exposed to various doses of CT radiation.

MATERIALS AND METHODS

Animals

Thirty healthy male Wistar albino rats weighing 180–200 g obtained from the Department of Veterinary Medicine, University of Nigeria, Nsukka, were used. The rats were housed under standard laboratory conditions (12 h light and 12 h dark) in a room with a controlled temperature (24°C ± 3°C) during the experimental period. The rats were provided a free standard pellet diet and water *ad libitum*. After 1 week of acclimatization, the rats were randomly assigned into five groups (groups A, B, C, D, and E) of six rats each. All the study's protocols and the animal care and handling were in accordance with the guidelines set by the University of Nigeria, Nsukka, Faculty of Veterinary Medicine Institutional Animal Care and use Committee (IACUC, FVM UNN) with approval number FVM-UNN-IACUC-2023-06/105.

Equipment

Irradiation was carried out using GE 16 Slice (General Electric) Revolution ACTs CT scanner (GE Hangwei Medical Systems Co. Ltd, China) with adaptive statistical iterative reconstruction features that allow manual entry of diagnostic exposure parameters to achieve desired radiation dose.

Methods

Radiation protocols

There were four irradiated groups (B, C, D, and E) and one sham irradiated control group (group A) of five rats each. The six rat per group were immobilized with a customized fixator in supine position with head first. Centering laser beam was at the mid sagittal plane and mid neck before axial beam total body irradiation was acquired from the tip of the nose to the tail. Two scout images, anterior-posterior and lateral for each group of the irradiated groups were first acquired with the same kV (80) and mAs (20) so as to prevent X-ray beam wastage and to ensure centering accuracy. Tube current (mAs) and tube potential (kV) were manually selected. The radiation dose for each group was automatically estimated by scanner software and displayed in the CT scanner screen as volume-weighted CT dose index (CTDIvol) and dose-length product (DLP). These values are standardized measures of radiation dose during CT examination.[19] A noncontrast helical scan was carried out for each group once a week for 2 weeks.

Group A rats received sham irradiation and served as control. Sham irradiation is the control group that received zero irradiation (0 mGy). Rats in group B were irradiated with 80 kV and 100 mAs. Rats in group C were irradiated with 100 kV. Group D rats were irradiated with 120 kV and 150 mAs while group E rats were irradiated with 140 kV and 160 mAs.

Blood/serum collection

Blood was collected from the orbital plexus at 72 h after the last irradiation. Then serum was separated by centrifugation at 3000 rpm/min for 5 min at 4°C and stored at 80°C until simultaneously studied.

Determination of biochemical parameters

Serum ALT, AST, ALP, total bilirubin (TB), total protein (TP), albumin (Alb), globulin (Glob) urea, uric acid, and creatinine were assessed colorimetrically using commercial kits (Randox, UK).

The activities of AST and ALT activities were evaluated according the method of Reitman and Frankel[20] while ALP was determined by the method of Tietz *et al*.[21] as outlined in Randox kit. The TP and Alb contents were determined using methods outlined by Buzanovskii.[22] Serum uric acid level was determined by an enzymatic method (uricase) as outlined in the Randox/UK kit.[23] The level of urea in the serum was determined by an enzymatic method (urease-modified Berthelot reaction) as outlined in the Randox/UK kit.[24] Serum level of creatinine was determined based upon the colorimetric method with deproteinization using Syrbio/France kit.[25]

Statistical analysis

Statistical analysis was carried out using the Statistical Package for the Social Science (SPSS) software version 22 (IBM company, Armonk, New York, USA). The data obtained were expressed as means ± standard error of the mean. One-way analysis of variance was performed among the mean values the groups followed by Duncan's multiple range test. The statistical difference was considered significant at $P < 0.05$.

RESULTS

Group A rats (sham irradiation control group) received 0.0 mGy radiation dose. Rats in group B received a total radiation dose of 2.76 mGy CTDIvol and 74.74 mGy/cm DLP. Rats in group C received a total radiation dose of 8.36 mGy CTDIvol and 352.38 mGy/cm DLP. Group D rats received a total radiation dose of 14.92 mGy CTDIvol and 628.6 mGy/cm DLP while group E rats received a total radiation dose of 78.74 mGy CTDIvol and 1388.42 mGy/cm DLP.

The mean serum levels of liver indices, TP, ALP, AST, ALT, TB, Alb, and globulin were presented in Table 1. The

study showed that serum levels of TP in the irradiated groups decreased significantly ($P < 0.05$) compared to the sham irradiated control group. In reverse, the mean serum levels of ALP, AST, ALT, TB, and Alb in the irradiated groups of rats increased significantly ($P < 0.05$) against the sham irradiated control group. CT radiation showed dose-dependent decrease in the serum levels of TP while the serum levels of ALP, AST, ALT, TB, Alb, and globulin increased in a dose-dependent manner.

The mean serum level of renal indices, urea, uric acid, and creatinine were presented in Table 2. The present study results showed significant elevation ($P < 0.05$) in serum levels of urea, uric acid, and creatinine in the irradiated groups compared to the sham irradiated control group. A dose-dependent increase in the urea, uric acid, and creatinine was observed in the present CT radiation dose study.

DISCUSSION

The current study focuses on the toxic effects of different doses of CT radiation on the hepatorenal organs after 2 weeks of weekly whole-body CT irradiation in Wistar male albino rats. From our study, all the radiation doses induced significant decline in serum levels of TP in a dose-dependent manner while dose-dependent serum elevation of ALP, AST, ALT, TB, and Alb was observed. Transaminases are involved in protein and amino acid metabolism. They are present in most of the cells of the tissues in the body, however, ALT and AST levels are the most specific markers for hepatic cell destruction and loss of hepatocyte integrity. Since they are present in cytoplasm, they are released into the circulation following diseases or injuries.[4,26] Our findings are related to the results by Sohrabi *et al*.[4] who observed high serum concentrations of liver enzymes in rats exposed to 2.00 and 8.00 Gy gamma radiation. Our results are also similar to the findings of Makhlouf and Makhlouf[27] who showed that levels of liver enzymes (ALT and AST) increased significantly in serum of rats after gamma irradiation. Kafafy[28] reported similar results in rats exposed to gamma radiation. The results of the current study are also consistent with those found previously which reported significant increase in liver enzyme levels in rats exposed to 8.00 Gy gamma radiation.[29,30] Our results are in agreement with reports by Abdelhafez and Kandeal[2] who showed that the mean serum levels of ALT, AST, and ALP increased significantly in rats exposed to single 4 Gy whole-body gamma radiation. The biochemical alterations observed in the current CT radiation are consistent with the previous studies which reported that whole-body gamma irradiation induced hepatotoxicity and increased serum ALT and AST activities.[29,31,32] Similarly, Eshak and Osman[33] and El-Desouky *et al*.[34] noticed elevations in ALT, AST, and ALP in sera of gamma irradiated (4 and 6 Gy) albino rats. Our observations are closely related to the previous results of Ramadan[35] who documented significant increase in ALT and AST in female albino rats exposed to 5 Gy gamma irradiation. The increase in the serum levels of liver enzymes in this study could be attributed to the CT radiation-induces damage of cellular membranes of hepatocytes, which leads to an increase in the permeability of cell membranes and facilitates the passage of these enzymes outside the cells. This is because increase in serum levels of liver enzymes are related to the extensive breakdown of liver parenchyma.[4] The observed elevations

Table 1: Mean ± SEM of serum levels of liver indices in rats with different doses of total-body computed tomography (CT) radiation

Group	TP (mg/dL)	ALP (mg/dL)	AST (mg/dL)	ALT (mg/dL)	TB (mg/dL)	Albumin (mg/dL)
Group A control (sham irradiation)	8.21±0.34^{a}	75.20±3.14^{a}	33.80±0.58^{a}	21.20±0.86^{a}	2.78±0.28^{a}	3.68±0.165^{a}
Group B (CTDIvol=2.76 mGy and DLP=74.74 mGy/cm)	6.08±0.30^{b}	111.60±1.60^{b}	45.40±2.29^{b}	36.00±0.84^{b}	3.70±0.18^{b}	5.96±0.21^{b}
Group C (CTDIvol=8.36 mGy and DLP=352.38 mGy/cm)	5.86±0.42^{b}	117.60±1.12^{c}	52.60±1.78^{c}	40.40±1.17^{c}	4.77±0.40^{c}	6.65±0.26^{c}
Group D (CTDIvol=14.92 mGy and DLP=628.6 mGy/cm)	5.22±0.30^{b,c}	124.40±2.48^{d}	58.60±2.64^{d}	37.40±0.93^{b}	5.88±0.11^{d}	8.15±0.23^{d}
Group E (CTDIvol=78.74 mGy and DLP=1388.46 mGy/cm)	4.72±0.16^{c}	133.60±2.46^{d}	63.60±0.81^{d}	41.60±1.03^{c}	6.34±0.04^{d}	8.91±0.17^{e}

^{a,b,c,d}Different superscripts across the column indicate significant ($P < 0.05$) variation in the mean values. Abbreviation of hepatic parameters and standard CT radiation dose indices: TP - Total protein, ALP - Alkaline phosphatase, AST - Aspartate aminotransferase, ALT - Alanine aminotransferase, TB - Total bilirubin, CTDIvol - Volume weighted computed tomography, DLP - Dose-length product

Table 2: Mean ± SEM of serum levels of renal indices in rats with different doses of total-body CT radiation

Group	Urea (mg/dL)	Uric acid (mg/dL)	Creatinine (mg/dL)
Group A control (sham irradiation)	42.40±1.17^{a}	5.65±0.36^{a}	2.05±0.13^{a}
Group B (CTDIvol=2.76 mGy and DLP=74.74 mGy/cm)	54.40±1.33^{b}	8.32±0.46^{b}	4.44±0.32^{b}
Group C (CTDIvol=8.36 mGy and DLP=352.38 mGy/cm)	56.00±1.76^{b}	8.87±0.11^{b}	5.81±0.17^{b}
Group D CTDIvol=14.92 mGy and DLP=628.6 mGy/cm)	54.60±1.72^{b}	9.13±0.29^{b,c}	6.31±0.03^{b}
Group E (CTDIvol=78.74 mGy and DLP=1388.46 mGy/cm)	57.80±1.39^{b}	9.91±0.29^{c}	6.63±0.40^{b}

^{a,b,c}Different superscript across the column indicate significant ($P < 0.05$) variation in the mean values. Abbreviation of CT radiation dose indices: CTDIvol - Volume weighted computed tomography, DLP - Dose-length product

could be also due to a hypoxia state in the liver cells or mitochondrial membrane induced by ionizing radiation.[28,36]

Radiation-induced serum elevation of urea, uric acid, and creatinine was observed in the irradiated groups compared with the sham irradiated control group. This significant rise in serum urea, uric acid, and creatinine in the irradiated groups are indication of radiation-induced renal impairment. These data were consistent with the findings of Hanafy and Kandil[17] who showed that the plasma creatinine, uric acid, and urea levels were significantly increased in response to whole-body gamma irradiation of albino rats. Similarly, Elmonem *et al*.[16] noticed significant increase in creatinine, urea and uric acid in rats exposed to whole-body 6 Gy, single dose gamma irradiation.

Based on the biochemical changes observed in the present results, it could be concluded that from the lowest to the highest doses of CT radiation, alteration in the biochemical parameters was evident and significant. This suggests possible deleterious biological effects of the different doses of CT radiation on the hepatorenal organs probably due to the effects of radiation-induced free radicals which adversely affected the hepatorenal organs.

Statement of ethics

This study was performed in line with the principles of the Declaration of Helsinki. All the study's protocols and the animal care and handling were in accordance with the guidelines set by the University of Nigeria, Nsukka, Faculty of Veterinary Medicine Institutional Animal Care and Use Committee (IACUC, FVM UNN) with approval number FVM-UNN-IACUC-2023-06/105.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Nakamura N, Hirai Y, Kodama Y. Gamma-ray and neutron dosimetry by EPR and AMS, using tooth enamel from atomic-bomb survivors: A mini review. Radiat Prot Dosimetry 2012;149:79-83.
2. Abdelhafez HM, Kandeal HA. Histological and histochemical changes in the liver of gamma-irradiated rats and the possible protective role of *Aphanizomenon flos-aquae* (AFA). J Biosci Appl Res 2018;4:1-21.
3. Reshma K, Debjith C, Sudha K, Chiranth C, Rahul R, Charu Y. Chronic effects of ionising radiation induced renal damage in albino Wistar rats. Biomedicine 2020;40:51-4.
4. Sohrabi A, Tehrani AA, Asri-Rezaei S, Zeinali A, Norouzi M. Histopathological assessment of protective effects of selenium nanoparticles on rat hepatocytes exposed to gamma radiation. Vet Res Forum 2020;11:347-53.
5. Shadad AK, Sullivan FJ, Martin JD, Egan LJ. Gastrointestinal radiation injury: Symptoms, risk factors and mechanisms. World J Gastroenterol 2013;19:185-98.
6. Riley PA. Free radicals in biology: Oxidative stress and the effects of ionising radiation. Int J Radiat Biol 2009;65:27-33.
7. Reisz JA, Bansal N, Qian J, Zhao W, Furdui CM. Effects of ionizing radiation on biological molecules – Mechanisms of damage and emerging methods of detection. Antioxid Redox Signal 2014;21:260-92.
8. Eze CA, Ogbanya KC, Obiakor KO. Mitigating effects of methanolic leave extract of *Duranta erecta* against x-rays irradiation-induced oxidative stress in Wister albino rats. Sokoto J Vet Sci 2022;20:103-10.
9. Klaus R, Niyazi M, Lange-Sperandio B. Radiation-induced kidney toxicity: Molecular and cellular pathogenesis. Radiat Oncol 2021;16:43.
10. Hoseini Azad SA, Moshiri M, Roohbakhsh A, Shakeri A, Fatemi Shandiz A, Etemad L. Efficacy of orally administered montmorillonite in myoglobinuric acute renal failure model in male rats. Iran J Basic Med Sci 2023;26:753-9.
11. Webster AC, Nagler EV, Morton RL, Masson P. Chronic kidney disease. Lancet 2017;389:1238-52.
12. Aunapuu M, Pechter U, Gerskevits E, Marjamägi MM, Suuroja S, Arend A, *et al*. Low-dose radiation modifies the progression of chronic renal failure. Ann Anat 2004;186:277-82.
13. Yurut-Caloglu V, Caloglu M, Deniz-Yalta T, Aktoz T, Nurlu D, Kilic-Durankus N, *et al*. Radiation- induced acute kidney toxicity: Protective effect of L- carnitine versus amifostine. Int J Radiat Res 2015;13:317-24.
14. Uehara Y, Ito Y, Taki K, Nenoi M, Ichinohe K, Nakamura S, *et al*. Gene expression profiles in mouse liver after long-term low-dose-rate irradiation with gamma rays. Radiat Res 2010;174:611-7.
15. Taki K, Wang B, Nakajima T, Wu J, Ono T, Uehara Y, *et al*. Microarray analysis of differentially expressed genes in the kidneys and testes of mice after long-term irradiation with low-dose-rate gamma-rays. J Radiat Res 2009;50:241-52.
16. Elmonem HA, Mahmoud AH, Abbas MM. Ameliorative effect of zinc oxide nanoparticles and Vitamin E on some biochemical and histological changes in irradiated albino rats. Egypt J Radiat Sci Appl 2021;34:1-10.
17. Hanafy N, Kandil EI. Evaluation of coenzyme Q10 role in reducing kidney damage in rats induced by acetaminophen and gamma radiation exposure. Isot Radiat Res 2010;42:587-607.
18. Lowe D, Roy L, Tabocchini MA, Rühm W, Wakeford R, Woloschak GE, *et al*. Radiation dose rate effects: What is new and what is needed? Radiat Environ Biophys 2022;61:507-43.
19. Bryll A, Krzyściak W, Jurczak A, Chrzan R, Lizoń A, Urbanik A. Changes in the selected antioxidant defense parameters in the blood of patients after high resolution computed tomography. Int J Environ Res Public Health 2019;16:1476.
20. Reitman S, Frankel S. A colorimetric method for the determination of serum glutamic oxalacetic and glutamic pyruvic transaminases. Am J Clin Pathol 1957;28:56-63.
21. Tietz NW, Burtis CA, Duncan P, Ervin K, Petitclerc CJ, Rinker AD, *et al*. A reference method for measurement of alkaline phosphatase activity in human serum. Clin Chem 1983;29:751-61.
22. Buzanovskii VA. Determination of proteins in blood. Part 1: Determination of total protein and albumin. Review J Chem 2017;7:79-124.
23. Barham D, Trinder P. An improved colour reagent for the determination of blood glucose by the oxidase system. Analyst 1972;97:142-5.
24. Fawcett JK, Scott JE. A rapid and precise method for the determination of urea. J Clin Pathol 1960;13:156-9.
25. Spencer K. Analytical reviews in clinical biochemistry: The estimation of creatinine. Ann Clin Biochem 1986;23:1-25.
26. Sallie R, Tredger JM, Williams R. Drugs and the liver. Part 1: Testing liver function. Biopharm Drug Dispos 1991;12:251-9.

27. Makhlouf R, Makhlouf I. Evaluation of the effect of spirulina against gamma irradiation induced oxidative stress and tissue injury in rats. Int J Appl Sci Eng Res 2012;1:152-64.
28. Kafafy YA. Protective effect of cysteine and Vitamin E on gamma irradiation injury in rats. Egypt J Radiat Sci Appl 2000;13:1727.
29. Ramadan LA, Shouman SA, Sayed-Ahmed MM, El-Habit OH. Modulation of radiation-induced organs toxicity by cremophor-el in experimental animals. Pharmacol Res 2001;43:185-91.
30. Nada AS. Modulating efficacy of rosemary extracts in rats exposed to oxidative stress. Egypt J Radiat Sci Appl 2008;21:499-514.
31. El-Gabry MS, Abou-Safi H, El-Yamany N, Abdel-Hamid G. Physiological studies on the efficacy of silymarin as antioxidant against the disorders in some blood constituents induced by irradiation in female rats. Egypt J Hosp Med 2003;11:1-14.
32. Muriel P. Role of free radicals in liver diseases. Hepatol Int 2009;3:526-36.
33. Eshak MG, Osman HF. Role of *Moringa oleifera* leaves on biochemical and genetical alterations in irradiated male rats. Middle East J Sci Res 2013;16:1303-15.
34. El-Desouky WI, Abd El-Aleem IM, Saleh ES. Effect of ethanolic ziziphus (*Ziziphus mauritiana* Lam.) leaves extract as radioprotector on some biochemical parameters of γ-irradiated male albino rats. Inter J Adv Res 2014;2:1046-57.
35. Ramadan FL. Evaluation of the synergistic effect of danazol and radiation exposure on some biochemical functions in female albino rats. Egypt J Hosp Med 2007;27:255-62.
36. Romero FJ, Bosch-Morell F, Romero MJ, Jareño EJ, Romero B, Marín N, *et al*. Lipid peroxidation products and antioxidants in human disease. Environ Health Perspect 1998;106 Suppl 5:1229-34.