Dosimetry Control Of X-Ray Radiation For Human DNA Safety

Oladotun .A. Ojo[1], Musibau .A. Ibrahim[2] and Peter .A. Oluwafisoye[3]

[1]Department of Physics, Faculty of Basic and Applied Sciences, Osun State University, Osogbo,

Osun State, Nigeria.

Email: dotun4realoj@gmail.com

[2]Department of Information and Communication Technology, Faculty of Basic and Applied Sciences,

Osun State University, Osogbo, Osun State, Nigeria.

Email: kunle_ibrahim2001@yahoo.com

[3] Department of Education Training and Inspectorate, Nigeria Institute of Science Laboratory, Ibadan,

Oyo State, Nigeria.

Email: paoluwafisoye@yahoo.com

[1]Correspondence Author: Oladotun A. Ojo., Email: dotun4realoj@gmail.com

Tel: +2348030987432

Abstract

The amount of absorbed X-ray dose by a particular human at a single exposure can have some effects on DNA. There is therefore the need to apply the correct range of dose to patients during X-ray exposures. X-ray films from exposed adult patients were collected for use at a hospital. Each of the film's optical densities was measured at various spots on the film and averaged as the mean, which is then converted to the absorbed dose using a model. An estimated range of absorbed dose for the films was found to be between 0.83 mGy to 8.86 mGy. The results were compared with the 1.2 mGy value, which is the absorbed dose that should not be exceeded during an exposure, so that the DNA is not altered. The doses above this value are capable of doing harm to the human DNA. As a result, that ionizing radiation of low dose values can produce an effect on human DNA, hence this occurrence may be checked with a research work of this nature.

Keywords: Absorbed dose, DNA, radiographic films, optical densities, ionizing radiation.

1. Introduction

Radiation can be produced in X-ray machine or a radionuclide. There may be some hazard in exposure to these form of radiation to human tissues (https://bioethicarchive.georgetown.edu 2020). Molecules of living tissues are enormous, and they operate by chemical reactions. The proper functionality is based on the structure or shape of the molecules. Any alteration in the bonds can result in change of their composition. A single dose of ionizing radiation can have enough energy to break chemical bonds of given molecules. Thus, with this potency, ionizing radiation been focused on a small area can disrupt chemical bonds (Caliskan and Caliskan 2018). DNA (Deoxyribose Nucliec Acid) is the most important molecules of all in the human body. It is a very useful tool to estimate the popularity of the history of genetical and material lineage and other functions (Towarnicki and Ballard 2020). The effects of DNA alteration can be transferred from parents to offspring, due to ionizing radiation overdose exposure on the tissue (Hanson and Skinner 2016, Miska and Ferguson 2016). The amount of dose at exposures to patients should be handled and estimated carefully by physicians prescription in order to prevent any harm (Kumagai et al. 2018). It takes much longer for the biological effects of ionizing radiation to become apparent. Appropriateness of imaging must be evaluated by every physician ordering those images to minimize future harm to the patient (Kumagai et al. 2018). There are some examples of over exposure, like sun tanning and skin cancer (Vaiserman et al. 2018). The sensitivity of tissues and organs determines the extent of the damage caused by the amount of radiation dose (WHO 2016). Sickness caused by over exposure have some symptoms like bleeding, hair loss, nausea and vomiting, confusion, fainting, mouth sores, skin sores and diarrhea (American Cancer Society 2015). The result of error in DNA occurs when cancer is not killed but the cell and this can help us understand how X-ray radiation can cause a damage to DNA (Campbell 2016). The effects of gene mutations caused by Ionizing Radiation (IR) can be an accumulated one from parents to offspring (Adewoye et al. 2015). The objective of this research work is to estimate the amount of dose that is applied at the point of x-ray exposures to patients, and use the value to check for the likelihood of excessiveness that could cause any form of alterations in a human DNA. This can serve as a form of

Quality Assurance (QA) and Quality Control (QC) measure in X-ray radiology, to safeguard human DNA alterations.

2. Materials and Methods

X-ray film samples numbering thirty six (36) were collected for use, from a hospital in Nigeria. A film densitometer was employed to measure the optical densities (D) of each film at various spots. The level of how dark or black an X-ray film is, is known as the optical density (D). The optical densities were measured at various spots on each film as D_1, D_2, D_3, D_4, D5 and recorded. Its mean is then found as mean optical densities (MD). These MD's are afterwards converted to the amount of X-ray radiation dose absorbed by each patient, in milliGray (mGy). The deviation in standard were also calculated as SD for every optical density. A diagram of the measurement of the optical densities, at various spots D_1, D_2, D_3, D_4 and D_5 is shown in Figure 1.
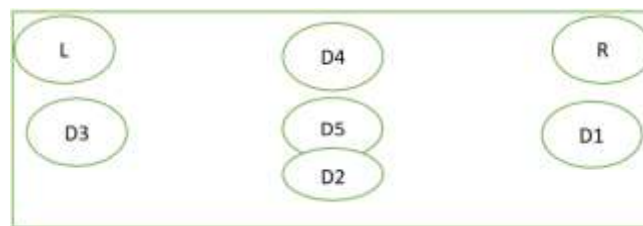

Figure 1. Schematic representation of measurements of optical densities at various

spots on an X-ray film.

The relationship between the mean optical density (MD) and received dose X (Teymurazyan 2003), is given by:

$$MD = D_{max}[1 - e^{-kX}] \qquad (1)$$

Where D_{Max} is the maximum optical density = 4 and k = 9.36, which is the conversion constant.

Substituting for D_{Max} and k in (1) gives:

$$MD = 4[1 - e^{-9.36X}] \qquad (2)$$

We can now solve (2) for X, to give:

$$X = \left(-\frac{1}{9.36}\right) log_e \left(1 - \frac{MD}{4}\right) \qquad (3)$$

Equation (3) represents the value of the absorbed X-ray radiation dose by each patient during examination. The name of the X-ray machine is GEC ROENTGEN 500, General Electric, made in Japan.

3. Results and Discussion

Table 1 presents the results of the measured optical densities as D1, D2, D3, D4 and D5. The Total Optical Density (TOD), Mean Optical Densities (MD), Standard Deviation (SD) and the estimated received absorbed X-ray radiation dose, X (mGy).

The effects of X-ray radiation absorbed dose received by patients at a single exposure have been investigated. The absorbed dose values X, varied throughout the X-ray radiographic films. The higher the optical density of the film, the more the value of the absorbed dose. The range of absorbed dose values for the films was found to be between 0.83 mGy to 8.86 mGy. A received absorbed dose of 1.2 mGy or higher has been found to be capable of causing some harmful effects on human DNA (Rothkamm and Lobrich 2003, Shimura and Kojima 2018). Figures 2a to 2f represents the bar chart of the absorbed dose X (mGy) and measured Mean Optical Densities (MD), for the entire thirty six (36) patients' radiographic films.

Table 1: Measured Optical Densities

FILM S/N	D1	D2	D3	D4	D5	TOD	MD ± SD	Estimated Absorbed Dose X (mGy)
1	1.60	1.52	1.44	0.14	1.41	6.11	1.22 ± 0.61	3.89
2	0.86	2.20	2.04	0.83	1.54	7.47	1.49 ± 0.64	5.00
3	1.18	0.43	0.43	3.06	0.62	5.72	1.14 ± 1.11	3.60
4	2.70	2.06	2.96	2.33	1.22	11.27	2.25 ± 0.67	8.86
5	0.13	0.27	0.34	0.19	0.56	1.49	0.30 ± 0.17	0.83
6	3.52	1.30	0.95	1.12	0.84	7.73	1.55 ± 1.12	5.22
7	0.55	0.57	0.86	0.19	0.20	2.37	0.47 ± 0.28	1.35
8	0.42	0.54	0.63	0.34	3.43	5.36	1.07 ± 1.32	3.33
9	2.02	2.00	1.36	1.04	1.27	7.69	1.54 ± 0.45	5.19
10	1.19	0.52	0.19	0.38	0.44	2.72	0.54 ± 0.38	1.56
11	1.12	0.76	1.76	1.73	0.85	6.22	1.24 ± 0.48	3.98
12	1.37	3.93	0.59	1.07	0.24	7.20	1.44 ± 1.46	4.77
13	0.52	0.51	0.30	0.33	0.89	2.55	0.51 ± 0.24	1.46
14	1.92	1.51	1.50	0.44	0.40	5.77	1.15 ± 0.69	3.64
15	2.77	3.56	0.14	2.70	1.31	10.48	2.10 ± 1.36	7.93
16	0.82	0.39	0.40	1.26	1.03	3.90	0.78 ± 0.38	2.32
17	1.15	0.17	0.39	1.30	0.31	3.32	0.66 ± 0.52	1.94
18	0.58	0.83	0.62	1.39	0.68	4.10	0.82 ± 0.33	2.45
19	1.02	0.03	0.40	0.86	0.58	2.89	0.58 ± 0.39	1.67
20	0.49	1.55	0.71	2.15	1.20	6.10	1.22 ± 0.66	3.89
21	0.91	1.11	0.50	1.13	1.94	5.59	1.12 ± 0.52	3.50
22	2.23	2.16	2.16	0.32	0.68	7.55	1.51 ± 0.93	5.06
23	0.55	0.94	1.11	2.35	0.52	5.47	1.09 ± 0.75	3.41
24	1.00	0.44	2.22	0.96	2.59	7.21	1.44 ± 0.92	4.78
25	0.68	1.26	0.63	0.57	0.92	4.06	0.81 ± 0.28	2.42
26	2.23	2.28	2.21	2.23	0.11	9.06	1.81 ± 0.95	6.45
27	0.93	1.03	0.65	0.37	1.23	4.21	0.84 ± 0.34	2.53
28	0.33	1.13	0.46	1.19	0.42	3.53	0.71 ± 0.42	2.07
29	0.53	0.80	0.23	0.99	0.52	3.07	0.61 ± 0.29	1.78
30	1.01	2.15	1.64	1.76	2.16	8.72	1.74 ± 0.47	6.12

31	1.98	1.39	1.07	0.05	1.36	5.85	1.17 ± 0.71	3.70
32	2.82	0.38	0.18	0.50	1.91	5.79	1.16 ± 1.15	3.65
33	0.42	2.02	0.30	0.26	1.33	4.33	0.87 ± 0.78	2.61
34	1.16	1.01	1.34	1.17	3.86	8.54	1.71 ± 1.21	5.95
35	2.07	2.29	1.86	2.02	2.22	10.46	2.09 ± 0.17	7.91
36	3.17	0.37	0.41	0.40	0.18	4.53	0.91 ± 1.27	2.74
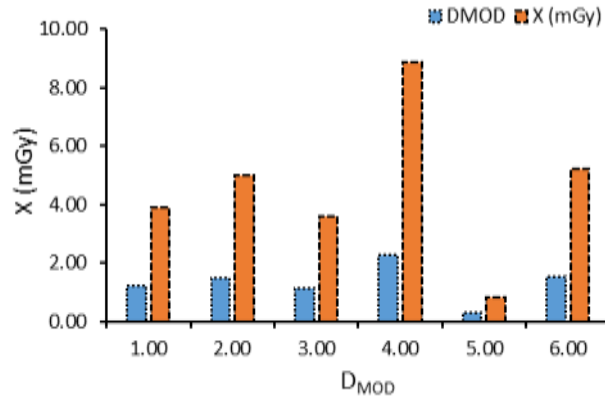
Figure 2a. Absorbed X-ray dose compared with measured mean optical density for film S/N 1 to 6.
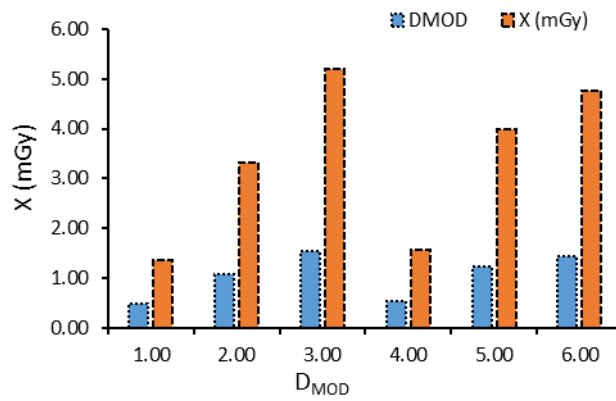
Figure 2b. Absorbed X-ray dose compared with measured mean optical density for film S/N 7 to 12.
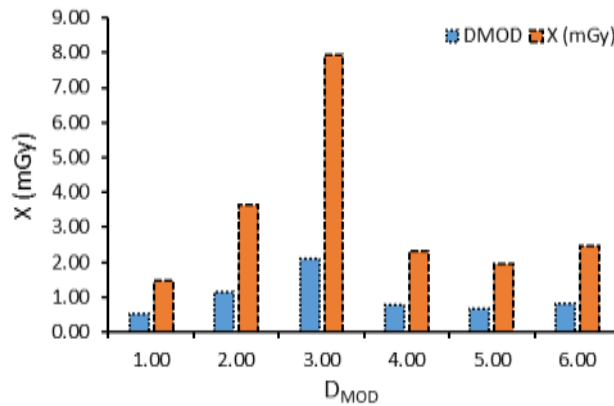

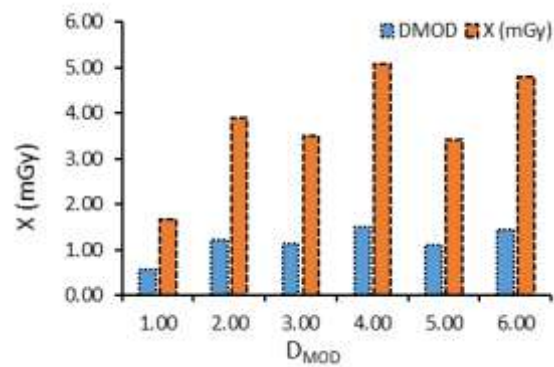Figure 2c. Absorbed X-ray dose compared with measured mean optical density for film S/N 13 to 18.

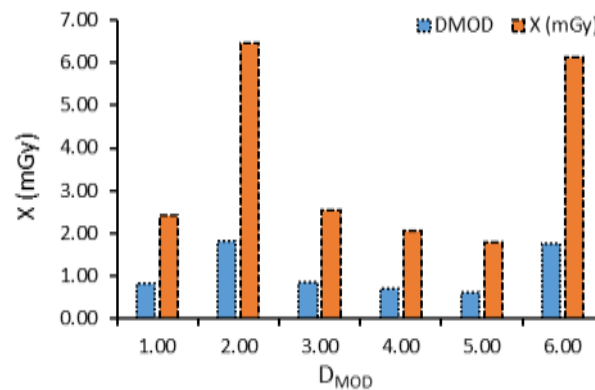Figure 2d. Absorbed X-ray dose compared with measured mean optical density for film S/N 19 to 24.

Figure 2e. Absorbed X-ray dose compared with measured mean optical density for film S/N 25 to 30.
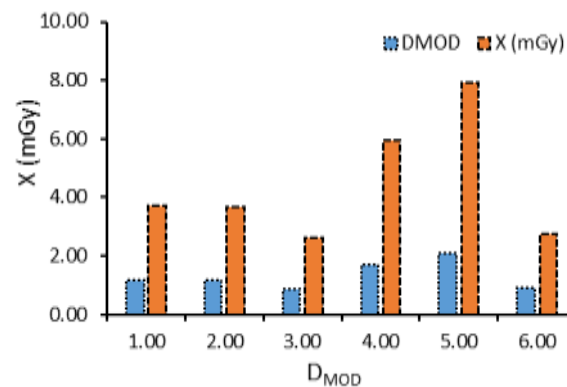

Figure 2f. Absorbed X-ray dose compared with measured mean optical density for film S/N 31 to 36.

Exposures of the human DNA to medical X-ray radiation has been said to have some effects (Lobrich et al.) and if not correctly repaired, this can lead to carcinogenesis and aging of vascular (Giard et al. 2013, Borek et al. 1986).

4. Conclusion

There can be cases of occurrence of increase in overdose of X-ray exposures in diagnostic procedures, which is risky to the human health when it comes to carcinogenic and cardiovascular conditions (Nguyen and Wu 2011, Picano et al. 2014). The side effects caused by low dose of X-ray radiation in

diagnostic imaging exposures can be a long-term one on human DNA (Hampton 2006). Hence regular and continuous Quality Assurance (QA) and Quality Control (QC) of the dose estimation should be done to check for the possibility of overdose during X-ray exposures, which can affect or alter the human DNA.

Conflict of Interest

The authors attest to the fact that there are no conflicts interest on this research work.

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