Dose Estimation of Absorbed X-ray Radiation to Safeguard Human DNA Alteration: A Quality Control and Quality Assurance Approach

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ABSTRACT

The amount of absorbed X-ray dose by a particular human at a single exposure can have some effect on DNA. There is therefore the need to apply the correct range of dose to patients during X-ray. 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. 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.

Submitted : March 20, 2021

Published : June 03, 2021

ISSN: 2593-8339

DOI: 10.24018/ejmed.2021.3.3.777

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I. 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 [1]. 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 [2]. 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 [3]. The effects of DNA alteration can be transferred from parents to offspring, due to ionizing radiation overdose exposure on the tissue [4], [5]. The amount of dose at exposures to patients should be handled and estimated carefully by physicians prescription in order to prevent any harm [6]. 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 [6]. There are some examples of over exposure, like sun tanning and skin cancer [7]. The sensitivity of tissues and organs determines the extent of the damage caused by the amount of radiation dose [8]. Sickness caused by over

exposure have some symptoms like bleeding, hair loss, nausea and vomiting, confusion, fainting, mouth sores, skin sores and diarrhea [9]. 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 [10]. The effects of gene mutations caused by Ionizing Radiation (IR) can be an accumulated one from parents to offsprings [11].

II. MATERIALS AND METHOD

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 , D_5 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 Fig. 1.

Fig. 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 [12], is given by:

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

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:

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

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

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

(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.

III. RESULTS AND DISCUSSION

Table I 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 [13], [14]. Fig. 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 I: MEASURED OPTICAL DENSITIES

FILM S/N	D1	D2	D3	D4	D5	TOD	MD $\pm$ SD	Estimated Absorbed Dose X (mGy)
1	1.60	1.52	1.44	0.14	1.41	6.11	1.22 $\pm$ 0.61	3.89
2	0.86	2.20	2.04	0.83	1.54	7.47	1.49 $\pm$ 0.64	5.00
3	1.18	0.43	0.43	3.06	0.62	5.72	1.14 $\pm$ 1.11	3.60
4	2.70	2.06	2.96	2.33	1.22	11.27	2.25 $\pm$ 0.67	8.86
5	0.13	0.27	0.34	0.19	0.56	1.49	0.30 $\pm$ 0.17	0.83
6	3.52	1.30	0.95	1.12	0.84	7.73	1.55 $\pm$ 1.12	5.22
7	0.55	0.57	0.86	0.19	0.20	2.37	0.47 $\pm$ 0.28	1.35
8	0.42	0.54	0.63	0.34	3.43	5.36	1.07 $\pm$ 1.32	3.33
9	2.02	2.00	1.36	1.04	1.27	7.69	1.54 $\pm$ 0.45	5.19
10	1.19	0.52	0.19	0.38	0.44	2.72	0.54 $\pm$ 0.38	1.56
11	1.12	0.76	1.76	1.73	0.85	6.22	1.24 $\pm$ 0.48	3.98
12	1.37	3.93	0.59	1.07	0.24	7.2	1.44 $\pm$ 1.46	4.77
13	0.52	0.51	0.30	0.33	0.89	2.55	0.51 $\pm$ 0.24	1.46
14	1.92	1.51	1.50	0.44	0.40	5.77	1.15 $\pm$ 0.69	3.64
15	2.77	3.56	0.14	2.70	1.31	10.48	2.10 $\pm$ 1.36	7.93
16	0.82	0.39	0.40	1.26	1.03	3.9	0.78 $\pm$ 0.38	2.32
17	1.15	0.17	0.39	1.30	0.31	3.32	0.66 $\pm$ 0.52	1.94
18	0.58	0.83	0.62	1.39	0.68	4.1	0.82 $\pm$ 0.33	2.45
19	1.02	0.03	0.40	0.86	0.58	2.89	0.58 $\pm$ 0.39	1.67
20	0.49	1.55	0.71	2.15	1.20	6.1	1.22 $\pm$ 0.66	3.89
21	0.91	1.11	0.50	1.13	1.94	5.59	1.12 $\pm$ 0.52	3.50
22	2.23	2.16	2.16	0.32	0.68	7.55	1.51 $\pm$ 0.93	5.06
23	0.55	0.94	1.11	2.35	0.52	5.47	1.09 $\pm$ 0.75	3.41
24	1.00	0.44	2.22	0.96	2.59	7.21	1.44 $\pm$ 0.92	4.78
25	0.68	1.26	0.63	0.57	0.92	4.06	0.81 $\pm$ 0.28	2.42
26	2.23	2.28	2.21	2.23	0.11	9.06	1.81 $\pm$ 0.95	6.45
27	0.93	1.03	0.65	0.37	1.23	4.21	0.84 $\pm$ 0.34	2.53
28	0.33	1.13	0.46	1.19	0.42	3.53	0.71 $\pm$ 0.42	2.07
29	0.53	0.80	0.23	0.99	0.52	3.07	0.61 $\pm$ 0.29	1.78
30	1.01	2.15	1.64	1.76	2.16	8.72	1.74 $\pm$ 0.47	6.12
31	1.98	1.39	1.07	0.05	1.36	5.85	1.17 $\pm$ 0.71	3.70
32	2.82	0.38	0.18	0.50	1.91	5.79	1.16 $\pm$ 1.15	3.65
33	0.42	2.02	0.30	0.26	1.33	4.33	0.87 $\pm$ 0.78	2.61
34	1.16	1.01	1.34	1.17	3.86	8.54	1.71 $\pm$ 1.21	5.95
35	2.07	2.29	1.86	2.02	2.22	10.46	2.09 $\pm$ 0.17	7.91
36	3.17	0.37	0.41	0.4	0.18	4.53	0.91 $\pm$ 1.27	2.74

Fig. 2a. Absorbed X-ray dose compared with measured mean optical density for film S/N 1 to 6.

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

Fig. 2b. Absorbed X-ray dose compared with measured mean optical density for film S/N 7 to 12.

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

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

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

Exposures of the human DNA to medical X-ray radiation has been said to have some effects [15] and if not correctly repaired, this can lead to carcinogenesis and aging of vascular [16], [17].

IV. 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 [18], [19]. The side effects caused by low dose of X-ray radiation in diagnostic imaging exposures can be a long-term one on human DNA [20]. 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.

ACKNOWLEDGEMENT

The authors would like to thank the Federal Medical Center (FMC) hospital, Nigeria and also the entire staff of the Radiology department, for making available the X-ray radiographic films for use, as well as access to their facilities.

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