Journal of Advances in Medicine and Medical Research

32(24): 11-16, 2020; Article no.JAMMR.61730
ISSN: 2456-8899
(Past name: British Journal of Medicine and Medical Research, Past ISSN: 2231-0614, NLM ID: 101570965)

Radiation Dose to the Closest Critical Organ during External Beam Radiotherapy of Head & Neck, Breast and Cervix at the University College Hospital, Ibadan, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Authors ABI and ATM designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors ACA and FIP managed the analyses of the study. Authors ATM and ABI managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAMMR/2020/v32i2430746
Editor(s):
(1) Dr. Chan-Min Liu, Xuzhou Normal University, China.
Reviewers:
(1) Roshan Telrandhe, Rashtrasant Tukadoji Maharaj Nagpur University (RTMNU), India.
(2) I. Putu Gede Adiatmika, Udayana University, Indonesia.
(3) Hussain Saleem, University of Karachi, Pakistan.
Complete Peer review History: http://www.sdiarticle4.com/review-history/61730

Original Research Article

Received 05 August 2020
Accepted 10 October 2020
Published 31 December 2020

ABSTRACT

Introduction: Radiotherapy is the use of ionizing radiation for treatment of diseases, mostly malignant and non-malignant. Its goal is to deliver maximum radiation dose to tumour cells while minimizing dose to the surrounding normal cells. Studies have shown that patients who underwent radiotherapy usually receive highest scattered radiation dose to organs closest to the treatment sites due to inevitable exposure and making them susceptible to cancer induction. This study aims at quantify scattered radiation dose to closest critical organs during external beam radiotherapy of

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the head & neck, breast, and cervix at the University College Hospital, Ibadan, Nigeria.
Materials and Methods: Seventy-nine patients living with cancer in the region of head & neck, breast or cervix, who gave permission to participate were considered. The closest critical organs of interest are the eye lens, thyroid and femur head respectively. Thermoluminescence dosimeters (TLDs) were used to measure scattered radiation dose to these reference organs during radiation therapy of the target organs. After each treatment session, the exposed TLDs were taken to the designated Research Laboratory for processing with manual TLD reader system, HARSHAW, model 3500.
Results: The mean scattered radiation doses to reference organs during the treatment of head & neck, breast and cervical cancer cases were 110 ±77 cGy (Eye lens), 211 ± 83 cGy (Thyroid), and 319 ±103 cGy (Femur head) respectively.
Conclusion: In all, Femur head received the highest (87% of prescribed dose to target organ) scattered radiation dose followed by thyroid (54%) and the eye lens (32%) from their respective target organ.

Keywords: Ionizing radiation; scattered radiation; radiotherapy; critical/reference organs; target organs; absorbed dose; Thermoluminescence Dosimeter (TLD).

1. INTRODUCTION

When ionizing radiation of certain energy interacts with a biological medium, including human cells, some or all of its energy is transfer to the molecules of this medium leading to ejection of orbital electrons in a process called ionization [1]. Ionizing radiation does not discriminate between cells of biological medium and any of them could suffer damage following their interaction. The nucleus of the cells, called Deoxyribonucleic acid (DNA), is the main target of radiation deleterious effects. These effects could be direct or indirect leading to either single strand break, double strand break, base or sugar damage or cross links between macromolecules (i.e. DNA-DNA or DNA-protein crosslinks). The DNA double strand break is the most critical event for lethal effects of ionizing radiation [1].

Previous studies in literatures have shown that patients treated with ionizing radiation carry a risk (stochastic effect) of induction of second cancer in their lifetime [2–4]. The age at exposure, time since inception of irradiation and radiation dose received in the process, are some of the factors that could dispose an individual to cancer induction [5–6].

Also reported in literatures was the association between low doses of scattered radiation received by critical organs near treatment sites during radiotherapy and formation of cataract of the eye lens, cardiac toxicity and increased risk of cancer induction [7-8].

There is a growing concern about the risk of radiation induced second cancer and of late tissue complications among cancer survivors, who were younger at the time of treatment and now living longer, thus increasing the rate of manifestation of radiation effects [9–12].

Head & Neck cancer is one of the cases considered in this study. It represents the sixth most common cancer worldwide, with approximately 630,000 new cases annually [13]. Other cases considered are the breast cancer, which is the leading female malignancy in the world and is currently the most common cancer among female population in Nigeria [14] and cervical cancer, which is the second most common cancer among female population in Nigeria [15].

Gamma radiation emitted from Cobalt-60 teletherapy machine was used to treat all the patients considered in this study. The radioactive source is currently in its second half-life, which means that the time required to deliver a given dose of radiation will be twice its initial value due to gradual reduction in the source activity and dose rate with passage of time. This could result in patient spending more time under the treatment machine and possibly the critical organs outside the treatment field could be exposed to large amount of scattered radiation dose.

This present study is aimed at measurement of scattered radiation dose to critical organs that are very close to the treatment sites of the following cancer target organs, namely, Head & neck, Breast and Cervix.

2. MATERIALS AND METHODS

This study was carried out at the University College Hospital (UCH), Ibadan between June and August, 2019. These patients comprise of twenty (20) Head & Neck cancer cases, thirty (30) Breast cases and twenty-nine (29) Cervical cases. This selection was based on patients who had been diagnosed for cancer and scheduled for treatment in the following region of their body namely, Head & neck, Breast and Pelvis. Each patient was represented by an identification number and they were all treated with external beam radiotherapy from Cobalt-60 Unit, model Bhabhatron-II from Panacea Medical Technologies Pvt. Ltd. India.

This treatment unit was commissioned for clinical services in the year 2013. It is a rotating type without a beam stopper and the treatment head is shielded with Tungsten instead of the conventional depleted Uranium. The piston located on the treatment head moves the radioactive source in and out of its shielded positions electronically. The collimator on the unit shapes the radiation beam to the desired treatment field. The minimum treatment square field on the machine is 4 cm while the highest squared field is 35 cm at the source to skin distance (SSD) of 80 cm. The activity of radioactive Cobalt-60 source at the time of installation in the year 2013 was 258 TBq. The calibration of the source for determination of its monthly dose rate (cGy/min) was based on the International Atomic Energy Agency (IAEA) protocol [7].

The data obtained from each patient included the treatment site, treatment field sizes, the prescribed dose, the number of fractions, age, height and weight. Their weight was measured with a weighing scale while their height was measured with a tape rule.

The treatment fields and techniques used for patients with head & neck cancer were not the same for all patients considered in this study. It ranged from medial, lateral (right or left), anterior and posterior fields. A customized lead block was used to shield the eye, the only recognized critical organ in head & neck treatment. Whereas, for patients with breast cancer, they were placed in supine position on an angled breast board to bring the chest wall parallel to the treatment couch. The chest wall was treated with two fields namely, the medial and lateral (left or right) tangential. Also, all patients with cervical cancer were treated with two opposed fields to their pelvis namely, anterior and posterior field. There was no lead shielding applied on the thyroid and femur head.

The scattered radiation dose to reference organs were measured with thermoluminescence dosimeter (TLD) chips. The TLD chips used for this research were made from Lithium Fluoride (LiF:TLD-100) and were obtained from Research Laboratory, Department of Physics and Engineering Physics, Obafemi Awolowo University, Ile-Ife, Osun state, Nigeria. The TLD chips were calibrated using radioactive Cobalt-60 source at the Secondary Standard Dosimetry Laboratory, National Institute of Radiation Protection and Research, University of Ibadan, Ibadan, Oyo State Nigeria.

Each annealed TLD chip was enclosed in a labelled light weight container and were (3 chips per organ) placed gently on the reference organ of interest on the patient’s body immediately after the patient has been set-up for treatment. The distance between the TLD chips placed on the reference organ and the central axis of the treatment field (treated organ) was also measured with a tape rule and recorded.

For head and neck cancer, the reference organ of interest is the eye lens while thyroid and femur head are respective reference organ of interest for breast and cervical cancer. After each patient’s treatment session, the exposed TLD chips were removed, placed in another container and labelled with the patient’s identification number. The treatment session for all patients ranged from 6 – 12 sessions (two fields per session) while the prescribed dose ranged from 24 – 45 Gy. They were thereafter taken to the department of Physics and Engineering Physics, Obafemi Awolowo University, Ile-Ife where they were processed/read with a manual TLD reader system, HARSHAW, model 3500 model.

After the readout of the exposed TLD chips and their absorbed doses recorded, they were placed in an oven for annealing. This heating took place at 400^0 C for one hour after which they were allowed to cool for 24 hours. Thereafter, the TLD chips were withdrawn from the oven and made ready for re-use on other set of patients. All relevant information was recorded and tabulated accordingly.

3. RESULTS

Table 1 shows the patients’ demographic information while Table 2 shows the number of patients in each of the category of cancer cases considered in this study. Also presented in Table 2 is the mean treatment field sizes which indicate the surface area of the patient's body that received the prescribed dose of ionizing radiation. The distance between the centre of the critical organ of interest measured in this study and the central axis of the treatment field of each of the cancer cases is presented in Table 3. The prescribed dose per session (combination of two fields) for treatment of each of the cancer cases and scattered radiation dose received by the reference organ of interest are presented in Table 4.

Table 1. Patients' demographic information

Parameter	Patient
Sex: Female	58 (73%)
Male	21 (27%)
Age, years	
Mean ± Std. deviation	48 ± 14
Weight, Kg	
Mean ± Std. deviation	71 ± 14
Height, m	
Mean ± Std. deviation	1.66 ± 0.08

4. DISCUSSION

Owing to relatively higher dose of scattered radiation to organs near the target volume of cancer patients who have undergone radiotherapy and its associated risk of cancer induction [16 – 18], this present study was conducted to quantify the dose scattered to the closest organ of cancer patients treated with Tele-Cobalt-60 unit in the region of the head & neck, breast and pelvis.

In this study, there were more female patients than their male counterparts (ratio 7:3) which could be due to increase in female specific malignancies (breast and cervix) as seen in Table 1. This agrees with the findings in a study conducted by Elumelu et al [7], where they reported an increase in female specific malignancies among Nigerian population. Most of the patients were in their productive years of life (< 50 years), where care must be taken to protect their critical organs, especially those considered in this study, against excessive radiation that can pose a threat to their livelihood after treatment.

It was observed that the radiation doses scattered to various reference organs of interest considered in this study namely, the eye lens, thyroid and femur head are function of the treatment field sizes, the distance between reference organ and the central axis of the treatment fields and whether a lead shield was applied during treatment of the site or not. It can be seen from Table 2, that the pelvis region has the highest treatment field size

Table 2. Number of patients with respect to the treatment site and field size

Treatment site	Number of patient (%)	Mean field size, cm^2
Head and Neck	20 (25.3%)	93 ± 50
Breast	30(38.0%)	166±26
Pelvis	29 (36.7%)	346 ± 64

Table 3. Mean distance of reference organ from the central axis of the treatment site

Reference organ	Head and neck	Breast	Pelvis
Eye lens	15 ± 4 cm	-	-
Thyroid	-	15 ± 2 cm	-
Femur Head	-	-	15 ± 2 cm

Table 4. Mean scattered dose to reference organ with respect to the prescribed dose per session and the treatment site

Parameter	Head & neck	Breast	Pelvis
Dose per Session, cGy	341	393	367
Dose to the Eye lens, cGy	110 ±79 (32%)	-	-
Dose to Thyroid, cGy	-	211 ± 84 (54%)	-
Dose to Femur Head, cGy	-	-	320 ± 109 (87%)
Application of lead shielding	Yes	No	No

(346 cm^2), followed by the breast (166 cm^2) and the least was the head & neck (93 cm^2). However, due to usual application of lead block to shield the eye lens (through the use of a Tray) during radiotherapy of the head and neck region, the eye lens received the least scattered radiation dose (110 cGy), followed by the thyroid (211 cGy) and the highest was received by the femur head (320 cGy). The thyroid and femur head are not usually shielded during radiotherapy of the breast and cervix respectively. However, in a similar study by Miah et al [19], the authors only reported the fact that scattered radiation dose to different parts of cancer patients during radiotherapy increased with increasing treatment field sizes.

It is important to note that the scattered radiation doses received by reference organs of patients with similar type of cancer cases varied from one patient to another. This may be due to differences in their body sizes and different field sizes chosen for their treatment. This is similar to the findings of Ogundare et al [20], where patients with the same type of cancer cases and treated with external beam radiotherapy received different scattered radiation doses to different parts of their body.

5. CONCLUSION

In conclusion, it was observed that the scattered radiation dose received by all the reference organs considered in this study were above (110 – 320 cGy) the threshold dose (10 cGy) for cancer induction [21]. Although dose rate and fractionation between treatment sessions employed during radiotherapy may influence DNA repair and lower the overall cancer induction, adequate care must still be taken to ensure appropriate shielding of critical organs that are very close to the treatment volume during external beam radiotherapy of cancer patients.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT AND ETHICAL APPROVAL

Following an existing UCH/UI ethical review committee's approval to carry out this study, verbal consent was sought from patients and seventy-nine (79) of them were enrolled.

ACKNOWLEDGEMENT

The Authors appreciate the Management and staff of all the institutions that are involved in this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/61730