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ASSESSMENT OF RADIATION DOSE TO PATIENTS RECEIVING RADIOTHERAPY TREATMENT AT THE AHMADU BELLO UNIVERSITY TEACHING HOSPITAL, ZARIA - NIGERIA.

*** Onoja[1], R.A. Idoko[2], E. E. Onoja[3] R.O. Kassimu[4] A.A. and Ogbeh, E.**
[1]Centre for Energy Research and Training, Ahmadu Bello University, Zaria-Nigeria
[2]Day Science College P. M. B. 3147, Kano-Nigeria
[3]Federal Government Girls College Zaria Kaduna
[4]Air Force Research & Development Centre Kaduna
[5]Department of Chemistry, Faculty Sciences A.B.U Zaria
* Corresponding Author: e-mail: raonoja@yahoo.com Phone No.: +2348051348465

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ABSTRACT

Radiation therapy according to Saunders (2003) is the treatment of disease, usually cancer, by ionizing radiation in order to deliver an optimal dose of either particulate or electromagnetic radiation to a particular area of the body with minimal damage to normal tissues. Radiation doses to cancer patients from the use of teletherapy and brachytherapy equipments from 2006 to 2011 were assessed at the Ahmadu Bello University Teaching Hospital (ABUTH), Zaria Nigeria. The analysed data comprised of 50 randomly selected cases of patients who were administered teletherapy treatment for various types of cancer, and another 30 randomly selected cases of patients that received brachytherapy treatment for cervical cancer. The ages of those patients varied from 4 70 years, 26 of those for teletherapy were females while 24 were males, and all the 30 cases for brachytherapy were females. The minimum dose administered was 15 Gy while the maximum dose was 66 Gy. The results showed that of all the 50 cases assessed for teletherapy, 5 of them were given the exact maximum tolerable doses for their treatment while 3 patients were administered the minimum prescribed doses, with doses to 6 patients falling within the prescribed range. Similarly, 21 patients received doses below the prescribed range due to the peculiarity of their conditions while only 2 patients, representing 4% of the total teletherapy cases received doses slightly higher than the recommended level. In conclusion, the study reveals a 96% adherence to International Commission for Radiation Protection (ICRP) recommended standard for teletherapy procedures and 100% compliance for brachytherapy throughout the period under review.

Keywords: *Radiation, Dose, Cancer, Patients, Teletherapy and Brachytherapy.*

INTRODUCTION

Cancer remains a leading cause of death globally; the International Agency for Research on Cancer (IARC) as cited by the American Cancer Society (2016) estimated in 2012 that there were 14.1 million new cases and 8.2 million cancer deaths worldwide. Baskar *et al.* (2012) noted that a significant proportion of this burden is borne by developing countries, and by 2030 the global burden is expected to grow to 21.7 million new cases and 13 million cancer deaths. The future burden might probably even be higher due to adoption of such western life styles as smoking tobacco, unhealthy diet, and physical inactivity mostly by economically developing countries. In a related research, the World Cancer Research Fund International in 2012 discovered that lung cancer is the most common cancer with 1.8 million new cases diagnosed, followed by breast cancer with 1.7 million new cases that same year. Nordqvist (2016) further revealed that breast cancer is the most common invasive cancer in women worldwide, accounting for 16% of all female cancers and 22% of invasive cancers in women. Nevertheless, another study revealed that the 5-year relative survival rate for all cancers diagnosed between 2002 and 2008 is 68% as against 49% between 1975 and 1977. The improvement in survival reflects both progresses in diagnosing certain cancers at an earlier stage and improvements in treatment (American Cancer Society, 2013).

The transformation from a healthy cell into a tumour cell is a multistage process. Facts obtained from WHO (2015) document on Cancer reveals that those changes are due to genetic factors of a person interacting with external agents including; physical carcinogens like ultra violet and ionizing radiation, chemical carcinogens like asbestos, tobacco smoke, aflatoxin food contaminant and arsenic drinking water contaminant, and finally, biological carcinogens like infections from certain viruses, bacteria and parasites. The incidence of cancer rises dramatically with age because the overall risk accumulation is combined with the reduced effectiveness of cellular repair mechanism as a person grows older. While benign tumour may only interfere with the normal working of the organ and seldom threaten a person's life, malignant tumour however, grow and replace normal tissue. An important clue suggested by Crosta (2015) as to why cancer cells spread has to do with their adhesive properties where certain molecular interactions between cells and the scaffolding that holds them in place called extra cellular matrix, which cause them to become unstuck at the original tumour site, they become dislodged, moves on and then reattach themselves at a new site. Cancer Council Australia (2012) also pointed that a metastasis keeps the name of the original cancer; for example, lung cancer that has spread to the bones is still called lung cancer, even though the person may be experiencing symptoms caused by problems in the bones.

Radiation therapy according to Saunders (2003) is the treatment of disease, usually cancer, by ionizing radiation in order to deliver an optimal dose of either particulate or electromagnetic radiation to a particular area of the body with minimal damage to normal tissues. This discipline, according to Michela (2014), was born following upon the discovery of X-ray in 1895 and radioactive phenomena in 1896. Although radiation damages both normal cells as well as cancer cells, the goal of radiotherapy is to maximize the radiation dose to abnormal cancer cells while minimizing the radiation dose to normal cells which are adjacent to cancer cells or in the path of radiation. Unlike chemotherapy which exposes the whole body to cancer fighting drugs, in most cases, radiation therapy is a local treatment (American Cancer Soceity, 2015). Hence, Baskar *et al*. (2012) affirmed that radiation therapy remains an important modality used in cancer treatment accounting for about 5% of total cost of cancer care, yet approximately 50% of all cancer patients will receive radiation therapy during their course of illness.

Rapid progress in this field continues to be boosted by advances in imaging techniques, computerized treatment planning systems, Radiation treatment machines as well as improved understanding of the radiobiology of radiation therapy. Peeters *et al.* (2006) hinted that one of the strategies to improve the efficiency of radiotherapy is increasing the dose. And fortunately, such a dose escalation has become possible with 3D Conformal Radiotherapy (3D-CRT). This technology allows one to better conform the radiation fields to the target volume, and to reduce the dose to the normal tissue. The standard conventional CRT however, poses a large dose bath outside the target and deposits high doses to normal organs, but recent advanced techniques, such as Intensity-Modulated Radiotherapy (IMRT) and Proton Beam Therapy (PBT) are known to provide superior conformal dose distribution for large, irregularly shaped tumors (Fuji *et al.*, 2013). Even though Linear Accelerators (LINAC) are even more advanced and accurate in detecting the target volume, healthy cells are also hit by radiations, which damage normal tissues and bring about side effects. Such effects are unwanted and unavoidable, but can be expected and treated according to the radiotherapist's instructions. Today, major advances in radiation technology have made it more precise, leading to fewer side effects, depending on the individual. Common side effects listed by the U.S National Library of Medicine include skin changes and fatigues. Other side effects depend on the part of the body being treated. Reactions often start during the second or third week of treatment, and may last for several weeks after the final treatment.

Generally speaking, radiation works best when given in higher rather than lower doses; the higher the dose (Energy) of radiotherapy the greater its effectiveness. However, normal cells that border the target cannot repair themselves very well after a high dose exposure. Hence, determining the best radiation dose is a balance between the maximum doses tolerated by normal cells versus the minimum dose. Therefore, the total dose is usually divided into smaller doses called fractions. Doctors take advantage of the body's own healing process by delivering a fraction of the complete dose over multiple sessions. Cancer Council observed that most people have radiotherapy Monday to Friday for 6 to 8 weeks and weekend rest break allow the normal cells to recover. In this method called fractionated radiotherapy, normal cells are allowed time to repair between each radiation session and are protected from permanent injury or death. Breneman and Warnick, (2003) further stated that the greater the number of fractions, the less the risk of injury to normal cells and the fewer the side effects. To ensure best results, radiotherapy can be in association with other oncologic therapies such as surgery, chemotherapy or both. Basker et al. (2012) regarded radiotherapy used before surgery aimed at shrinking the tumor as neoadjuvent therapy while radiotherapy used after surgery is adjuvant therapy and this is aimed at destroying microscopic tumor cells that may have been left. Radiation according to Cameron (1991), is very easy to measure but difficult to measure accurately. However, in radiation protection, an accurate measurement is not needed.

Not all diseases or cancer however, can be cured with radiation. Radiation therapy is also used to shrink tumors and reduce pressure, pains and other symptoms of cancer. Breneman and Warnick, (2003) referred to this kind of treatment as palliative radiation therapy and is used when it is not possible to completely cure the disease. Other times it is used to prevent tumors from developing or spreading (Prophylactic treatment). The type of radiotherapy given will depend on the type of cancer, where it is located and on individual's situation. In fact, MacGill (2016) revealed that cancers that can be particularly suitable for radiation therapy aimed at curing the disease are those that are well defined and confined. This allows the whole area of cancerous tissue to be targeted by the radiation. The goal of this therapy is to improve a person's quality of life. The treatment will be completely painless and each session should only take a few minutes.

The objective of this research is to ascertain whether or not the radiation doses administered to patients during treatment in this hospital complies with the ICRP standard dose prescription for cancer treatment.

MATERIALS AND METHODS

The study area of this research is Ahmadu Bello University Teaching Hospital (ABUTH), Shika-Zaria. Although Ionising radiation is being use here for both radiodiagnostic and the radiotherapy purposes, our area of interest is the radiotherapy unit. The standard gamma ray emitting sources are Cobalt-60 and Cesium-137.

Acquisition of tumor data is usually through the use of optimum imaging modalities defined in tumor site protocols developed in collaboration with diagnostic imaging experts. Tumor information is first obtained using ultra sound, Computed Tomography (CT), Magnetic Resonance Imaging (MRI) as well as from clinical observation, surgical findings and from Simulators.

Two major modalities for administering radiotherapy at ABUTH are the Teletherapy and the Brachytherapy. Teletherapy, sometimes called external beam radiation, is the method where the source, usually Cobalt -60 is placed outside the body cavity and is used in treating localized tumors such as cancer of the skin, tongue, larynx, brain, breast, uterine cervix and others. The treatment machine in use today was developed by BARC and having a capacity of 200 MMR source. It is operated at a source to skin distance (SSD) of 80 cm while on an axis centered on a fixed point called isocentre, the focal spot to skin distance (FSD) is 100cm.

Brachytherapy, also known as internal radiation therapy or sealed source therapy, uses Cesium-137 sources which are placed very close or in contact with the targeted tumor. Here, the absorbed dose falls off rapidly with increasing distance from the source as $1/R^2$ for a point source and 1/R for a line source. Two ways brachytherapy could be delivered include; Low dose rate (LDR) brachytherapy which involves implanting radiation sources that emit radiation at the rate of 2 Gy hr^{-1} and commonly used for cancers of the oral cavity, oropharynx, sarcomas and prostate cancer. High dose Rate (HDR) brachytherapy is an advanced treatment where the dose administered exceeds 12 $Gyhr^{-1}$. It is a computer controlled delivery system that optimizes close distribution to a target as the radiation is delivered with extreme precision through the use of flexible needles or application inserted into a body cavity or tissue. The radiation dose was delivered to a position of tumor with 1mm accuracy and this is done typically within several minutes only. The brachytherapy suit include the curiestock used for storing live sources, the curietron used for delivering live sources into the patient's target volume, the remote control for loading sources and the wall mounted timer.

The approach employed in this research involves random collection of data of patients who underwent teletherapy as well as brachytherapy cancer treatment for comparison with the International Commission for Radiation Protection (ICRP) standard recommended dose. Brachytherapy is mainly used at ABUTH as a support for teletherapy in treating cancer of the cervix for women. This is done to spare the delicate organs like the rectum and bladder from receiving their maximum dose, yet destroying the remaining tumor by focusing the dose directly without danger to the surrounding normal tissues. The type of brachytherapy carried out here is that of the low dose rate, so the patients spend up to two or three days in the unit receiving treatment.

RESULTS AND DISCUSSIONS

The information generated in the course of this research is presented in the following tables. The period under review covers from 2006 to 2011.

Table 1: Treatment Table of Teletherapy in 2006

S/NO	YEAR	AGE	SEX	DIAGNOSIS	DOSE
1	2006	35	F	Cancer of cervix	50 Gy in 25 #
2	2006	47	M	Nasopharyngeal Cancer	64 Gy in 27 #
3	2006	25	M	Anorectal cancer	50 Gy in 35 #
4	2006	25	M	Cancer of parotid	56 Gy in 28 #
5	2006	60	M	Cancer of Rectum	44 Gy in 22 #
6	2006	4	F	Retino blastoma	40 Gy in 20 #

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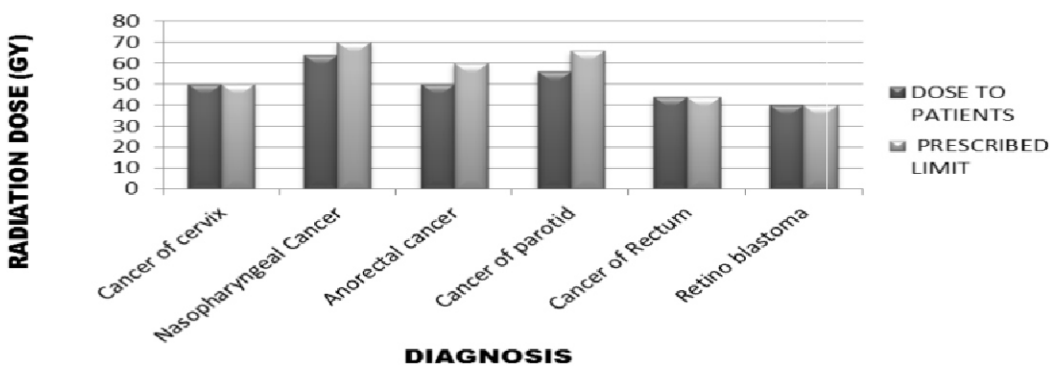

Figure 1: *Comparing the doses to patients in 2006 with the standard prescribed limit.*

The chart of figure 1 shows that Retino blastoma and Cancer of the Rectum were treated with their exact prescribed doses in 2006. Anorectal Cancer and Cancer of the Parotid received doses that were within the prescribed range given in Table 7 while the Cancer of the Cervix was administered the maximum prescribed dose. However, the dose received by Nasopharyngeal Cancer was slightly lower than the prescribed range of doses.

Table 2: Treatment Table of Teletherapy in 2007

S/NO	YEAR	AGE	SEX	DIAGNOSIS	DOSE
1	2007	15	M	Maxillary Cancer	15 Gy in 15 #
2	2007	25	F	Anorectal Cancer	15 Gy in 5 #
3	2007	65	F	Oropharyngeal Cancer	66 Gy in 33 #
4	2007	22	M	Kaposi Sarcoma	25 Gy in 10 #
5	2007	65	F	Oropharynx	66 Gy in 33 #
6	2007	50	F	Cancer of Cervix	50 Gy in 25 #

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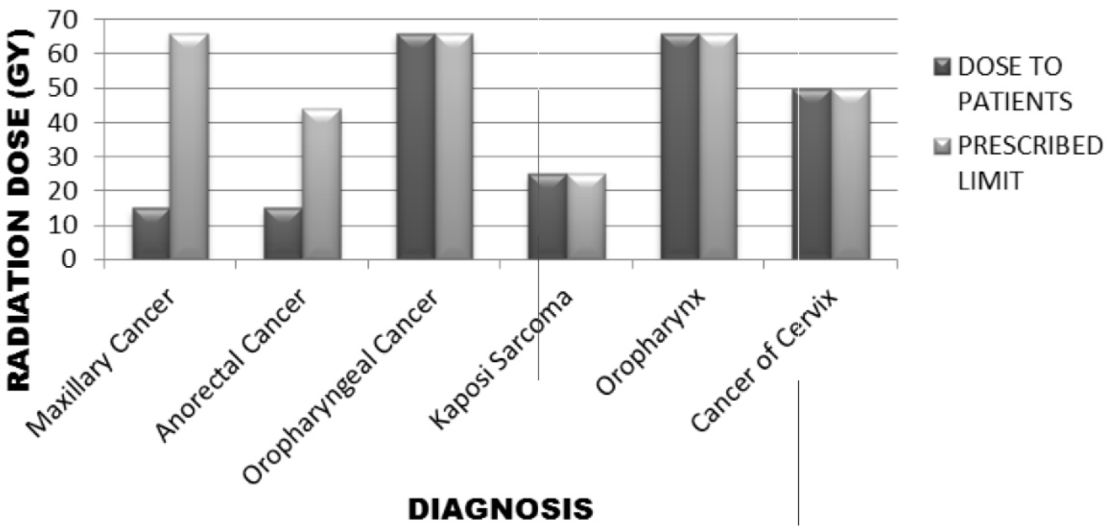

Figure 2: *Comparing the doses to patients in 2007 with the standard prescribed limit.*

In comparison with the standard dose prescription of Table 7, Oropharyngeal Cancer, Kaposi Sarcoma Anorectal as well as Oropharynx were given the exact recommended doses. Cancer of the Cervix was treated with the maximum required dose, whereas the cases of Maxillary Cancer and the Anorectal Cancer received doses far less than the stated level.

S/NO	YEAR	AGE	SEX	DIAGNOSIS	DOSE
1	2008	50	F	Breast Cancer (Right)	50 Gy in 25 #
2	2008	54	F	Breast Cancer (Left)	50 Gy in 25 #
3	2008	50	M	Cancer of Bladder	45 Gy in 20 #
4	2008	39	F	Nasopharyngeal Cancer	66 Gy in 33 #
5	2008	65	F	Oropharyngeal Cancer	40 Gy in 20 #
6	2008	70	M	Metastatic Prostate Cancer	17.5 Gy in 5 #
7	2008	18	M	Cancer of Parotid	60 Gy in 30 #
8	2008	50	M	Cancer of Bladder	44 Gy in 22 #
9	2008	47	M	Neuroblastoma	40 Gy in 20 #
10	2008	70	F	Cancer of Cervix (IV^A)	15 Gy in 5 #
11	2008	51	M	Cancer of Breast	50 Gy in 25 #
12	2008	41	M	Cancer of Anus	15 Gy in 5 #
13	2008	50	F	Cancer of Rectum	45 Gy in 20 #

= Sessions

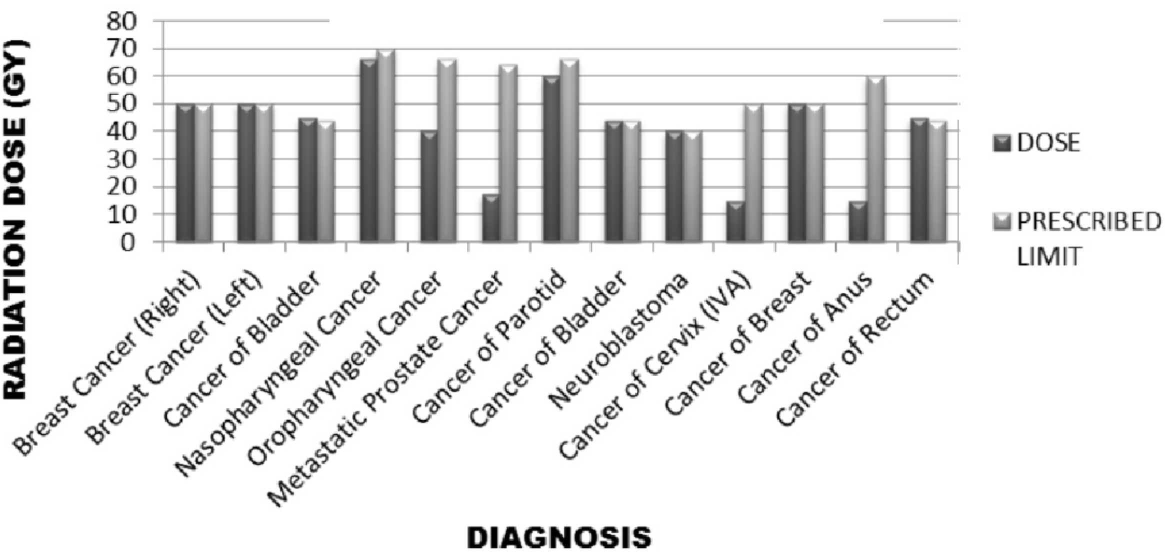

Figure 3: *Comparing the doses to patients in 2008 with the standard prescribed limit.*

In year 2008, Cancer of the Bladder (in row 3 of Table 3) as well as Cancer of the Rectum (of the last row in Table 3) got doses that were slightly higher than the prescribed level by 1 Gy. All the cases of Breast Cancers and the second Cancer of the Bladder received the exact prescribed doses while treatment dose for cancer of the Parotid was within the normal range. Nasopharyngeal Cancer received the minimum required dose while the case of Neuroblastoma got the maximum dose. However, Oropharyngeal Cancer, Cancer of the Cervix as well as Cancer of the Anus were treated with doses much less than the prescribed range due to the peculiarity of the patient's condition

Table 4: Treatment Table of Teletherapy in 2009

S/NO	YEAR	AGE	SEX	DIAGNOSIS	DOSE
1	2009	24	F	Nasopharyngeal Cancer	50 Gy in 25 #
2	2009	38	M	Kaposi Sarcoma	40 Gy in 20 #
3	2009	38	M	Cancer of Prostate	15 Gy in 5 #
4	2009	30	M	Maxillary Tumor	30 Gy in 30 #
5	2009	30	M	Renal Tumor	20 Gy in 5 #
6	2009	30	M	Kaposi Sarcoma	15 Gy in 5 #
7	2009	35	F	Advanced Breast Cancer	30 Gy in 10 #
8	2009	57	F	Endometrial Cancer	47 Gy in 21 #

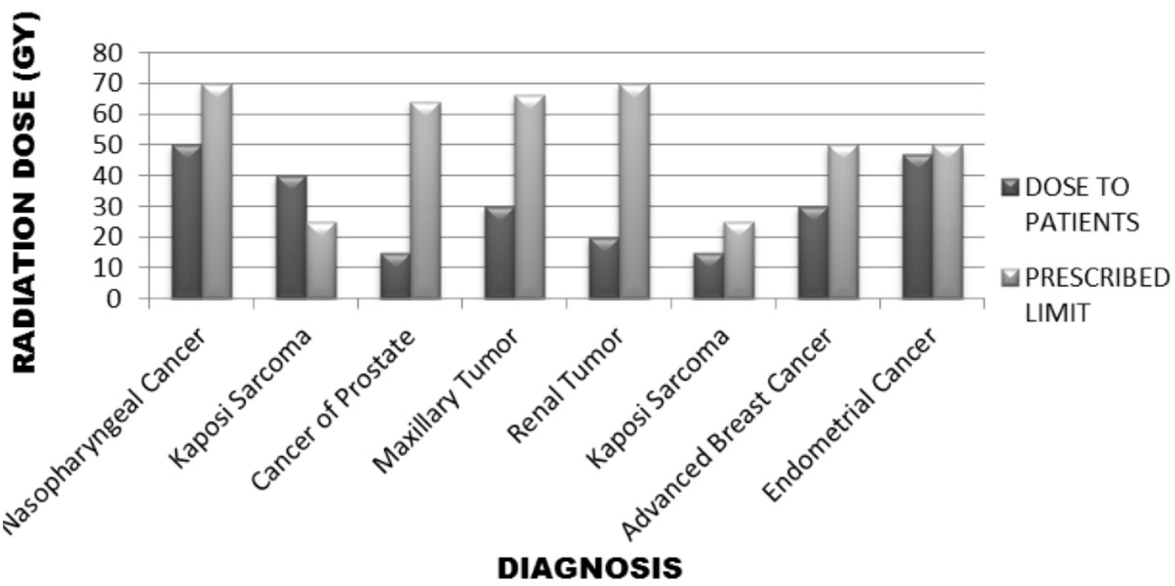

Figure 4: *Comparing the doses to patients in 2009 with the standard prescribed limit.*

Figure 4 shows that the first Kaposi Sarcoma of 2009 was treated with 40 Gy instead of the recommended dose of 25 Gy due to the severity of the condition and other factors considered. Nasopharyngeal Cancer and the second case of Kaposi Sarcoma were each treated dose values that were less than the maximum range while Cancer of the Prostate, Maxillary Tumor as well as the advanced Breast Cancer were given much less radiation doses.

Table 5: Treatment Table of Teletherapy in 2010

S/NO	YEAR	AGE	SEX	DIAGNOSIS	DOSE
1	2010	40	F	Cancer of Cervix	50 Gy in 25 #
2	2010	40	F	Metastatic Cancer of Cervix	40 Gy in 20 #
3	2010	62	F	Breast Cancer	15 Gy in 5 #
4	2010	30	M	Cancer of Bladder	30 Gy in 30 #
5	2010	32	M	Advanced Cancer of Bladder	20 Gy in 5 #

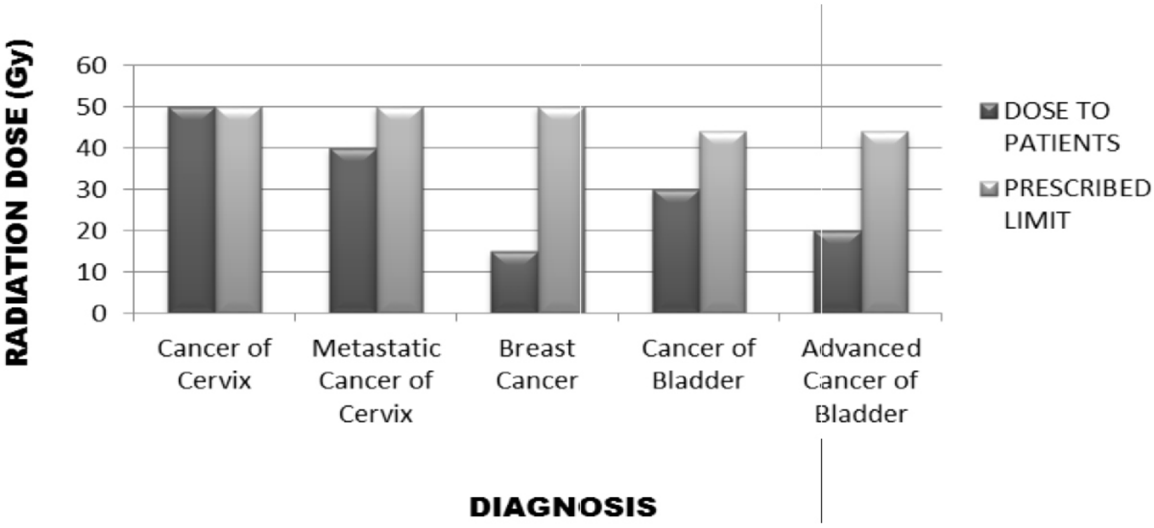

***Figure 5:** Comparing the doses to patients in 2010 with the standard prescribed limit.*

In 2010, Breast Cancer and both Cancers of the bladder were treated with much less radiation doses than expected. The Metastatic Cancer of the Cervix received the minimum required dose while the first Cancer of the cervix got the maximum recommended dose.

Table 6: Treatment Table of Teletherapy in 2011

S/NO	YEAR	AGE	SEX	DIAGNOSIS	DOSE
1	2011	50	F	Cancer of Cervix (III[A])	50 Gy in 25 #
2	2011	45	F	Cancer of Cervix (I[B])	50 Gy in 25 #
3	2011	35	F	Cancer of Cervix	15 Gy in 5 #
4	2011	37	M	Rectal Cancer	25 Gy in 10 #
5	2011	45	M	Maxillary Sarcoma	60 Gy in 30 #
6	2011	35	F	Cancer of Larynx	50 Gy in 25 #
7	2011	40	F	Oropharyngeal Cancer	50 Gy in 25 #
8	2011	30	M	Cancer of Larynx	50 Gy in 25 #
9	2011	50	F	Cancer of Breast (Left)	50 Gy in 25 #
10	2011	40	F	Cancer of Breast (Right)	50 Gy in 25 #
11	2011	47	F	Recurrent Breast Cancer	40 Gy in 20 #
12	2011	40	M	Rhabdomyosarcoma	45 Gy in 25 #

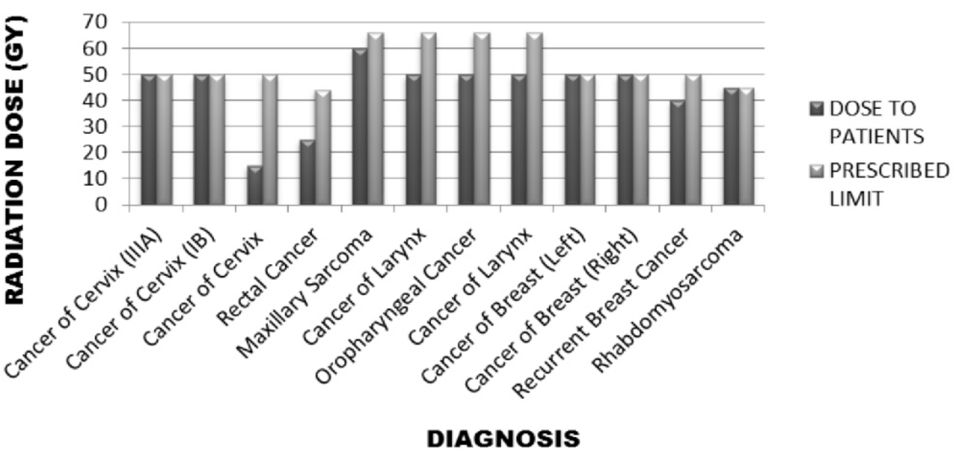

***Figure 6:** Comparing the doses to patients in 2011 with the standard prescribed limit.*

Figure 6 reveals that Rhabdomyosarcoma and both cancers of the Breast were administered their exact needed doses and the first two Cancers of the Cervix got the maximum treatment doses, Maxillary Sarcoma was treated that year with doses within the prescribed range while the third Cancer of the Cervix, Rectal Cancer, Oropharyngeal Cancer and the recurrent Cancer each got less radiation doses than their specified limits.

The period under review in this research is a span of 6 years. A total number of 50 patients who were previously administered teletherapy were randomly selected; notable among them were 8 diagnosed of cancer of the cervix while another 8 had breast cancer. The ages of those patients ranged from 4 to 70 years, 26 of them were females while the remaining 24 were males. The column charts of figures 1 to 6 compares the administered dose to patients in this hospital with the universal standard prescribed dose range for teletherapy. Comparing our data in the treatment tables with the standard prescribed dose of Table 7, it was noted that about 13 of the various cases have just a single recommended treatment dose value while the rest have a rage of tolerable values. The standard Universal dose specified in Dobbs *et al*. (1999) is given in table 7.

Table 7: Standard Dose Prescription for Cancers

S/No	CANCERS	DOSE PRESCRIPTION
1	Cancer of Cervix	40 50 Gy in 20 25 #
2	Cancer of Breast	50 Gy in 25#
3	Nasopharyngeal Cancer	66-70 Gy in 33-35 #
4	Oropharynx	66 Gy in 33 #
5	Maxillary Antrun	55-66 Gy in 20-33 #
6	Retino Blastoma	40 Gy in 20 #
7	Rhabdomyosarcoma	45 Gy in 25 #
8	Carcinoma	50-60 Gy in 20-30#
9	Melanoma	0 70 Gy in 25 35 #
10	Poratid	55-66 Gy in 27-33#
11	Pancreas	45 60 Gy in 20 30#
12	Prostate	64 Gy in 32 #
13	Rectum	44 Gy in 22 #
14	Bladder	44 Gy in 22 #
15	Rectis	30 Gy in 15 #
16	Penis	60 Gy in 30 #
17	Pelvis	44 Gy in 22 #
18	Ovary	25 Gy in 20 #
19	Vagina	40-45 Gy in 20 #
20		35-40 Gy in 20 #
21	Bone and Soft tissue Sarcoma	50 60 Gy in 27 33 #
22	Corpus Uteri	40-50 Gy in 20-25#
23	Testis	35 45 Gy in 15 20 #
24	Kaposi Sarcoma	25 Gy in 10 #
25	Oral Cavity	40-66 Gy in 20-33 #
26	Anus	40-60 Gy in 20-30 #
27	Cervix Uteri	40-50 Gy in 20-25#
28	Neuroblastoma	35-40 Gy in 20 #

= Sessions

From the results, it can be observed that of the 50 cases analysed, 5 of them were given precisely the maximum tolerable doses for their treatment while 3 patients were administered just the minimum prescribed doses, with dosed to 6 patients in-between these limits. Furthermore, 21 patients received doses bellow the prescribed range due to the peculiarity of their conditions while only 3 patients, representing 6% of the total number, received dosed slightly higher than the recommended level; a case of cancer of the bladder and another cancer of the rectum, both in 2008, were administered with 45 Gy each instead of the recommended 44Gy, and another case of Kaposi Sarcoma in 2009 was treated with 40Gy instead of the specified 25G y. The remaining cases amounting to 94% were treated with the standard dose range.

Table 8: Treatment with Brachytherapy Machine

S/NO	YEAR	DIAGNOSIS	DOSE
1	2006	Cancer of Cervix	20 Gy
2	2006	Cancer of Cervix	20 Gy
3	2006	Cancer of Cervix	20 Gy
4	2006	Cancer of Cervix	20 Gy
5	2007	Cancer of Cervix	20 Gy
6	2007	Cancer of Cervix	20 Gy
7	2007	Cancer of Cervix	20 Gy
8	2007	Cancer of Cervix	20 Gy
9	2007	Cancer of Cervix	22 Gy
10	2008	Cancer of Cervix	20 Gy
11	2008	Cancer of Cervix	20 Gy
12	2008	Cancer of Cervix	20 Gy
13	2009	Cancer of Cervix	22 Gy
14	2009	Cancer of Cervix	12 Gy
15	2010	Cancer of Cervix	18 Gy
16	2010	Cancer of Cervix	25 Gy
17	2010	Cancer of Cervix	20 Gy
18	2010	Cancer of Cervix	20 Gy
19	2010	Cancer of Cervix	20 Gy
20	2010	Cancer of Cervix	20 Gy
21	2010	Cancer of Cervix	20 Gy
22	2010	Cancer of Cervix	20 Gy
23	2010	Cancer of Cervix	20 Gy
24	2011	Cancer of Cervix	20 Gy
25	2011	Cancer of Cervix	20 Gy
26	2011	Cancer of Cervix	20 Gy
27	2011	Cancer of Cervix	20 Gy
28	2011	Cancer of Cervix	20 Gy
29	2011	Cancer of Cervix	20 Gy
30	2011	Cancer of Cervix	18 Gy

Even though brachytherapy could be used to treat other types of cancers, it was used during the period under review mainly for treatment of cancer of the cervix and as a complement for dose giving by teletherapy treatment in this hospital; hence, it does not follow any rigid dose specification. The average brachytherapy treatment dose administered as seen in table 8 is 20 Gy which is moderate and very safe for the cervical environment, although three cases received radiation doses above as well as another three cases below this average level, These dose limits are absolute constraints and exceeding those values could have severe effects on the patients. The limits were set for each tumour, among other criteria, on the basis of the knowledge of the tolerance dose of the surrounding normal tissues, the resistivity of the tumour to radiation, as well as the location of the tumour. While under exposure brings about re-growth of the tumour, over exposure leads to radiation caused ailments that could manifest in the nearest future. The detriment to health is directly proportional to the effective dose equivalence resulting from the treatment and is called the risk factor. The risk in this case is the probability that a patient will incur any given radiation effects as a result of radiation exposure.

CONCLUSION

This research compared the radiation doses administered to patients at ABUTH in both teletherapy and brachytherapy procedures within the period spanning 2006 to 2011, with the standard doses prescribed by ICRP. The analysed data indicates a 96% adherence to the ICRP standard for teletherapy treatment and 100% compliance for all the brachytherapy carried out so far. These results imply that the radiotherapy procedures carried out in the radiology department of this hospital is safe, reliable and in compliance with notable world standards.

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