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Evaluation of Organ at Risk Doses Based on 2D Treatment Planning in Intracavitary Brachytherapy of Cervical Cancer at Radioisotope Center in Khartoum State

Nadia O Alatta[1], Wadah. M. Ali[1,2], Nosiba Elkhair[1], Altahir Abdalmalik[2], Ahmad Hasan[1]

[1]National Ribat University, Faculty of Radiological Science and Nuclear Medicine, Khartoum, Sudan

[23]Gulf Medical University, College of Health Science Department of Medical Imaging, Ajman, UAE

Abstract: ***The purpose of this study was to analysis and evaluate the organ at risk (OAR) doses estimated based on International Commission on Radiation Units and Measurements (ICRU) reference-point in patients with cervical cancer treated with high-dose-rate (HDR) Intracavitary brachytherapy (ICBT) in Radiation and Isotopes Center – Khartoum (RICK). This study was conducted at Radiation and Isotopes Center – Khartoum (RICK). The study included 90 cases of patients with cervical cancer. All patients received a therapeutic dose in the Department of brachytherapy of 9 Gy. In addition, the dose was measured for the bladder and rectum and the results were analyzed and evaluated. Patients who exceeded the dose of rectum they had the permissible dose of the total number of patients were 33.3% & patients who exceeded the dose of Bladder they had the permissible dose of the total number of patients were 14.4%. In this study, it was found that the dose to OARs was higher in some cases received treatment in (HDR) Intracavitary Brachytherapy of the dose of OARs based on the (ICRU). It is important to keep the dose as low as possible to avoid the side effect of radiation. Taking into account that the treatment was in two dimensions. This means that the study was based on the measurement of potions for points and not for the whole size so it is preferable to use a three-dimensional treatment technique.***

Keywords: Brachytherapy, cervical cancer, dose of rectum, dose of Bladder, radiotherapy

1. Introduction

The physical advantage of brachytherapy treatment compared with External beam radiotherapy is the improved localized delivery of dose to the Target volume of interest. The disadvantage is that brachytherapy can only be used in cases in which the tumor is well localized and relatively small. In atypical radiotherapy department about 10–20% of all radiotherapy patients are treated with brachytherapy. [2]

Brachy is from the Greek word for 'short' so brachytherapy (also known as sealed source radiotherapy) roughly translated means short-distance therapy. A radioactive Material is inserted directly into or next to a tumor and concentrates the dose there.

The dose falls off very rapidly according to the inverse square law, and surrounding normal tissues receive substantially lower doses than the tumor. [1]

Consist of a very local irradiation. The dose is delivered by one or several sealed sources.

Interstitial radioactive sources are inside the tumor. Contact: sources are close to the tumor. Intracavitary. In which the sources are placed in body cavities close to the tumor volume. Intracavitary treatments are always temporary.[2] Interstitial. In which the sources are implanted within the tumor volume. Interstitial treatments may be temporary or permanent.[2] Endovascular. A single source is placed into small or large arteries.[3] Surface brachytherapy. Sources are placed over the tissue to be treated.[3]

Permanent dose is delivered over the lifetime of the source until complete decay.[2] Temporary dose is delivered over a short period of time and the sources are removed after the prescribed dose has been reached.[2]

The applicator is placed first into the target position and the radioactive sources are loaded later, either by hand (manual after loading) or by a machine (automatic remote after loading) [4]

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Also short treatment times and minimal irradiation protection problems .Radioactive seeds or sources are placed in or near the tumor itself, giving a high radiation dose to the tumor while reducing the radiation exposure to surrounding healthy tissues, inverse square law -ISL being most effective at short distances.[4]

Similar irradiation procedures to external beam irradiation. Optimization of dose distribution being relatively straight forward. [5]

Brachytherapy must be fractionated to avoid normal tissue morbidity. An HDR remote after loading unit contains a single source of high activity (370 GBq). [1]

Although cobalt-60 and cesium- 137 have been used in the past, iridium- 1 92 is the most commonly used radioisotope in HDR. [1]

The HDR unit is equipped with several channels and an indexer system to direct the source to each channel. In some models, channels are provided on a rotating turret in which any channel can be aligned with the source wire path Applicators or catheters implanted in the patient are connected to the channels by catheters called transfer tubes or transfer guides. Before the active source wire is extended for treatment, a dummy wire is extended to verify that the path is clear of any obstruction. [1]

The principal advantage of HDR over LDR is that it permits treatments on an outpatient basis. [2]

For that reason, it is well suited for treating large patient populations. Greater control over dose distribution is another major advantage, which is being used for delivering highly conformal dose to well-localized tumors, for example, as a boost or primary treatment for prostate cancer. Although the role of HDR in brachytherapy is not yet fully established, all indications point toward its widespread use as a sole procedure or in conjunction with external beam. If the current trends continue, it is quite possible that HDR will replace all brachytherapy techniques in the not too distant future. [2]

The International Commission on Radiation Units and Measurements (ICRU) 50 report (ICRU 1993) stipulates standard protocols for recording and reporting radiotherapy treatments of all degrees of complexity. These include the adoption of standard terminology to describe the volumes relevant to radiotherapy treatment planning. The adoption of these terms serves several purposes:

- Improves clarity of thought and encourages a logical approach to planning
- Promotes consistency in physics planning and clinical practice
- Allows standardization of clinical trial protocols, particularly for complex, multiphase treatments
- *Facilitates communication between different centers and within clinical trials. [2]

The Gross Tumor Volume (GTV) is the gross palpable or visible/demonstrable extent and location of malignant growth. [6]

The GTV is usually based on information obtained from a combination of imaging modalities (CT, MRI, ultrasound, etc.), diagnostic modalities (pathology and histological reports, etc.) and clinical examination. [6]

The Clinical Target Volume (CTV) is the tissue volume that contains a demonstrable GTV and/or sub-clinical microscopic malignant disease, which has to be eliminated. This volume thus has to be treated adequately in order to achieve the aim of therapy, cure or palliation. It is usually determined by the radiation oncologist, often after other relevant specialists such as pathologists or radiologists have been consulted. [2]

The Internal Target Volume (ITV) consists of the CTV plus an internal margin. The internal margin is designed to take into account the variations in the size and position of the CTV relative to the patient's reference frame (usually defined by the bony anatomy), i.e., variations due to organ motions such as breathing, bladder or rectal contents, etc . [6]

The Planning Target Volume (PTV) is a geometrical concept**.**

It is defined to select appropriate beam arrangements, taking into consideration the net effect of all possible geometrical variations, in order to ensure that the prescribed dose is actually absorbed in the CTV. [6]

Organ at Risk is an organ whose sensitivity to radiation is such that the dose received from a treatment plan may be significant compared to its tolerance, possibly requiring a change in the beam arrangement or a change in the dose. [6]

Meanwhile, the most frequent clinical complications of the treatments result from a high dose delivered to portions of the rectum and bladder that are in close proximity to the irradiation area. Applicator placement in intracavitary brachytherapy is very important in order to keep the dose received by these critical organs as low as possible. Therefore the dose received by these two organs must be evaluated in order to avoid complications. [7]

2. Materials and method

2.1 Study design

Measurement, analysis and evaluation of a number of cases.

2.2 Study Area

Radiation and Isotopes Center - Khartoum (RICK) - Department of brachytherapy .

2.3 Study population

This study is conducted on 90 patients cervical cancer aged from 40 to 60 years.

2.4 Data collection

The data will be collected by the medical physicist in the department and the researcher so that the dose is measured under his supervision and analyzed and evaluated by the researcher.

2.5 Material

2.5.1 The Devices

Simulator

Patient simulation was initially developed to ensure that the beams used. For treatment were correctly chosen and properly aimed at the intended target. At present, treatment simulation has a .more expanded role in the treatment of

patients, consisting of:

- Determination of the patient treatment position
- Identification of the target volumes and organs at risk
- Determination and verification of the treatment field geometry
- Generation of simulation radiographs for each treatment beam for
- Comparison with treatment port films
- Acquisition of patient data for treatment planning

Applicator

Gynecological applicators are usually made of stainless steel. This will attenuate the radiation by a small percentage. Standard source models do not take this into account, but an adequate correction (albeit not considering oblique filtration) may be made by reducing the source activity by a small amount and each applicator contains semiconductor detector (Used to measure dose).

Used two types of applicator:
Ring cervix Applicator.
Cylindrical cervix applicator.
Semiconductor detector

Semiconductor dosimeters are an excellent choice for such an application due to the following advantages:

1) A much higher sensitivity (18000 times) than ionizing chambers (IC) of the same volume due to a higher density and ionization energy that is approximately 10 times smaller than what is required in a gas.
2) A small dosimetric volume size leading to satisfaction of the Bragg- Gray cavity theory, high spatial resolution dosimetry and the possibility of placement within a confined space of a body or phantom.
3) Good mechanical stability. The three main semiconductor detectors for accumulated type dosimetry

That will be considered in this section are silicon diodes, diamond detectors and MOSFET (Metal Oxide Semiconductor Field Effect Transistor) detectors. All of them have advantage in photon and electron therapy due to tissue equivalency. It is achieved due to the mass collision stopping power ratio (silicon-to water being almost energy independent for electron energies in conventional MV therapy.

Treatment machine (CO60)

Multisource [Eckert & Ziegler] BEBIG. The Multisource® HDR after loading system is designed for the entire range of HDR brachytherapy applications. The Multi Source(R) is medical device equipment that allows performing the Temporary brachytherapy treatment of cancers. Using a radioactive source (Co-60) contained and shielded in a trolley, catheters are

Inserted by the physician into the body and allow for a 'temporary implant ‘to be positioned directly inside the tumor ('remote afterloading' technique).

Note:
Company: Eckert & Ziegler Strahlen- und Medizintechnik AG
Robert-Rössle-Str.10 13125 Berlin Deutschland

2.5.2 Computer software

Treatment Planning System (TPS)
Multisource PLUSE [Eckert & Ziegler] BEBIG. TPS uses Brach vision software both two-dimensional method. Two-dimensional method based on points on two-dimensional radiographic image of the patient. The points are A, B, rectum and bladder.

Note:
Company: Eckert & Ziegler Strahlen- und Medizintechnik AG Robert-Rössle-Str.10 13125 Berlin Deutschland
Excel program
Use to analyze data.

2.5.3Patients

A total of 90 cervical cancer patients (women) ranging in age from (40 to 60) Yr. All patients were given a dose 9 Gy.

2.6 Methods

Simulation is a treatment planning session that is done before the doctor first HDR brachytherapy treatment. During simulation, measurements and x-rays are taken to help Radiation oncologist and medical physicist plan the doctor treatments. The nurse will ask the patient to empty his bladder and change into a hospital gown. The patient will be taken into the simulation (planning) room, where the patient will lie down on a table.

- Radiation oncologist will place an applicator into the patient vagina. The applicator is similar to a large tampon. At first, the patient may experience a stretching feeling at the entrance to the patient vagina. Then the patient will just have a feeling of fullness. Taking slow, deep breaths through the patient mouth will help the patient relax. A CAT (CT) scan or MRI may be done to complete the planning of treatment.
- Radiation oncologist will prescribe the amount of radiation the patients are to receive.
- The doctor will determine the number of treatments the patient will need.
- During the session the dose to the rectum and bladder is calculated.
- Each application is performed under spinal an aesthesia in the lithotomic position.
- The selections of the applicator set applied to patient were chosen according to the suitability of patient’s anatomical structures. Packing procedure was conducted during insertion of applicators to avoid any shifts or changes in the geometry of the applicators position and at the same time prevent the relocation of rectum and bladder.
- The OAR markers and applicators were checked to position the probe at the right place before patients moved to the simulation room.
- For simulation procedures, x-ray markers or dummies were inserted through the applicator’s cavity. The markers are function to visualize the image of each applicator on

the radiographs and source loading positions in treatment planning.

- During the session the dose to the rectum and bladder is calculated.
- The dose was calculated in the rectum and bladder by the medical physicist and researcher.
- 90 readings were taken and placed in tables and analyzed by the researcher.

3. Result

These results were taken from the in Radiation and Isotopes Center– Khartoum (RICK) – Radiation Therapy Department. This study was conducted on 90 patients and each patient received a therapeutic dose of 9Gy. These results include the bladder and rectal dose. These results were divided into the number of units. Tables 1, 2, to 6 shows bladder and rectum doses in the six units

Table 1: Measurements of bladder and rectal doses and Percentage of dose for 26 patients of the unit A

Patient Number	Bladder dose Gy	Percentage of Bladder dose %	Rectum dose Gy	Percentage of Rectum dose %
1	3.69	41%	4.03	44.7%
2	4.11	45.6%	4.81	53.4%
3	3.91	43.4%	4.13	45.8%
4	2.46	27.3%	5.27	58.5%
5	2.05	22.7%	4.42	49.1%
6	5.72	63.5%	3.66	40.6%
7	4.4	48.8%	2.93	32.5%
8	6.13	68.1%	3.54	39.3%
9	6.37	70.7%	6.04	67.1%
10	3.84	42.6%	4.81	53.4%
11	5.01	55.6%	6.06	67.3%
12	3.61	40.1%	2.94	32.6%
13	6.32	70.2%	5.04	56%
14	3.39	37.6%	4.34	48.2%
15	5.82	64.6%	4.82	53.5%
16	6.7	74.4%	6.07	67.4%
17	5.5	61.1%	4.93	54.7%
18	5.81	64.5%	4.43	49.2%
19	7.99	88.7%	7	77.7%
20	7.62	84.6%	6.32	70.2%
21	3.17	35.2%	2.31	25.6%
22	2.82	31.3%	4.54	50.4%
23	3.73	41.4%	2.33	25.8%
24	1.95	21.6%	3.54	39.3%
25	3.84	42.6%	2.44	27.1%
26	4.52	50.2%	2.63	29.2%

Table 2: Measurements of bladder and rectal doses and Percentage of dose for 20 patients of the unit B

Patient Number	Bladder dose Gy	Percentage of Bladder dose %	Rectum dose Gy	Percentage of Rectum dose %
1	4.11	45.6%	5.09	56.5%
2	6.12	68%	4.65	51.6%
3	3.29	36.5%	4.32	48%
4	4.29	47.6%	4.53	50.3%
5	7.93	88.1%	6.6	73.3%
6	7.88	87.5%	6.62	73.5%
7	7.36	81.7%	6.92	76.8%
8	5.29	58.7%	6.25	69.4%
9	4.64	51.5%	3.34	37.1%
10	4.79	53.2%	2.55	28.3%
11	2.02	22.4%	6.35	70.5%
12	5.76	64%	3.85	42.7%
13	3.82	42.4%	4.54	50.4%
14	5.08	56.4%	5.01	55.6%
15	6	66.6%	2.72	30.2%
16	1.68	18.6%	3.56	39.5%
17	5.74	63.7%	5.21	57.8%
18	6.97	77.4%	5.45	60.5%
19	5.98	66.4%	4.51	50.1%
20	7.48	83.1%	6.03	67%

Table 3: Measurements of bladder and rectal doses and Percentage of dose for 18 patients of the unit C

Patient Number	Bladder dose Gy	Percentage of Bladder dose %	Rectum dose Gy	Percentage of Rectum dose %
1	3.25	36.1%	2.02	22.4%
2	2.78	39.7%	5.03	55.8%
3	1.74	19.3%	4.87	54.1%
4	2	22.2%	4.68	52%
5	3.78	42%	1.84	20.4%
6	3.88	43.1%	2.73	30.3%
7	6.47	71.8%	6.14	68.2%
8	3.14	34.8%	5.44	60.4%
9	6.08	67.5%	7.1	78.8%
10	3.79	42.1%	6.07	67.4%
11	7.4	82.2%	6.63	73.6
12	7.59	84.3%	7.88	87.5%
13	3.76	41.7%	4.54	50.4%
14	4.8	53.3%	6.84	76%
15	6.49	72.1%	4.99	55.4%
16	5.46	60.6%	4.34	48.2%
17	6.39	71%	5.89	65.44%
18	7.05	78.3%	7.02	78%

Table 4: Measurements of bladder and rectal doses and Percentage of dose for 18 patients of the unit D

Patient Number	Bladder dose Gy	Percentage of Bladder dose %	Rectum dose Gy	Percentage of Rectum dose %
1	1.96	21.7%	6.77	75.2%
2	1.82	20.33%	5.12	56.8%
3	7.94	88.2%	6.98	77.5%
4	4.12	45.7%	4.93	54.7%
5	6.95	77.2%	4.28	47.5%
6	5.43	60.3%	1.98	22%
7	4.41	49%	5.03	55.8%
8	5.32	59.1%	5.22	58.2%
9	5.97	66.3%	4.51	50.1%
10	8.48	94.2%	6.09	67.6%
11	7.82	86.8%	6.19	68.7%
12	8.03	89.2%	7.6	84.4%
13	6.26	69.5%	4.86	54%
14	3.63	40.3%	2.97	33%
15	2.14	23.7%	6.75	75%
16	1.83	20.3%	4.69	52.1%
17	2.52	28%	4.67	51.8%
18	4.02	44.6%	0.97	10.7%

Table 5: Measurements of bladder and rectal doses and Percentage of dose for 6 patients of the unit E

Patient Number	Bladder dose Gy	Percentage of Bladder dose %	Rectum dose Gy	Percentage of Rectum dose %
1	4	44.4%	2.88	32%
2	5.82	64.6%	3.84	42.6%
3	1.95	21.6%	6.77	75.2%
4	7.93	88.1%	1.47	16.3%
5	3.12	34.6%	5.8	64.4%
6	2.28	25.3%	4.55	50.5%

Table 6: Measurements of bladder and rectal doses and Percentage of dose for 2 patients of the unit F

Patient Number	Bladder dose Gy	Percentage of Bladder dose %	Rectum dose Gy	Percentage of Rectum dose %
1	4.37	48.5%	5.18	57.5%
2	6.43	71.4%	5.13	57.0%

Table 7: Percentage of dose for Bladder for 90 patients

No of Patient	Percentage of Bladder dose%
0	0-10 %
2	10 – 20%
12	20 – 30%
8	30 – 40%
21	40 – 50%
8	50 – 60%
16	60 – 70%
10	70 – 80%
13	>80%

Table 8: Percentage of dose for rectum for 90 patients

No of Patient	Percentage of Bladder dose%
0	0-10 %
2	10 – 20%
8	20 – 30%
10	30 – 40%
10	40 – 50%
30	50 – 60%
30	>60%
0	0-10 %

Table 9: Number of patients with the total OARs exceeding Standard department practice According (ICRU)

	Bladder	Rectum
Number of patients (n = 90)	13/90	30/90
Percentage (%)	14.4%	33.3%

4. Discussion

In the ideal case, the dose of the bladder and rectum should be equal dose. The bladder and rectal dose is based mainly on how the applicator is placed by the oncologist.

Table 1 shows that 16 of the patients (26 patients) had a greater proportion of the dose that reached the bladder than Rectum dose. It was also found that 2 patients had exceeded the permissible dose of bladder. It was also found that 5 patients had exceeded the permissible dose of rectum.

Table 2 shows that 12 of the patients (20 patients) had a greater proportion of the dose that reached the bladder than Rectum dose. It was also found that 4 patients had exceeded the permissible dose of bladder. It was also found that 7 patients had exceeded the permissible dose of rectum.
Table 3 shows that 9 of the patients (18 patients) had a greater proportion of the dose that reached the bladder than Rectum dose. It was also found that 2 patients had exceeded the dose permissible of bladder for. It was also found that 9 patients had exceeded the dose permissible of rectum.

Table 4 shows that 11 of the patients (18 patients) had a greater proportion of the dose that reached the bladder than Rectum dose. It was also found that 4 patients had exceeded the permissible dose of bladder. It was also found that 6 patients had exceeded the dose of rectum for them the permissible dose. Table 5 shows that 3 of the patients (6 patients) had a greater proportion of the dose that reached the bladder than the Rectum dose. It was also found that 1 patient had exceeded the permissible dose of bladder. It was also found that 2 patients had exceeded the permissible dose of rectum. Table 6 shows that 1 of the patient (2 patients) had a greater proportion of the dose that reached the bladder than Rectum dose.It was also found that NO patient had exceeded the permissible dose of bladder. It was also found that NO patient had exceeded the permissible dose of rectum.

5. Conclusion

In general, it was found that the most patients who exceeded the permissible dose of rectum in unit C. In contrast, it was found that the most patients who exceeded the permissible dose of bladder in unit (B&D). Overall, it was found that 14.4% of the total number of patients (90 patients) exceeded the permissible dose of bladder. In contrast, 33.3% of the total number of patients (90 patients) exceeded the permissible dose of rectum.

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