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A study of different external beam radiotherapy techniques for cervix cancer and measurement of dose to the rectum

Sajad Ahmad[1], M. Mohib-ul Haq[1], Feroze Ahmad Mir[2], Nazir Ahmad Khan[3] and Ajaz Ahmad[1]

[1]Department of Radiological Physics and Bio-Engineering, Sher-i-Kashmir Institute of Medical Sciences, Srinagar 190011, J&K, India.
[2]Department of Nuclear Medicine, Sher-i-Kashmir Institute of Medical Sciences, Srinagar 190011, J&K, India.
[3]Department of Radiation Oncology, Sher-i-Kashmir Institute of Medical Sciences, Srinagar 190011, J&K, India.

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ABSTRACT

The aim of the present study is to investigate the rectal dose during three different radiotherapy techniques of cervical cancer. The study was carried out using a Anderson Rando female phantom. The thermo-luminescent dosimeter (TLD) capsules and detectors of rainbow dosimeter were employed for rectal and target volume dose determination. Several techniques of external beam radiation therapy such as two-field (AP-PA), three-field and four-field with equal applied dose were planned. During application of different radiotherapy techniques, the maximum dose received by rectum is due to the two-field technique. The results of two dosimetry types were compared with each other, In three-field, four-field equal applied dose, rectal dose was lower than tumor dose. This study showed that using TLD and rainbow dosimetry during radiotherapy could have a useful role as a predictor of choosing appropriate technique for preventing future rectal complications. Dose limitation to the rectum could possibly be achieved by using three-field and four-field techniques with equal tumor dose while maintaining a high dose to the tumor.

Introduction

Cancer is the most progressive and devastating disease posing a threat of mortality to the entire world despite significant advances in medical technology for its diagnosis and treatment. It is estimated that by the year 2020 there will be almost 20 million new cases. Worryingly, it is not only in the number of new cases that will increase but also the proportion of new cases from the developing countries like India will also rise to around 70%. The magnitude of the problem of cancer in the Indian Sub-Continent is alarming [1]. Though the cancer incidence rate in India is less than that of the Western countries but due to the large population size, number of cases is more prevalent at any time [2]. The most common cancers among females are cervix, breast, ovary, oesophagus and mouth. Of this, cervical cancer is the second most common cancer among women worldwide after breast cancer. According to the WHO report, globally, cervical cancer comprises 12% of all cancers in women and it is the leading gynaecological malignancy in the world [3]. Carcinoma of the uterine cervix is the most common malignancy to affect females in developing countries. In developing countries, it accounts for about 3.4 lakh new cases and 1.6 lakh deaths every year [4]. It is a leading cause of death among women between 35 and 45 years [5]. Cervical cancer is the second most common cancer in females in the world with around 500,000 new cases occurring annually, but the first in the developing countries with a high mortality if not diagnosed early [6]. In India about 1.25 lakh new cases and 80,000 deaths are reported every year from this disease. At present, the age-adjusted incidence rates for cervical cancer range from 19 to 44 per lakh women in various cancer registries of India. The life time risk of cancer cervix would be estimated at 3.7 % in the absence of screening. Either surgery or radiotherapy alone can be used to treat early stages of cervix cancer. The main objective of radiotherapy is to deliver lethal dose to tumor cells without inducing irreparable or unacceptable damage to the surrounding normal tissues.

Radiotherapy plays an important role in the treatment of cancers. It treats cancer by using high-energy rays which destroy the cancer cells, while doing as little harm as possible to normal cells. Radiotherapy for cancer of the cervix can be given externally or internally, and often as a combination of the two. It is usually given if the cancer has spread beyond the cervix and is not curable with surgery alone and may also be used after surgery if there is a high risk that the cancer may come back. It is often given in combination with chemotherapy.

External beam radiotherapy (EBRT) plays an important role in the management of patients with carcinoma cervix. EBRT treats the whole pelvis, including clinically and radiologically apparent tumor, uterine corpus, upper part of vagina, parametrium, and the draining lymph nodes. EBRT is best utilized for tumors that are geometrically defined, isolated, and hard to treat surgically.

Radiotherapy of cervix carcinoma often results in high doses to surrounding structures, such as rectum and bladder. Therefore, these organs should be closely monitored. The late complications manifesting on these organs, as a result of radiotherapy, can lower the therapeutic ratio and significantly decrease patient quality of life [7-9]. The most important treatment related factors that could lead to creation of late complications on rectum include total dose to the rectum and the volume of irradiated rectum. Of those, the dose delivered to the rectum is particularly important [10]. Researchers try to develop new treatment techniques by which increasing patients survival and concomitantly minimizing morbidity [11, 12]. Apart from

Tele:
E-mail addresses: sajadahmad777@yahoo.com

accuracy of the dose at the point concerned, a uniform dose distribution within the target volume is also crucial for successful radiotherapy. It is generally accepted that variance in the dose delivered to the patient should not be greater than 5% at the reference point [13]. More recently, a tolerance of 3.5% has been suggested [14]. Subsequently, the International Commission on Radiation Units and Measurements report No. 50 has recommended dose homogeneity of between -5% and +7% of the prescribed dose throughout the planned target volume [15].

Materials and methods

Alderson Rando female phantom was used as a patient for determining the received dose. The phantom is transacted horizontally into 2.5 cm thick slices. Each slice has holes which are plugged with bone equivalent, soft-tissue or lung tissue equivalent pins which could be replaced by TLD capsules and detectors of rainbow dosimeter and are ordered separately. Figure 1 shows an Alderson Rando female phantom.

Figure 1. Alderson Rando female phantom

Figure 2. Radiograph of the pelvis of the phantom

The Rando phantom was placed on the Co-60 teletherapy machine table. Total Dose of 5000 cGy is given in 25 fractions with a dose of 200cGy per fraction. Several techniques of external beam radiation therapy such as two-field (AP-PA), three-field and four-field were planned. Three-field technique consisted of two lateral fields and one anterior field. Four-field arrangement consists of two laterals and one anterior and one posterior fields with equal applied dose to each field. Treatment fields were simulated using a simulator. The dosimetry results based on TLD and rainbow dosimeter measurements were compared with each other.

The detectors of rainbow dosimeter were employed for the measurement of radiation doses. The dosimeter has applications for relatively low doses and dose-rate independent up to 10^{-8} Gy s^{-1}. The system is also independent of relative humidity and can be used over a broad temperature (0 to 5 ^{o}c). The integrated radiation effect that is used for the measurement is the shift in threshold voltage due to trapped charge in the multilayered device. This threshold voltage is evaluated in the measurement of the channel (drain) current as a function of gate voltage at a constant supply voltage to the device. Three detectors were put at the points of interest in irradiation volume.

A TLD reader system together with some TLDs of $CaSO_4$ were used for dose measurement. TLD capsules in the size with diameter 0.4 cm and with length 1.4 cm were used for dose measurement. For annealing procedures the TLDs were heated to 400 °C and maintained at that temperature for 1 hr, followed by 100 °C for 2 hr then cooled to room temperature. For dose measurement, TLDs were inserted by vacuum tweezers in a sequential order of labelled TLDs at the pre-determined sites in slice 31 of the phantom. The position was determined by the fact that the cervix is the lower part of the uterus. Figure 2 shows the radiograph of the pelvis of the phantom. Three TLD capsules were used at each measurement site.

Results

The comparison of the mean absorbed dose by TLD and rainbow dosimeter in all techniques following cervix cancer treatment are given in table-A. The calculated dose for rectum by TLD was as follows: 1.97 Gy with two-field, 1.62 Gy with three-field, 1.33 Gy with equal applied dose and the calculated dose for rectum by rainbow dosimeter was as follows: 2.03 Gy with two-field, 1.87 Gy with three-field, 1.69 Gy with equal applied dose.

The results obtained from the TLD and rainbow dosimeters were grouped according to their locations points of interest in the irradiation volume. Three points were selected for dosimetry on the phantom slice (slice 32).

Table A: Comparison of the mean absorbed dose by TLD and rainbow dosimeter for treatment of cervix cancer in different techniques with Co-60 teletherapy unit.

Different techniques	**Dose to the Rectum (TLD) Gy**	**Dose to the Cervix (TLD) Gy**	**Dose to the Rectum (Rainbow dosimeter) Gy**	**Dose to the Cervix (Rainbow dosimeter) Gy**
Two field technique	1.97	2.03	2.03	2.07
Three field technique	1.62	1.88	1.87	2.10
Four field technique	1.33	1.92	1.69	1.96

Conclusions

By using multiple fields, the ratio of the tumor dose to the normal tissue dose was increased. Although multiple fields could provide good distribution, there are some clinical and technical limitations in these methods. For example, certain beam angulations were practically impossible due to the presence of critical organs. Also, the set-up accuracy of a treatment may be better with parallel opposed than with multiple angles beam arrangement.

As far as comparison of point measured dose is concerned the following conclusions could be drawn:

- Maximal rectal dose was obtained using two-field technique.
- Considering similar target volume, best normal tissue sparing was obtained by using the three-field and four field techniques with equal tumor dose.
- There is a uniform dose distribution throughout the tumor volume.

- In comparison of the TLD and rainbow dosimetry results with the prescribed dose, it was demonstrated that there was significant difference between the measured and prescribed dose by tumor volume and rectum

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