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Comparison of Radiation Absorbed Dose Received by Bladder and Rectum between Conventional and Conformal Treatment Planning Methods in Radiotherapy of Prostate Cancer

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Nowadays prostate cancer is the second widespread cancer among men. It is important to use new techniques in radiation therapy of prostate cancer that make lower exposure to normal tissues. Not withstanding the conformal radiotherapy methods with 3-dimensional treatment planning which are known as 3-D conformal radiotherapy and IMRT are using for radiotherapy of prostate cancer, the Co-60 Unit with conventional 2-dimensional treatment planning is still using for radiotherapy of prostate cancer in some of radiotherapy centers, particular in developing countries. Therefore, this study is designed to evaluate the method that, with using of shielding blocks and 3-D treatment planning instead of 2-D planning for Co-60 unit therapy, is able to reduce the received dose by critical uninvolved organs such as bladder and rectum. Both treatment planning methods were done on a tissue-equivalent and anthropomorphic phantom in the way of equally weighted 4-field (Box method), that consist of two pairs of parallel-opposed anterioposterior and right and left lateral beams to deliver 200 cGy to isocenter point. The TLD-100 dosimeters were used for measuring the absorbed doses of rectum and bladder. Cerrobend blocks for shaping each radiation field were constructed and used in 3-D treatment planning method. The experiments were repeated five times and absorbed dose values compared with paired student's t-test for a confidence level of 95%. The average of measured values of received dose by bladder and rectum in 2-D conventional treatment planning were 117.5±3.4, 120.5±4.6, 80.4±3.8 and 77±3.2 cGy, respectively, in 3-D conformal treatment planning. The results show that use of Cerrobend blocks in 3-D conformal treatment planning, significantly reduces the absorbed dose to critical uninvolved structures in proportion to 2-D conventional radiotherapy of prostate cancer with using Co-60 unit.

Key words: Radiation therapy, treatment planning, absorbed dose of bladder and rectum, prostate cancer, thermoluminescent dosimetry

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INTRODUCTION

Increasing of death due to prostate cancer shows the growth of this disease, nowadays prostate cancer is the second wide spread cancer and also is the second most common cause of cancer mortality among men (Parkin *et al*., 2005; CDC, 2001). It is estimated that more than 300,000 new instances of prostate cancer are discovered in the United States, that 41,000 of them are certainly fatal (ACS, 2007).

Modern technology and new treatment techniques play important role in effective external radiotherapy of prostate cancer which leading to lower exposure to normal tissues and consequently decreasing the side effects of radiation therapy that improves the quality of life of patients (Vijayakumar *et al*., 1993; Dearnaley *et al*., 1999). Today, the conformal radiation therapy methods with 3-dimensional treatment planning are used for carcinoma of prostate in the most modern/developed radiotherapy centers, while there are too many centers that because of some problems such as cost use the conventional method with 2-dimensional treatment planning.

Therefore in this study, we measured the received dose by critical uninvolved organs such as bladder and rectum in two methods using Co-60 unit via anthropomorphic phantom.

MATERIALS AND METHODS

Phantom: The phantom was consisting of three segments: Head and neck, trunk and hip (Fig. 1). In this study we used only its hip region. The phantom is constructed with natural human skeleton and its geometrical sizes are nearly according to standard human (ICRP., 1975). (Its total high is 95 cm and the trunk's thickness is 22 cm). Its internal organs are made of mixture of wax and salt (sodium chloride), that their average effective atomic number (Z_{eff} = 6.57) and electron density (3.36×10^{23} electron/cm^3) were close to soft tissue values (Khan, 2003). The amount of percent combination of wax and salt varied (density range was 0.9-0.97 g cm^{-3}) to making different densities corresponding to different tissues. To mimicking lung tissue, The porous wood with density of 0.3 g cm^{-3} was used. Considering to these qualifications, we can declare that the phantom is tissue-equivalent and anthropomorphic and could utilize in radiotherapy applications.

Thermoluminescent dosimetry: Natural LiF TLD-100 (LiF:Mg,Ti) chips with closely matched sensitivities were used. These TLDs have the dimension of $3.1\times3.1\times0.9$ mm^3 (~28 mg), the effective number of 8.14, the main peak in the glow curve of 195°C and the fading rate of 5% per year at 20°C. The TLD chips were calibrated with Co-60 gamma rays and the prerequisite corrections for increasing the precision of dosimetry were done and the values of absorbed doses were calculated with reading the chips on TLD-reader system (3500 manual model, Harshaw, USA) (Kron, 1994, 1995; Wood and Mayles, 1995; McKinlay, 1981).

A cylindrical hole with its central axis in anterioposterior direction crossing the bladder, center of prostate gland and rectum was established for placing the chips in hip (Fig. 2).

Treatment planning: The 2-D and 3-D treatment planning was done with ALFARD and Core-PLAN softwares, respectively, on the tissue-equivalent and anthropomorphic phantom, in the way of, CT-scan images data of region of hip from phantom downloaded in treatment planning computer.

In treatment planning, the volume of prostate gland was selected as a Planning Target Volume (PTV) with 0.8 cm margin, also equally weighted 4-field (Box method) (Khan, 1998; Perez *et al*., 1997), that consist of two pairs of parallel-opposed AP (8×8 cm^2) and right and left

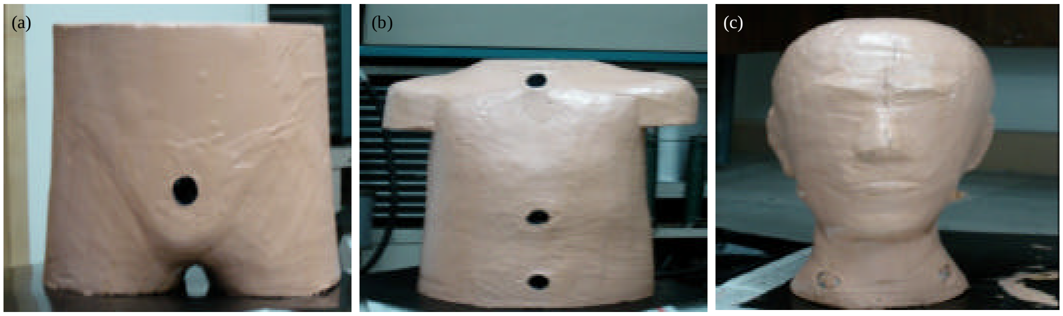

Fig. 1(a-c): Constructed phantom. We used only its hip region (a) Hip, (b) Trunk and (c) Head region

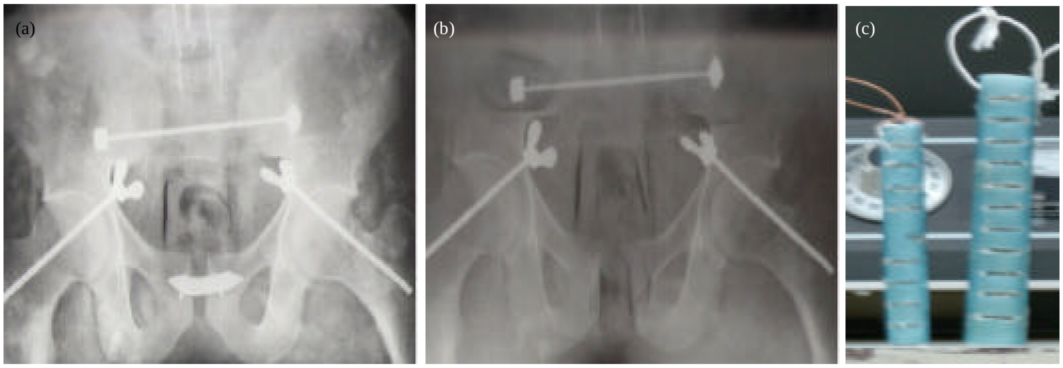

Fig. 2(a-c): Radiographs of hip region of phantom, (a) Before and (b) After creation the cylindrical emplacement for placing the TLD chips within (c) Cylindrical container

Fig. 3(a-b): (a) Cerrobend blocks for shaping each radiation field were constructed and used in (b) 3-D treatment planning method

(8×6 cm^2) fields, to deliver 200 cGy isocenter point with SAD setup was established. Cerrobend blocks for shaping each radiation field were constructed and used in 3-D treatment planning method (Fig. 3). The experiments were repeated five times and the values of absorbed dose compared with paired student t-test for 95% confidence interval of the difference.

RESULTS

For measuring absorbed dose in hip of phantom, TLD chips were placed in triple groups in the different depths from skin (at anterior surface) to 21.5 cm with 2 cm interval distance. The absorbed dose at these depths were obtained in two methods by averaging of resultant data after 5 times repetitions which each repetition point is the average of three measurements itself (Fig. 4).

To have the soft tissue's anatomical data in phantom, we fused the CT-image of phantom with the CT-image of a patient, who had the similarity in dimensions with phantom.

The depth of bladder, prostate gland (tumor) and rectum centers in coronal plane from anterior surface were determined 8.5, 12.5, 16.5 cm, respectively.

The amount of received dose by bladder was obtained by averaging absorbed doses at depths of

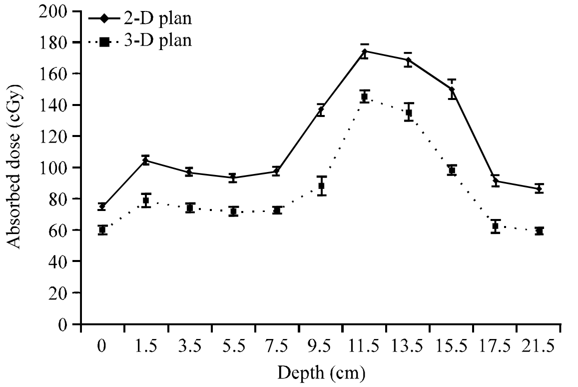

Fig. 4: Comparison of absorbed dose in terms of depth between two treatment planning methods with the same exposure conditions

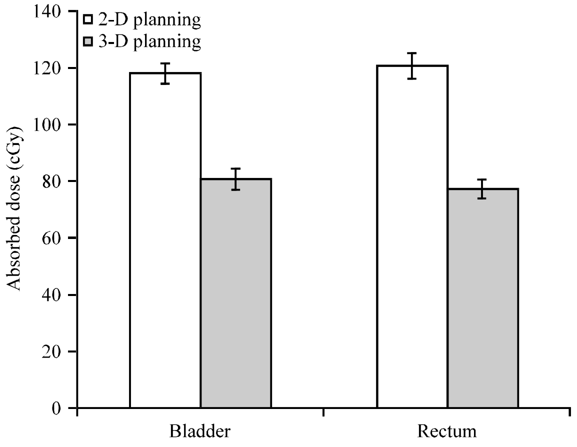

Fig. 5: Comparison of absorbed dose of bladder and rectum between 2-D conventional and 3-D conformal treatment planning methods

7.5 and 9.5 cm, for prostate (tumor) averaging absorbed doses at 11.5 and 13.5 cm (depth) and for rectum, by averaging at depths of 15.5 cm (anterior rectal wall) and 17.5 cm (posterior rectal wall) similarity. Absorbed dose values in critical organs bladder and rectum, in two planning methods are compared together in Fig. 5.

As shown in Fig. 5 the use of 3-D conformal treatment planning causes significant reduction in absorbed dose to uninvolved structures such as bladder and rectum, compare to 2D conventional treatment planning ($p<0.01$).

To quantify the non-uniformity, we calculate the Uniformity Index (UI) was calculated in irradiated volume (approximate range: 9.5-15.5 cm in depth) in two planning techniques with the following equation:

$$UI=\left(\frac{D_{Max}-D_{Min}}{D_{Max}+D_{Min}}\right)\times 100 \qquad (1)$$

where, D_{Max} and D_{Min} are the maximum and minimum absorbed dose in irradiated volume, respectively (Khan, 1998).

Table 1: Dosimetric data derived from treatment planning softwares at critical uninvolved structures (bladder and rectum) in two planning methods

Treatment planning techniques	Bladder (cGy)			Rectum (cGy)		
	D_{min}	D_{mean}	D_{max}	D_{min}	D_{mean}	D_{max}
2-D	96.5	127.4	198.0	108.0	134.8	201.0
3-D	63.4	96.9	174.1	51.5	89.7	168.3

Based on the Eq. 1, the UI in irradiated volume for 2-D conventional and 3-D conformal treatment plans were 10.9 and 22.4%, respectively. This means the 2-D method concedes nearly twice more uniform distribution dose to irradiated volume than 3-D conformal method.

We also compared the dosimetric data (minimum dose (D_{Min}), maximum dose (D_{Max}) and mean dose (D_{Mean})) derived from treatment planning softwares based on dose-volume histograms at critical uninvolved structures bladder and rectum between two planning methods (Table 1). It is observed that absorbed dose values in bladder and rectum with 3-D conformal method are significantly lesser than 2-D conventional method. The reduction in absorbed dose from 2-D to 3-D planning is more noticeable in rectum (33.5%) than bladder (23.9%) on the basis of mean dose (D_{Mean}).

DISCUSSION

Cerrobend blocks with 3-D conformal treatment planning, significantly reduce the magnitude but no uniformity of absorbed doses to critical uninvolved structures in proportion to 2-D conventional radiotherapy of prostate cancer with using Co-60 unit.

As we know, the use of multiple fields in radiotherapy increases the tumor dose relative to the dose to surrounding normal tissues and also cause to acceptable uniform distribution absorbed dose to PTV (Khan, 2003; Hendee *et al*., 2005). In this study, the 4-field or Box method, other than uniformity, was selected because of the lymph nodes to place in radiation fields (Perez *et al*., 1997).

As expected from isodose distributions, the absorbed dose in therapeutic volume has a little non-uniformity in two methods involve 2-D conventional (10.9%) and the 3-D conformal techniques (22.4%). The uniformity of conformal method was improper than conventional one because of asymmetry of radiation fields.

The reduction in absorbed dose results from reduction in field size, since one of effective factors in absorbed dose is the radiation field size (Khan, 2003). For the sufficient large fields, such as those, that are routinely used in radiotherapy, the absorbed dose at deep layers are result from primary and secondary photons. However, the relative contribution of scattered radiation to the absorbed dose increases more rapidly at the depth than at locations or near the surface because the photons tend to be scattered in the forward direction (Hendee *et al*., 2005). Since scattered radiation depend on irradiative area (Khan, 2003; Hendee *et al*., 2005), blocking the fields for shaping beam, results in diminution in effective or total field size, thus scattered rays decrease and consequently the absorbed dose is reduced. Another reason, is that, for any x or gamma ray beam of specific cross-sectional area, the percent depth dose decreases with decreasing symmetry of the field shape. Although, the volume of irradiated medium may remain constant, fewer scattered photons reach the central axis of an asymmetric beam because the average distance is greater the origin of the scattered photons and the central axis (Hendee *et al*., 2005).

It seems, increasing the absorbed dose due to left and right lateral fields with more weightening, will be logical, to compensate the absorbed dose in PTV up to prescribed dose and even more, but the received dose by anterior rectal wall must be considered (Vijayakumar *et al*., 1993; Lee *et al*., 1996). In these fields, more volume of critical organs (bladder and rectum) that were under exposure previously is removed from radiation fields using blocks and thus the most reduction in absorbed dose and also in integral dose of these structures are from blocking the lateral fields.

According to retrospective works, this increas in dose at PTV, without significant increase at critical organs, cause more control on treatment prostate cancer and also improves quality of life patients (Dearnaley *et al*., 1999; Zelefsky *et al*., 1998; Sale *et al*., 2005).

We conclude that using Cerrobend blocks with 3-D conformal treatment planning significantly reduces the absorbed dose to bladder and rectum in proportion to 2-D conventional radiotherapy of prostate cancer.

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