TJC Turkish Journal of Cancer
Volume 37, No. 2, 2007

Comparison of high and low energy treatment plans by evaluating the dose on the surrounding normal structures in conventional radiotherapy

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ABSTRACT

The aim of this study was to quantitatively compare treatment plans of high (15 MV) and low energy photon (6 MV) beams in pelvic sites (Bladder, Prostate, Cervix and Femur heads) for conventional radiation therapy. A total of 13 patients were studied. X-ray simulation was performed on Shimadzu treatment simulator. Patient contours were acquired using a conformator type contour plotter. Optimal treatment plans were prepared with the help of Decision Support System (DSS by Multidata). In all cases three field (3-F) technique was compared for high and low energy photons, except for cervix and femur heads where in addition to 3-F technique box technique was compared as well. The parameters analyzed for the effectiveness of a treatment plan were; Quality Index, Global maximum dose, Doses to Organs at Risk (OAR), dose uniformity with in the tumor and entrance doses. The entrance doses from anterior side for 15 MV photons in case of bladder and prostate were reduced by 20% and 19.2% respectively. Where as the dose to rectum (OAR) for 15 MV photons, was reduced by 300 cGy and 210 cGy for bladder and prostate patients respectively. A 26% reduction in entrance dose from the anterior aspect was observed for 15 MV photons in Cervix patients (3-F technique). The dose to bladder and rectum were reduced by 810 cGy and 255 cGy respectively for 15 MV photons in cervix (3-F). Dose to left femur head for 6 MV increased by 16% as compared to 15 MV photons. For right femur head the dose for 6 MV photons was 16.5% higher as compared to 15 MV photons. The major conclusion was that patient re-planning was necessary in case of pelvic sites; otherwise very high doses were received by OAR. [Turk J Cancer 2007;37(2):59-65]

KEY WORDS:

High and low energy photons, pelvic sites, OAR, three field technique

INTRODUCTION

Radiation therapy has progressed significantly over the last few decades in the treatment of cancer. The arrival of sophisticated treatment modalities like IMRT, IGRT and Tomo-therapy has enhanced the effectiveness of Tele therapy in the cure of cancer. Nevertheless many centers hospitals around the world especially in developing countries are still using conventional radiation therapy.

The aim of this study which was carried out at Radiation Therapy Department of Karachi Institute of Radiotherapy and Nuclear Medicine (KIRAN), was to assess the impact of patient transition from 15 MV to 6 MV in body sites where the use of high-energy beams has been preferred (like pelvic region). The important consideration in any such transition was to keep in mind

the tumor control probability (TCP) and the dose to the organs at risk (OAR). Prior to site selection a literature survey was carried (1-4).

MATERIALS AND METHODS

A total of 25 patients were studied. Two types of patients were included in this study: 1) those whose body contours were already obtained for planning purposes and were maintained in the hospital record and, 2) those who arrived at KIRAN during the course of this study (two and half months). Patient's consent was not obtained for this study as only their data was used to compare the treatment plans and no change in the treatment was made for the sake of this study. During the course of study at every stage patient's privacy was respected fully. X-ray simulation was performed on Shimadzu simulator. The three main areas of interest that were addressed during the simulation process were: Alignment and positioning of the patient, tumor localization and field marking. During the simulation process the physicist was accompanied by the radiation oncologist, so as to discuss various issues regarding target localization, beam parameters and patient setup (5,6).

Single slice body contours were obtained for each patient and the oncologist drew the target area and OAR. These marked contours were digitized. One better alternative to the above step was to use CT scans instead of manual contour taking; manual contours were not taken for those patients who had already undergone a CT scan. 'Vidar VXR-12 Plus film Digitizer' was used to scan these CT slices to treatment planning system. Target localization with the help of CT scan was more accurate. But there were very few patients available with CT scans. Optimal treatment plans were prepared for 6 MV and 15 MV photon beams for each patient. The treatment planning software used was DSS (Decision Support System) by Multidata. This software closely resembled the properties of a 2.5D modern treatment planning system. Finally both the plans were reviewed by the radiation oncologist.

RESULTS AND DISCUSSION

High and low energy treatment plans comparison results have been provided, also a hypothetical situation was considered where patient originally planned for 15 MV has been mistakenly treated on 6 MV or directly shifted from high to low energy without re-planning, and this case was called the direct transition case (DT). Treatment plans have been provided for one patient from each pelvic site (because of restriction of space). In addition the mean data in the form of tables for each pelvic site has been furnished as well.

Unless and otherwise mentioned, three field technique was used.

Bladder

Seven bladder patients were studied. The total dose prescribed to the tumor was 6000 cGy delivered in daily fraction of 200 cGy (30 fractions). In all cases 15 MV photon beams were superior to 6 MV in terms of quality index, global maximum doses, doses to the organs at risk

Fig 1. Bladder 15 MV plan

(OAR), target uniformity and the entrance doses (table 1). Comparison of entrance doses amongst 15 MV and 6 MV revealed that from the anterior field an additional 20% dose was delivered in case of 6 MV photons. Direct

Fig 2. Bladder 6 MV plan

transition (DT) resulted in 10% extra dose from the anterior field, and also delivered high doses from lateral aspects. However no such dose concentration was seen for 15 MV and 6 MV optimum plans (Figures 1 & 2). In case of DT the entrance dose from left lateral side was higher by 13.3% and 10.9% as compared to 15 MV and 6

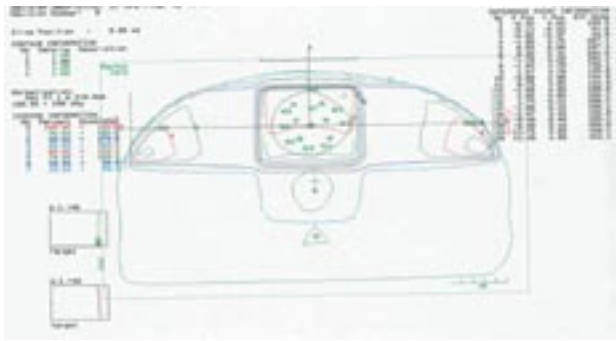

Fig 3. Bladder DT plan

MV respectively, where as from right lateral side in case of DT the entrance dose was up by 13.6% and 10.4% from 15 MV and 6 MV respectively (Figures 2 & 3).

The above trends indicated that careful patient planning was required before making any transition from 15 MV to 6 MV incase of bladder, other wise there were chances of skin reaction from the lateral sides, normally above 3000 cGy skin reactions are very common. Mean quality index for tumor (Table 1) indicated that in case of 15 MV the area under DVH was more and target coverage was better, because quality index is the ratio of area under the DVH and the total area. Mean dose to rectum for 15 MV was less by 10 cGy that implied that in 30 fractions a total reduction of 300 cGy was made to bladder dose, which was clinically significant. The TD5/5 dose for bladder is 6000 cGy. For bladder and other pelvic sites to be discussed in the following sections, superiority of high-energy beams in various parameters of interest was because of the reason that lateral body separation in pelvic region was greater as compared to any other body site, which favored the use of higher energy beams.

Prostate

Three prostate patients were studied. 7000 cGy was delivered in 35 fractions (200 cGy per fraction). In all cases 15 MV photon beams were superior to 6 MV in terms of

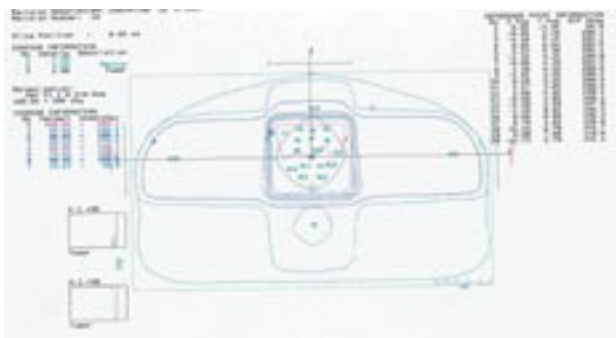

Fig 4. Prostate 15 MV plan

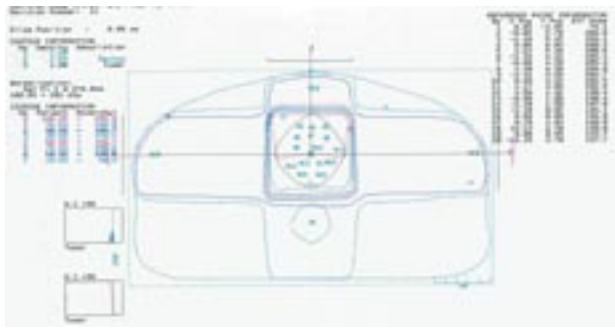

Fig 5. Prostate 6 MV plan

quality index, global maximum doses, doses to the organs at risk (OAR), target uniformity and entrance doses (Table 2). The 50% isodose curve for 15 MV photon beam was closer to the tumor both from anterior and posterior ends

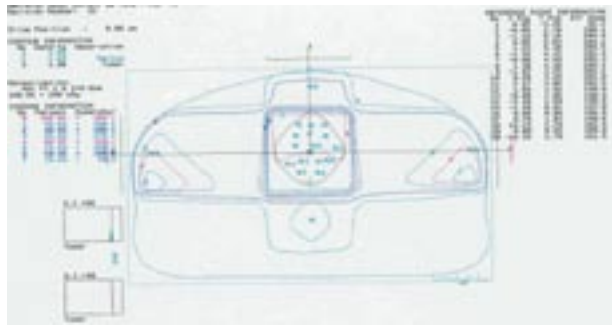

Fig 6. Prostate DT plan

as compared to 6 MV and DT cases (Figures 4, 5 & 6). Comparison of entrance doses between 15 MV and 6 MV showed that from the anterior field an additional 19.2% dose was delivered in case of 6 MV photons. DT resulted in an additional 6.8% dose from the anterior field. From left lateral side in case of direct transition the entrance dose was up by 13.2% and 9.7% as compared to 15 MV and 6 MV respectively. For right lateral side in case of direct transition the entrance dose was up by 13.3% and 10.2% as compared to 15 MV and 6 MV respectively. As high as 85% isodose curve was visible from the lateral sides (Figure 6), where no such dose concentration was visible for 15 MV and 6 MV (Figures 4 & 5). Mean dose to rectum for 15 MV beam was lower by 7 cGy as compared to 6 MV (Table 2). This suggested a reduction of 245 cGy in bladder dose during 35 fractions. Quality index (Table 2), global maximum doses, and doses to rectum and target uniformity followed similar trends as explained in section (7,8).

Uterine cervix

Two uterine cervix cases were studied (high and low

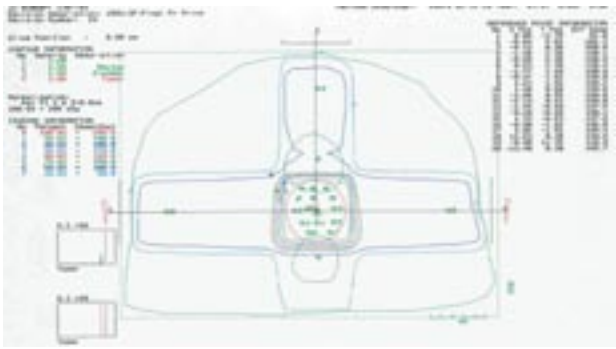

Fig 7. Uterine cervix 15 MV 3-F plan

energy for both 3-F and box techniques, Table 3). The prescribed dose was 6000 cGy with 200 cGy per fraction and a total of 30 fractions, the organs at risk were bladder and rectum and the TD5/5 for both these organs was 6000 cGy. For 3-F technique entrance doses from anterior side for 15 MV photons was reduced by 26% and 10% as

Fig 8. Uterine cervix 6 MV 3-F plan

compared to 6 MV and DT cases respectively (Figures 7, 8 & 9). For DT the doses from right lateral sides were higher by 15.5% and 12% as compared to 15 MV and 6 MV respectively. For left lateral side the entrance dose was up by 9.75% and 6.75% as compared to 15 MV and 6 MV. Mean dose to rectum and bladder were reduced by 8.5 cGy and 27 cGy respectively for 15 MV beams in case of 3-F technique, resulting in a reduction of 255 cGy and 810 cGy to rectum and bladder doses respectively during

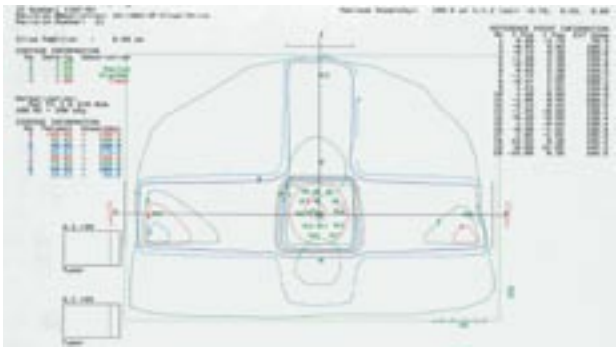

Fig 8. Uterine cervix DT 3-F plan

30 fractions.

For box technique entrance doses from anterior side was up by 8.25% and 5.75% for 6 MV and DT cases respectively as compared to 15 MV. From posterior side dose was up by 14.5% and 6.5% for 6 MV and DT cases respectively In case of DT the doses from right lateral side were up by 14.5% and 7.75% in comparison with 15 and 6 MV respectively. For left lateral side the entrance dose was up by 9.75% and 6.75% as compared to 15 MV and 6 MV respectively. Mean doses to rectum and bladder were lower by 10 cGy and 13 cGy respectively for 15 MV beams in case of 3-F technique, resulting in a reduction of 260 cGy and 200 cGy to rectum and bladder doses respectively in 30 fractions. Directly shifting the patients from 15 MV to 6 MV was not feasible as there were high doses from lateral aspect and the doses to femur head was quite significant.

Fig 10. Femur head 15 MV plan

Data in table 3 also suggested that dose to bladder and rectum in box as well as 3-F techniques was quite reduced in case of 15 MV beams and especially in case of 3-F technique the dose to bladder was significantly reduced; therefore DT would result in unacceptable doses to bladder and there fore should be avoided. The quality index in case of high- energy beams was improved. (Table 3).

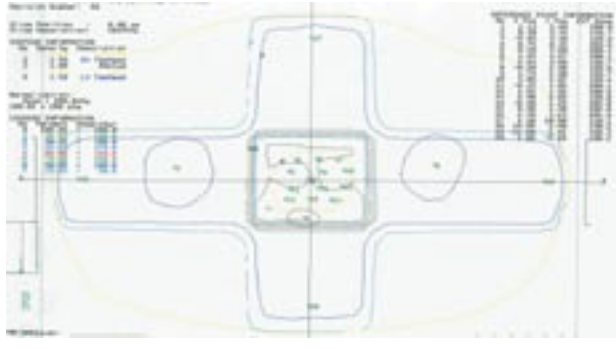

Fig 11. Femur head 6 MV plan

Comparison of doses on femur head

While irradiating the pelvis, femur head doses are important; it is desired to keep these doses as low as possible. The doses for femur head were calculated on a single patient, where the femur heads were marked on the CT scan so as to determine their exact location. Doses on left and right femur heads for 15 MV photons were 42% & 43% of the prescribed dose respectively. For 6 MV left and right femur heads received 58% & 59.5% of the prescribed dose. This trend could be verified from the isodose distributions (Table 4, Figures 10, 11 & 12). Therefore before shifting a patient directly from 15 MV to 6 MV proper planning for femur head doses was required. Despite the fact that quality index for all cases were the, still the lateral doses were high and therefore re-planning was necessary.

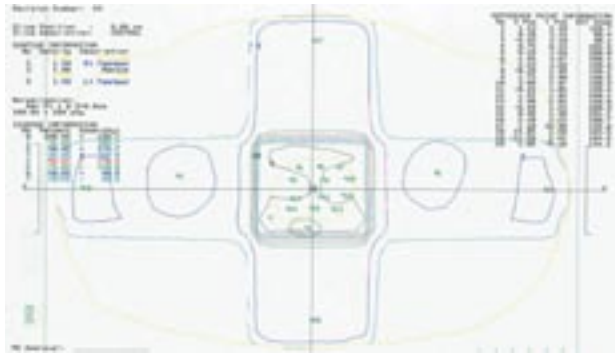

Fig 12. Femur head DT plan

Table 1
Bladder patient mean data

	15 MV	6 MV	*DT
Quality index	98	95	97
Global maximum dose (cGy)	200.6	213	208.8
Relative target uniformity (%)	5	10	7
Dose to rectum (cGy)	197	204	203
Entrance doses as % of 200 cGy (i.e. the prescribed dose)			
Anterior beam	48.5	68.6	58.7
Right lateral beam	57.3	56.6	67.3
Left lateral beam	53.3	55.7	66.7

Table 2
Prostate patient mean data

	15 MV	6 MV	*DT
Quality index	97	95	97
Global maximum dose (cGy)	205.4	214.5	210.1
Relative target uniformity (%)	5	11	7.4
Dose to rectum (cGy)	75	82	71
Entrance doses as % of 200 cGy (i.e. the prescribed dose)			
Anterior beam	47.8	67	54.6
Right lateral beam	52.5	55.8	65.8
Left lateral beam	52.1	55.6	65.3

Table 3
Cervix patient mean data

Box Technique	15 MV	6 MV	DT
Quality index	99	99	99
Global maximum dose (cGy)	200.5	200.2	201.2
Relative target uniformity (%)	5	3	4
Dose to rectum (cGy)	93	103	92
Dose to bladder (cGy)	85	98	87
Entrance doses as % of 200 cGy (i.e. the prescribed dose)			
Anterior beam	26.7	37.5	32.2
Right lateral beam	54.5	62.2	69
Left lateral beam	49.5	54.5	60.7
Posterior beam	22.2	29.5	25.5
Three Field Technique			
Quality index	99	98	99
Global maximum dose (cGy)	200.4	203	200.7
Relative target uniformity (%)	5	6	4
Dose to rectum (cGy)	87.6	96	85
Dose to bladder (cGy)	97	124	101
Entrance doses as % of 200 cGy (i.e. the prescribed dose)			
Anterior beam	51.5	77.5	61.5
Right lateral beam	53	56.5	68.5
Left lateral beam	52	55	61.7

Table 4
Femur head patient mean data

	15 MV	6 MV	*DT
Quality index	99	99	99
Global maximum dose (cGy)	200.4	206.4	204.6
Relative target uniformity (%)	5	4	3
Dose to rectum (cGy)	197	204	203
Dose to left femur head (cGy)	84	116	88
Dose to right femur head (cGy)	86	119	90
Entrance doses as % of 200 cGy (i.e. the prescribed dose)			
Anterior beam	42.5	40	32.2
Right lateral beam	34.5	60.5	45
Left lateral beam	34	59	44
Posterior beam	40	37	46.5

CONCLUSIONS

The major conclusion of this study was that patient re-planning was necessary in case of bladder, cervix and prostate, because if the patient was not re-planned very high entrance doses from lateral aspects were received and therefore direct transition was not recommended. Similarly the doses received by organs at risk were reduced significantly for high-energy photons. Quantitatively 15 MV beams demonstrated better results for normal tissue sparing and the doses to the organs at risk. Pakistan being a developing nation is still in process of installing linear accelerators at various medical centers where already Co-60 units are used for external beam therapy; therefore if high-energy beams are available they should be used in pelvic cancers.

FUTURE RECOMMENDATIONS

In the future the findings of this study should be verified from in vivo dosimetry, so as to compare the values of doses calculated on the planning software with that of the actual doses received by the patient. Similarly a second comparison could be made to compare these results with that obtained from true 3D planning software and to assess that how much extra dose was delivered by a 2D planning system. The difference between dose calculated and actual dose received by the patient would serve as an important parameter for the integrity of the whole radiation treatment planning process.

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