Original Article

The dosimetric impact of different photon beam energy on RapidArc radiotherapy planning for cervix carcinoma

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ABSTRACT

The main purpose of this study is to know the effect of three different photon energies viz., 6, 10, and 15 mega voltage (MV) on RapidArc (RA) planning for deep-seated cervix tumor and to develop clinically acceptable RA plans with suitable photon energy. RA plans were generated for 6, 10, and 15 MV photon energies for twenty patients reported with cervix carcinoma. RA plans were evaluated in terms of planning target volume (PTV) coverage, dose to organs at risk (OARs), conformity index (CI), homogeneity index (HI), gradient measure, external volume index of dose distribution produced, total number of monitor units (MUs), nontumor integral dose (ID), and low dose volume of normal tissue. A two-sample paired *t*-test was performed to compare the dosimetric parameters of RA plans. Irrespective of photon energy used for RA planning, plans were dosimetrically similar in terms of PTV coverage, OARs sparing, CI and HI. The numbers of MUs were 13.4 ± 1.4% and 18.2 ± 1.5% higher and IDs were 2.7 ± 0.8% and 3.7 ± 0.9% higher in 6 MV plans in comparison to that in the 10 and 15 MV plans, respectively. V_{1Gy}, V_{2Gy}, V_{3Gy}, and V_{4Gy} were higher in 6 MV plans in comparison to that in 10 and 15 MV plans. Based on this study, 6 MV photon beam is a good choice for RA planning in case of cervix carcinoma, as it does not deliver additional exposure to patients caused by photoneutrons produced in high energy beams.

Key words: Dose distribution, neutron dose, photon energy, RapidArc

Introduction

Cervical cancer remains the most common gynecological cancer worldwide. Radiotherapy is commonly used to treat cervix cancer.[1,2] RapidArc (RA) is one of the advanced technologies available for cancer treatment in radiotherapy. It is the extension of the principle of intensity modulated arc therapy proposed by Yu in 1995,[3] which involves simultaneous rotational movement of the linear accelerator's gantry along with movement of the multi-leaf collimator (MLC) leaves to produce fluence modulation while beam is on.[4] The ability of the RA technique to synchronize dose rate, gantry speed, and MLC motion during radiation beam-on makes RA superior than intensity modulation radiotherapy (IMRT).[5]

Many authors have conducted a study on IMRT but Otto *et al*.[6] and Palma *et al*.[7] reported that RA technique generates superior target coverage and provides superior organs at risk (OARs) sparing in comparison to IMRT. RA is more efficient in treatment delivery as it reduces number of monitor units (MUs) and requires less beam-on time.

Rao *et al*.[8] compared volumetric modulated arc therapy (VMAT) with fixed field IMRT and helical tomotherapy.

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They reported that VMAT time varied from 2.1 to 4.6 min, IMRT treatment varied from 7.9 to 11.1 min, and tomotherapy time varied from 4 to 7 min.

Verbakel *et al*.[9] and Otto *et al*.[6] found that VMAT is more MU efficient in comparison to IMRT. As VMAT requires less beam-on time, it will result in reduced leakage and integral dose (ID) to OARs.

The above facts state that RA technique is superior in comparison to IMRT, hence, in this study, we have tried to investigate the effect of different photon energies on cervix RA planning and to evaluate their dosimetric parameters in terms of planning target volume (PTV) coverage, OARs sparing, different physical indices, MUs, and ID to normal tissues with 6, 10, and 15 mega voltage (MV) photon beam energies.

Materials and Methods

Immobilization devices

All the patients were immobilized in supine position with the help of All-in One board (AIO, Orfit Industry NV, Belgium), thermoplastic mold cast (Orfit Industry NV, Belgium), and knee rest.

Simulation

Siemens SOMATOM Sensation Open CT Scanner (Siemens Medical Systems, Germany) was utilized for computed tomography (CT) of all the patients. CT images of 3.0 mm slice thickness were acquired extending from L2 to proximal third femoral diaphysis. All patients were scanned with full bladder as per institutional protocol.

Target and organs at risks delineation

Target volumes were delineated on CT images for clinical target volume (CTV) and PTV as per Radiation Therapy Oncology Group guidelines.[10] PTV was defined by adding a 5 mm margin to CTV that includes the cervix, uterus, parametrial tissues, and pelvic nodes including presacral. OARs such as bladder, rectum, femoral heads, and bowel were also delineated.

Patient characteristics

Twenty patients reported with cervix carcinoma (stages II–IIIB) who were treated by IMRT and RA techniques (8 patients treated with IMRT and 12 with RA using 6 MV) were selected retrospectively for this study. The patient anterior-posterior mean separation was 22.0 ± 2.3 cm ranging from 18.4 cm to 26.0 cm and right-lateral mean separation was 35.9 ± 4.8 cm ranging from 29.2 cm to 48 cm. Mean PTV volume was 1318.9 ± 189.0 cc ranging from 1112.0 cc to 1710.6 cc. Bladder and rectum mean volume was 379.6 ± 189.0 cc ranging from 169.7 cc to 748.0 cc and 64.6 ± 22.0 cc ranging from 45.9 cc to 101.4 cc, respectively.

Bladder and rectum volumes overlapped with PTV were also calculated by Boolean operation. Non-overlapping volumes of bladder (bladder minus PTV) and rectum (rectum minus PTV) were also calculated using Boolean operation. Bladder minus PTV mean volume was 38.5 ± 6.9% ranging from 29.7cc to 48.7cc. Rectum minus PTV mean volume was 40.7 ± 9.8% ranging from 24.9cc to 51.3cc.

Planning objective and prescription

RA plans were generated with 6, 10, and 15 MV photon beams for the prescribed dose (PD) of 50.4 Gray (Gy) in 28 fractions to the PTV at the rate of 1.8 Gray per fraction. Planning objective was to deliver 100% PD to 95% of PTV with no more than 2% of PTV volume receiving 107% of PD as recommended in International Commission on Radiation Units and Measurements report number 50 (ICRU 50)[11] and ICRU 62.[12] Dose to bladder and rectum was restricted in such a way that V_{50Gy} (volume receiving 50 Gy) should be <50% of OARs volume and mean dose of both femoral heads should remain within 20 Gy as per institutional protocol.

Planning technique

RA plans were generated for delivery on linac True Beam STx (Varian Medical Systems, Palo Alto, CA, USA) which is capable of delivering IMRT and RA. This linac is equipped with high definition-MLC of 60 pairs, inner 32 leaf pairs of 0.25 cm, and outer 28 leaf pairs of 0.50 cm projection width at isocenter. Machine was calibrated at 1 cGy/MU as per Technical Reports Series No. 398 of International Atomic Energy Agency[13] for all the energies.

Treatment planning system (TPS) Eclipse version 10.0 (Varian Medical Systems, Palo Alto, CA, USA) was used for RA planning. Double arcs were used for all the RA plans. The first arc was clockwise with gantry angle 179–181° and collimator angle 10–30° and the second arc was counter clockwise with gantry angle 181–179° and collimator angle 10–30°. Collimator rotation was used to cover entire target volume and reduce tongue and groove effect during gantry rotation, which subsequently minimizes inter-leaf leakage.[14,15] The progressive resolution optimizer algorithm was used for optimization and anisotropic analytical algorithm with 0.25 cm grid size was used for photon dose calculation for all plans. All the plans were generated with all the three energies viz., 6, 10, and 15 MV with dose rate of 600 MU/min.

Dosimetric comparison and plan evaluation

Cumulative dose volume histogram generated by TPS was used to evaluate dosimetric parameters. PTV coverage was evaluated by calculating mean dose, $V_{95\%}$ (PTV volume receiving 95% of PD), $V_{98\%}$, $V_{100\%}$, and $V_{107\%}$. Bladder and rectum were evaluated for mean dose, V_{30Gy} (volume receiving 30 Gy), V_{40Gy}, and V_{50Gy}. Femoral heads were also

evaluated for mean dose, maximum dose, V_{10Gy} (volume receiving 10 Gy), V_{20Gy}, V_{30Gy}, and V_{40Gy}.

The homogeneity index (HI) and conformity index (CI) were calculated using following formulae

$HI = D_{5\%}/D_{95\%}$[16]

Where $D_{5\%}$ and $D_{95\%}$ are the doses to 5% and 95% PTV volumes, respectively.

CI (for 98% of PD) = Volume receiving 98% of PD/PTV[17]

Gradient measure (GM) was calculated as radius difference between the equivalent spheres of prescription and half prescription isodose volumes, which indicates dose falloff around PTV. Small value of GM indicates higher dose gradient around PTV.[18]

External volume index (EVI) was calculated as follows;

EVI = Volume of normal tissue receiving reference dose (NTV_{DRef})/PTV.[19]

Integral dose

ID is the dose deposited to the normal tissues outside the PTV in a patient. It is also the area under the curve of a differential absolute-dose, absolute volume histogram. It was calculated to assess the plan quality based on the following formula considering uniform tissue density:

Nontumor integral dose (NTID) = mean dose × volume of normal tissue outside PTV.[20]

For low dose volume evaluation of normal tissues, $D_{1\%}$ (dose to 1% volume of normal tissues), $D_{2\%}$, $D_{5\%}$, V_{1Gy} (volume receiving 1 Gy), V_{2Gy}, V_{3Gy}, V_{4Gy}, and V_{5Gy} were calculated.

Statistical analysis

The comparison between dosimetric parameters of 6, 10, and 15 MV RA plans was performed using two-sample paired *t*-test. The analyses were performed with International Business Machines Corporation (IBM), IBM SPSS Statistics for Windows, (Version 20.0. Armonk, NY: IBM Corp). A $P < 0.05$ was considered as statistically significant.

Results

Table 1 presents the different dosimetric parameters of RapidArc plans for 6, 10, and 15 MV photon energies. There was no statistically significant ($P > 0.05$) difference found in terms of PTV coverage for 6, 10, and 15 MV energies. There was a slight increase in PTV volume receiving dose 107% of the PD with increase in energy, but results were not statistically significant ($P > 0.05$).

Figure 1 represents the isodose distribution resulting from RA planning with 6, 10, and 15 MV photon energies for a representative patient along axial, coronal and sagittal views, in which one can easily distinguish the difference in 50% isodose line in RA plans using 6, 10, and 15 MV energies.

The *P* value for HI and CI of all the plans with all the three different energies viz., 6, 10, and 15 MV was found to be >0.05, thus there is no statistical significant difference with respect to change in energy. However, Table 2 shows that 10 MV plans have slightly better HI and CI as compared to 6 and 15 MV plans. The *P* value for GM was found to be <0.05 with respect to change in energy. There was a decrease in GM value with increase in photon energy. The 15 MV plans have 6.6% and 1.7% improved GM as compared to that of 6 and 10 MV plans respectively. EVI value in 6 MV plans was smaller in comparison to that in 10 and 15 MV. The *P* value for the EVI of 6 MV versus 15 MV plans was found to be <0.05 which shows the significant difference.

Dose to bladder

Table 3 shows that 15 MV offers statistically significant ($P < 0.05$) improvement in mean dose and V_{30Gy} of the bladder in comparison to 6 MV. There were gradual improvements in mean dose and V_{30Gy} of bladder with increase in energy. There was no statistically significant ($P > 0.05$) difference found in V_{40Gy} and V_{50Gy} of the bladder, but there was improvement in mean bladder dose for 15 MV in comparison to 6 and 10 MV.

Dose to rectum

Table 3 represents that 10 MV offers statistically significant improvement ($P < 0.05$) in mean dose and V_{40Gy} of rectum in comparison to 15 MV. There was a slight improvement in rectum dose for 10 MV in comparison to 6 and 15 MV.

Table 1: DVH dosimetric data of PTV for RA using 6, 10, and 15 MV photon energies

PTV parameter	*6 MV*		*10 MV*		*15 MV*		*P*		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*6 versus 10*	*6 versus 15*	*10 versus 15*
Mean (Gy)	52.0	0.2	52.0	0.2	52.0	0.3	NS	NS	NS
$V_{95\%}$ (%)	99.7	0.2	99.6	0.2	99.6	0.8	NS	NS	NS
$V_{98\%}$ (%)	98.3	0.2	98.3	0.3	98.3	0.2	NS	NS	NS
$V_{100\%}$ (%)	95.1	0.2	95.1	0.1	95.1	0.1	NS	NS	NS
$V_{107\%}$ (%)	0.4	0.8	0.5	1.0	0.7	1.3	NS	NS	NS

*SD: Standard deviation, NS: Nonsignificant, DVH: Dose volume histogram, PTV: Planning target volume, RA: RapidArc, MV: Mega voltage, Gy: Gray

Results show that 15 MV delivers higher mean dose to rectum. V_{30Gy} and V_{50Gy} of rectum were also evaluated, but results were not statistically significant ($P > 0.05$).

Dose to femoral heads

Femoral heads were evaluated for mean dose, D_{max} V_{10Gy}, V_{20Gy}, V_{30Gy}, and V_{40Gy}, but results were not found statistically significant ($P > 0.05$) as shown in Table 3.

Integral dose to normal tissues (nontumor integral dose)

There was a statistically significant ($P < 0.05$) improvement in NTID with increase in photon energy. There was a reduction of 2.7 ± 0.8% and 3.7 ± 0.9% in NTID in 10 and 15 MV plans respectively in comparison to that in 6 MV plans. NTID in 15 MV plans was 1.0 ± 0.5% less in comparison to that in 10 MV plans.

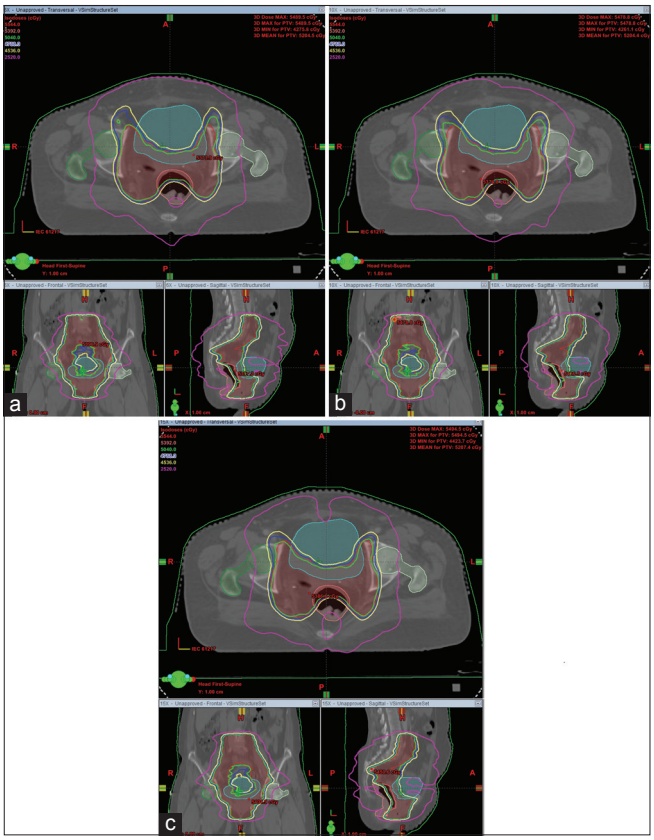

Figure 1: The isodose distribution generated from RapidArc planning in case of Ca.Cervix for same patient in axial, coronal and sagittal planes with (a) 6 MV, (b) 10 MV, and (c) 15 MV photon beam energies

Evaluation for low dose volumes of normal tissue

Dose to the volumes of 1%, 2%, and 5% and volumes of 1, 2, 3, 4, and 5 Gy of normal tissues were also calculated as shown in Table 4 and compared for analysis. For the 6, 10 and 15 MV plans, there were no significant (P > 0.05) differences in doses to 1%, 2% and 5% of normal tissues whereas the differences were significant in the cases of percentage volumes receiving 1, 2 and 3 Gy doses with 6, 10 and 15 MV beams. There was a gradual decrease found in 1, 2, and 3 Gy volumes of normal tissues with increase in photon beam energies. V_{4Gy} and V_{5Gy} were not found significantly ($P > 0.05$) different for 6, 10, and 15 MV plans.

Monitor units

There was a statistically significant ($P < 0.05$) reduction in number of MUs with increase in energy. Table 2 shows that number of MUs in 15 MV plans were 18.3 ± 1.6% and 5.6 ± 1.9% less in comparison to that in 6 and 10 MV plans. Also, the number of MUs in 10 MV plans is 13.4 ± 1.4% less in comparison to that in 6 MV plans.

Discussion

This study represents a thorough investigation of dose distribution in RA plans for cervix cancer using 6, 10, and 15 MV photon beam energies. The analysis is to evaluate the dosimetric impact of 6, 10, and 15 MV photon energies on RA plans for cervix cancer. The calculated *P* value for the PTV coverage was >0.05 in 6, 10, and 15 MV plans, which does not show statistically significant ($P > 0.05$) difference. The results of this study concurred with the results presented already by few authors. Sternick *et al.*[21] reported in their study that there was no significant difference in the dose distribution in rotational IMRT plans using energies ranging from 4 to 18 MV in the case of prostate cancer.

Ost *et al.*[22] also reported no advantage of high energy over low energy for IMRT and VMAT plans for primary prostate radiotherapy with simultaneous integrated boost.

Table 2: Plan comparison parameters for RA plans using 6, 10, and 15 MV energies

PTV parameter	*6 MV*		*10 MV*		*15 MV*		*P*		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*6 versus 10*	*6 versus 15*	*10 versus 15*
HI	1.052	0.006	1.051	0.007	1.053	0.008	NS	NS	NS
CI	1.004	0.017	1.003	0.019	1.008	0.017	NS	NS	NS
EVI	0.020	0.010	0.022	0.013	0.027	0.014	NS	<0.05	NS
GM	3.896	0.185	3.717	0.165	3.654	0.168	<0.05	<0.05	<0.05
MUs	520.5	26.1	450.6	23.2	425.4	21.0	<0.05	<0.05	<0.05

SD: Standard deviation, NS: Nonsignificant, RA: RapidArc, MV: Mega voltage, PTV: Planning target volume, HI: Homogeneity index, GM: Gradient measure, CI: Conformity index, EVI: External volume index, MUs: Monitor units

Table 3: Dose-volume parameter for different OARs for RA plans using 6, 10, and 15 MV energies

Structure	*6 MV*		*10 MV*		*15 MV*		*P*		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*6 versus 10*	*6 versus 15*	*10 versus 15*
Bladder									
Mean (Gy)	40.9	1.3	40.8	1.5	40.6	1.5	NS	<0.05	NS
V_{30Gy} (%)	77.4	3.8	76.7	4.7	75.7	4.1	NS	<0.05	NS
V_{40Gy} (%)	54.2	5.0	54.1	5.4	53.7	5.5	NS	NS	NS
V_{50Gy} (%)	34.9	5.4	35.0	5.5	34.8	5.7	NS	NS	NS
Rectum									
Mean (Gy)	40.4	1.4	40.4	1.5	40.5	1.6	NS	NS	<0.05
V_{30Gy} (%)	78.6	5.1	78.6	5.7	78.9	6.0	NS	NS	NS
V_{40Gy} (%)	55.3	6.1	55.2	6.5	55.7	6.7	NS	NS	<0.05
V_{50Gy} (%)	26.3	5.3	26.2	5.3	26.6	5.1	NS	NS	NS
Right femur									
Mean (Gy)	18.5	0.8	18.5	0.9	18.4	0.6	NS	NS	NS
D_{max} (Gy)	49.8	1.4	50.4	0.7	50.4	1.0	NS	NS	NS
V_{10Gy} (%)	79.5	12.0	79.4	10.1	76.0	9.5	NS	NS	NS
V_{20Gy} (%)	34.8	3.6	34.0	4.1	34.0	3.9	NS	NS	NS
V_{30Gy} (%)	17.0	3.6	17.7	3.0	17.2	3.4	NS	NS	NS
V_{40Gy} (%)	6.3	2.7	6.9	2.5	6.7	2.7	NS	NS	NS
Left femur									
Mean (Gy)	18.8	0.7	18.8	0.9	18.5	0.5	NS	<0.05	NS
D_{max} (Gy)	50.5	0.8	50.4	0.9	50.4	1.0	NS	NS	NS
V_{10Gy} (%)	78.8	11.7	79.6	11.3	74.0	6.7	NS	NS	<0.05
V_{20Gy} (%)	36.3	3.9	35.3	4.3	35.3	2.5	NS	NS	NS
V_{30Gy} (%)	17.7	3.5	17.6	4.3	17.9	3.2	NS	NS	NS
V_{40Gy} (%)	6.4	2.6	6.7	3.1	6.9	2.9	NS	NS	NS

SD: Standard deviation, NS: Nonsignificant, RA: RapidArc, MV: Mega voltage, OARs: Organs at risk, Gy: Gray

Table 4: DVH parameters of normal tissues (body-PTV) for NTID and low doses from RA plans using 6, 10, and 15 MV

Body-PTV	*6 MV*		*10 MV*		*15 MV*		*P*		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*6 versus 10*	*6 versus 15*	*10 versus 15*
Mean (10^5 Gy.cm^3)	2.72	0.36	2.65	0.34	2.62	0.33	<0.05	<0.05	<0.05
$D_{1\%}$ (Gy)	48.0	0.8	48	0.8	48.1	0.8	NS	<0.05	NS
$D_{2\%}$ (Gy)	44.7	1.5	44.7	1.6	44.8	1.6	NS	NS	NS
$D_{5\%}$ (Gy)	37.3	2.0	37.1	2.2	37.1	2.4	<0.05	<0.05	NS
V_{1Gy} (%)	79.0	8.0	75.1	8.3	73.4	8.4	<0.05	<0.05	<0.05
V_{2Gy} (%)	66.7	7.9	65.2	7.9	64.8	7.9	<0.05	<0.05	<0.05
V_{3Gy} (%)	60.8	7.4	60.3	7.5	60.2	7.5	<0.05	<0.05	<0.05
V_{4Gy} (%)	57.3	7.2	57.2	7.3	57.2	7.2	NS	NS	NS
V_{5Gy} (%)	54.8	6.9	54.9	7.0	54.9	6.9	NS	NS	NS

SD: Standard deviation, NS: Nonsignificant, RA: RapidArc, MV: Mega voltage, Gy: Gray, DVH: Dose volume histogram, PTV: Planning target volume, NTID: Nontumor integral dose

Plans with 15 MV photon beam offer statistically significant difference only for mean bladder dose, V_{30Gy} of the bladder, GM, NTID, and number of MUs in comparison to 6 MV. But there will be neutron production in case of 15 MV, and inclusion of neutron will eventually increase the risk of secondary malignancies.[23]

Thangavelu *et al*.[24] reported that 15 MV provides slightly better target coverage and better OARs sparing, but it cannot be considered as better choice as there is risk of secondary malignancies due to neutron production.

The 10 MV beam offers statistically significant sparing of rectum mean dose and V_{40Gy} in comparison to 15 MV, and slightly better sparing of bladder and rectum in comparison to 6 MV. It also offers better results for GM (4.8%), MUs (13.4%), lesser NTID (2.7%), less V_{1Gy}, V_{2Gy}, V_{3Gy}, and $D_{5\%}$ of normal tissue volume in comparison to 6 MV plans. The results of this study are inconsistent with the results recently reported by Mattes *et al*.[25] Their study evaluated the dosimetric effect of photon energy on quality of VMAT for large number of prostate cancer patients and found that the 10 MV plan delivered lower NTID (4.1%), GM (4.1%),

and 13% lesser number of MUs than the 6 MV plans, although in their study they did not evaluate low dose volume of normal tissue and EVI.

Pasler *et al.*[26] also assessed treatment plan quality and dosimetric accuracy of VMAT and IMRT plans using 6, 10, and 15 MV photon energies for prostate and found only statistically significant difference in NTID for 10 MV in comparison to 6 MV, they did not evaluate the difference in MUs, GM, EVI, and low dose volume of normal tissues. Onal *et al.*[27] also compared IMRT and VMAT plans with different energy levels 6, 10, and 15 MV using Monte-Carlo algorithm for prostate cancer. They found the significant difference only in number of MUs for 10 MV and 6 MV plans, as they did not calculate GM, EVI, and low dose volume of normal tissue.

This study revealed that variation in NTID was <5% for RA plans using 6, 10, and 15 MV energies. Pirzkall *et al.*[28] also reported a variation of 5% in NTID among prostate IMRT plans using 6, 10, and 18 MV energies. D'Souza and Rosen[20] reported that higher energy beams reduced the NTID and this effect is approximately independent of the numbers of beams, their beam orientation, and relative weights. Table 4 presents that 6 MV delivers 2.7 ± 0.8% and 3.7 ± 0.9% more NTID in comparison to 10 and 15 MV, respectively, and this is consistent with the results of the studies already published.[20,28,29] Our study also evaluated the $D_{1\%}$, $D_{2\%}$, and $D_{5\%}$ and found $D_{5\%}$ to be significantly high in 6 MV plans as compared to that in 10 and 15 MV plans. The normal tissue volumes receiving 1, 2, and 3 Gy in 6 MV plans were significantly highest.

Hall *et al.*[30,31] illustrated in their study that this low dose volume may not cause acute or subacute clinical morbidity but could potentially be carcinogenic. They reported that IMRT is likely to have 1–1.75% higher incidence of secondary malignancies compared to conventional radiotherapy in the patients surviving for 10 years. Followill *et al.*[32] estimated whole-body dose equivalent resulting from IMRT, they concluded that IMRT may increase the risk of secondary cancers by 0.4–1% as compared to conventional radiotherapy.

Kry *et al.*[33,34] also calculated the risk of second fatal malignancies. They reported that risk of second fatal malignancies in patients treated with 6 MV can be 38 times higher than that in patients treated with 10 MV. They reported the conservative maximum risk of fatal second malignancy was 2.1% for IMRT using 10 MV and 5.1% for IMRT using 18 MV. Intermediate risk associated with IMRT using 6 MV beam were 2.9% for treatment with Varian linear accelerator and 3.7% for treatment with Siemens linear accelerator, as well as using 15 MV X-rays 3.4% for Varian and 4.0% for Siemens linear accelerators respectively.

Major limitation of this study is that it does not consider the contribution of dose deposited by photoneutrons produced in high energy beam of 10 and 15 MV.[35] Dose from neutrons is more important because of their high relative biological effectiveness (RBE) and also radiation weighting factor of 20, hence higher biological damage compared to photons.[36]

In case of 6 MV RA plans, there is no photoneutron production, thereby reducing the biological damage. Also, there is no statistical significant difference between 6, 10, and 15 MV plans in terms of target coverage, OARs sparing, HI, and CI. Six mega voltage plans delivers significantly higher number of MUs, NTID and expose more normal tissues to low doses. However, this can be accepted against the higher risk of secondary cancer associated with photoneutrons in high energy beam. Many authors have also reported 6 MV as a good choice for treating deep-seated tumors like cervix and prostate.[16,28,37]

Conclusion

This study has been done to compare the dosimetric impact of different photon energy on carcinomas of cervix RA radiotherapy planning. There were no statistical significant differences in the 6, 10, and 15 MV plans in terms of PTV coverage, OARs sparing, HI, and CI. Although the number of MUs exposure of normal tissues to low doses was significantly higher in 6 MV plans compared to that in 10 and 15 MV plans, these drawbacks can be neglected as the probability of risk of secondary malignancies due to photoneutron production in 10 and 15 MV plans is higher. Hence, it can be concluded that RA technique using 6 MV beam is dosimetrically better in comparison to 10 and 15 MV.

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Conflicts of interest

There are no conflicts of interest.

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