Volumetric Modulated Arc Therapy Treatment Planning Assessment for Low-Risk Prostate Cancer in Radiotherapy

Abstract

Aims: This research study was carried out for dose verification of volumetric modulated arc therapy (VMAT) plan in the patients of low-risk prostate cancer using different indices in radiotherapy. **Materials and Methods:** Twenty patients with low-risk prostate cancer after histopathological confirmation were included which were divided into two groups with prescribed dose of 7400 and 6000 cGy according to their disease and 3 mm sliced for each patient by computed tomography was obtained for planning. To evaluate the dose conformity and its distribution using VMAT plans such as homogeneity index (HI), radial dose HI, moderate dose HI, coverage, and uniformity index for each patient. These plans were constructed for each patient separately using Eclipse Treatment planning software. **Statistical Analysis Used:** Statistical Package for the Social Sciences statistical software is used to calculate mean standard deviation and standard error of all these indices. **Results:** Obtained results and findings enabled this research work to conclude that VMAT is a better treatment technique for the patients of low-risk prostate cancer with uniform dose distribution. **Conclusion:** It has been suggested that VMAT with Eclipse Treatment planning system is a good treatment modality to treat the patients of low-risk prostate cancer with better results.

Keywords: *Dose distribution, eclipse treatment planning software, indices in radiotherapy, prostate cancer, volumetric modulated arc therapy plan verification*

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Introduction

Radiotherapy is one of the most adaptive methods of cancer treatment in the world. Ionizing radiations are being used to destroy cancerous cells in human body. Basically, in radiotherapy, only tumors cells are required to receive the prescribed dose while normal tissues and nearby organs at risk be secured. This requires an excellent care in planning for dose distribution and delivery. On the basis of anatomical structure, accurate treatment plan is made taking geometric and dosimetric consideration. For tumor treatment geometric accuracy of 2–3 mm in dose delivery is essentially needed.[1] In conformal dose distribution, 5%–7% dosimetric differences in target volume can harm healthy cells and considerable change of tumor control.[2,3] Treatment plans verification and exact delivery of dose in quality assurance programs prevent errors and accidents and provide high-level accuracy in radiotherapy. Advancement in radiotherapy, especially in external beam radiotherapy (EBRT) and modern treatment planning systems have revolutionized the treatment of tumor at any site. In EBRT, volumetric modulated arc therapy (VMAT) is the best example. VMAT technique is the advanced form of intensity modulated radiotherapy (IMRT). VMAT deliver dose with control dose rate and multi-leaf collimator with the adjustment of gentry's rotation speed.[4] When gentry rotate about the isocenter the beam with multiple or single arc (SA) is delivered in this technique. The aim of this article is to study the different parameters for dose verification of VMAT double arc (DA) treatment plans for prostate cancer. Prostate cancer is mostly diagnosed in gents and is second commonly occurring cancer after skin cancer in the developed countries.[5,6] VMAT in EBRT provides the best opportunity due to conformal dose distribution to tumor and decrease the dose to other parts of body.[7-9] VMAT is preferred in prostate cancer treatment over IMRT as it consumes lower number of monitor units and same dose distribution like IMRT.[7-9] Many studies have been carried out to understand the clinical application of RapidArc for prostate cancer treatment. In all these studies variations in the outputs were observed because of

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planning techniques, shape of the target, objective defined, and target volume margins.[10-18] Two types of plans are utilized for prostate cancer patients having SA and DA. Sze *et al*.[11] gave the comparison of 14 prostate cancer patients between SA and DA and proved that DA technique is better than SA due to better homogeneity, conformity, and lowest hotspot. This study also explains rectal dose using SA was maximum than DA techniques. Pengpeng Zhang with his colleagues also compared the VMAT plan and Standard IMRT plan and showed that VMAT treatment decreases the Beam-on time up to 55% while keeping the dosimetric quality same.[13] James L Bedford and his Companion also investigated VMAT plans for different site included prostate site and proved that VMAT has high-quality dose delivery in shorter time as compared to IMRT.[19] Currently, a prostate cancer RapidArc plan with two full arcs has been considered to be the standard plan for the improvement in prostate cancer treatment.

Materials and Methods

In this research project, twenty patients with low-risk prostate cancer were included after confirmation by histopathological test. Computed tomography of 3 mm sliced was obtained of all patients for consideration in simulation and planning to investigate the dose conformity and distribution by different parameters for VMAT plans. All these patients were treated by 6MV photon beam of Clinic DHX linear accelerator (Varian Medical Systems Inc., Palo Alto, CA). VMAT treatment Plans were made on the basis of computed tomographs relevant to each patient separately using Eclipse Treatment Planning Software (ARIA 11) (Varian Medical Systems Inc., Palo Alto, CA). This study involves only low-risk prostate cancer patients with defined clinical target volume (CTV) [Figure 1].

In all directions, the addition of 1 cm to CTV planning target volume (PTV) was considered excluding posterior. 7 mm margin from CTV is taken for PTV to minimize dose of rectum. According to radiation therapy oncology group (RTOG-0815) protocol[20] plans are drawn for Critical organs such as femoral heads, rectum, and bladder. A cumulative dose-volume histogram (DVH) was obtained

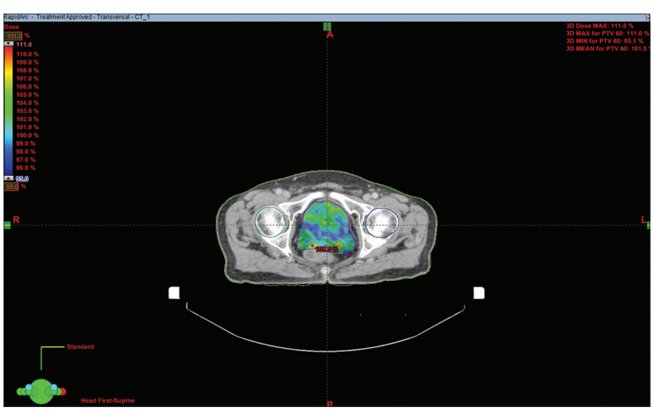

Figure 1: Transversal view of volumetric modulated arc treatment planning

from these plans and used to calculate respective dose values and volumes for each Patient separately for 6-MV beam. The homogeneity index (HI) and dose coverage defined by RTOG in 1993 was used for analyzing the reliability of plan.[21] Radical HI and moderate dose homogeneity indices defined by Oliver in 2007[22] are utilized in this research study for VMAT plan verification. Uniformity index (UI) used by Chitapanarux I in 2015[23] is also calculated, and all these indices are calculated according to defined relations.

Following relations have been used for calculation of these indices are described by their users.

HI = MD/PD (MD = maximum dose used in DVHs and PD = prescribed dose).

Coverage = D_{min}/PD (D_{min} = minimum dose described in the DVHs).

Radical dose HI (rDHI) = D_{min}/D_{max} (D_{max} = MD).

Moderate dose HI (mDHI) = D_{95}/D_5 (D_{95} = dose at 95% and D_5 = dose at 5% of target volume)

UI = D_5/D_{95}.

The cumulative DVHs are generated automatically by the treatment planning software from where all these values are calculated.

Results

Two values of the prescribed dose are used in this project for PTV that is 7400 cGy and 6000 cGy. A total of 20 cases were analyzed, 9 were treated by 7400 cGy PTV and 11 patients were planned for 6000 cGy for PTV. Only the dose values of PTV are considered to calculate these indices which are shown in the graph by red line and the other lines showing the dose delivery to different nearby organs.

D5 and D95 are the doses at 5% and 95% volumes calculated from DVHs carefully. D_{max} and D_{min} are the maximum and minimum doses used and defined in DVHs that can also be seen in Figure 2. These values are defined separately for each case, which are different from each other listed in Table 1.

D_5 ranges from minimum value of 6190 to maximum value of 7950 while the range of D_{95} is from 5780 to 7470. D_{max} contains the values between 6412.7 and 8083.4 and D_{min} having the values between 5289.7 and 6832.0.

Table 2 contains calculated values of indices (HI, coverage, UI, mDHI, and rDHI) for each case. Standard deviation and mean standard error is calculated for twenty cases, first nine cases having the PD 7400 cGy and last eleven cases having the PD 6000 cGy separately.

Discussion

In this research study, findings of 20 patients were analyzed, 9 of them were treated by PD of 7400 cGy and 11 were treated by 6000 cGy. In both cases, HI occupies the range of 0.07 from 1.04 to 1.11. Lower values of homogeneity reflect better dose distribution.[24] Standard deviation of homogeneity comes to be 0.02 and mean standard error is 0.004. These are very low and nonconsiderable values. Dose coverage for all cases has values 0.88–0.92 with range of 0.4. With standard deviation of 0.02 and mean standard error of 0.002. Such lower values are in satisfactory limit with UI range of 0.05 from 1.04 to 1.09 with standard deviation of 0.02 and mean standard error of 0.004. Moderate HI for all cases occupied the range of 0.06 from 0.90 to 0.96 with standard deviation of 0.02 and mean standard error of

Table 1: Values of prescribed dose, D_5, D_{95}, D_{max} and D_{min}

Cases	PD	D_5	D_{95}	D_{max}	D_{min}
1	7400	7870	7400	8083.4	6760.5
2	7400	7950	7470	8097.5	6832.0
3	7400	7530	7210	7724.6	6724.6
4	7400	7550	7130	7666.9	6634.3
5	7400	7540	7130	7713.5	6672.0
6	7400	7790	7400	7983.6	6756.5
7	7400	7890	7420	8008.6	6688.2
8	7400	7760	7380	7939.9	6699.7
9	7400	7720	7290	7959.1	6710.4
10	6000	6255	5785	6445.5	5365.2
11	6000	6370	5910	6505.2	5297.9
12	6000	6270	5800	6447.8	5355.1
13	6000	6370	5800	6518.4	5398.3
14	6000	6310	5890	6467.8	5323.9
15	6000	6450	5820	6548.7	5378.2
16	6000	6280	5840	6460.3	5327.3
17	6000	6190	5780	6412.7	5289.7
18	6000	6360	5830	6557.5	5313.7
19	6000	6420	5870	6621.0	5397.0
20	6000	6300	5830	6533.4	5325.5

PD: Prescribed dose

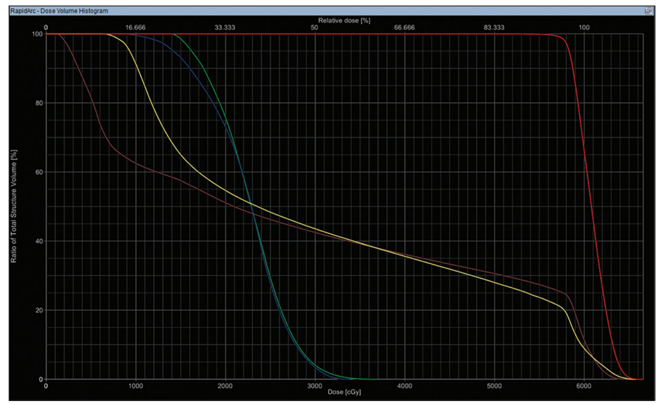

Figure 2: Volumetric modulated arc therapy plan for prostate Showing control system, planning target volume and graphs of dose to nearby organs

Table 2: Containing homogeneity index, coverage, uniformity index, medical dose homogeneity index, and radical dose homogeneity index

Cases	$HI=D_{max}/PD$	$Coverage=D_{min}/PD$	$UI=D_5/D_{95}$	$mDHI=D_{95}/D_5$	$rDHI=D_{min}/D_{max}$
1	1.09	0.91	1.06	0.94	0.84
2	1.09	0.92	1.06	0.94	0.84
3	1.04	0.91	1.04	0.96	0.87
4	1.04	0.90	1.06	0.94	0.86
5	1.04	0.90	1.06	0.94	0.86
6	1.08	0.91	1.05	0.95	0.85
7	1.08	0.90	1.06	0.94	0.84
8	1.07	0.90	1.05	0.95	0.84
9	1.08	0.90	1.06	0.94	0.84
10	1.09	0.89	1.08	0.92	0.83
11	1.08	0.88	1.06	0.93	0.81
12	1.07	0.89	1.08	0.92	0.83
13	1.09	0.90	1.09	0.91	0.83
14	1.08	0.89	1.07	0.93	0.82
15	1.10	0.90	1.06	0.90	0.82
16	1.09	0.89	1.09	0.93	0.82
17	1.10	0.88	1.09	0.93	0.82
18	1.11	0.88	1.09	0.92	0.81
19	1.10	0.90	1.09	0.91	0.82
20	1.08	0.89	1.09	0.92	0.82
Mean standard error	0.004	0.002	0.004	0.003	0.004
SD	0.02	0.011	0.016	0.015	0.017
Mean standard error 9/11	0.007/0.003	0.002/0.002	0.002/0.004	0.002/0.003	0.004/0.002
SD 9/11	0.022/0.011	0.007/0.008	0.007/0.012	0.007/0.010	0.012/0.007

SD: Standard deviation, PD: Prescribed dose, HI: Homogeneity index, UI: Uniformity index, mDHI: moderate dose HI, rDHI: Radial dose HI

0.003. Radical HI has the range of 0.06 from 0.81 to 0.87 with standard deviation of 0.02 and mean standard error of 0.004. Same range of moderate dose HI and radical dose HI reflects the uniform distribution of dose.[25]

In both cases, it is observed for UI, medical dose HI, and dose Coverage that with increasing PD the standard deviation and mean standard error decreases however for HI and radical dose HI it is observed that with increasing PD the standard deviation and mean standard error also increase. Regardless of this trend, it is seen that all the values are so smaller fractions that these are insignificant. All these indices show the values in the satisfactory range defined by RTOG and no single entry shows any deviation from the defined limit. In addition, puniness in the values of standard deviation of these indices in signifies the changes in the delivery of dose.

Conclusion

This research work aimed for dose verification in low-risk prostate cancer cases using different indices of VMAT plan and on the basis of obtained data it has been concluded that VMAT is a better treatment technique for low-risk prostate cancer cases with uniform dose distribution. Furthermore, it is also suggested that the combination of LINAC DHX linear accelerator and Eclipse Treatment planning software is a good treatment modality to treat the patients of low-risk prostate cancer with better efficacy.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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