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DVH Analysis of Cobalt-60 treatment plans incorporating a recently developed MLC

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Original Article

Abstract

Purpose: The aim of this investigation was to measure the gain in DVH indices when the recently developed MLC was used for Cobalt-60 treatments. **Methods:** A prototype multileaf collimator (MLC) that was retrofitted to telecobalt-60 therapy machine was reported and is currently proposed for clinical trials in our institution. Ten patients' plans that were previously planned through an ECLIPSE® treatment planning system and were treated with open beams from Cobalt-60 machine were imported into Radiation Oncology Planning System [ROPS] and the dose calculations and dose volume histogram (DVH) analysis were performed. The plans were re-planned using the Cobalt-MLC, a feature available in the ROPS planning system. The DVH analysis consisted of conformity index (CI), homogeneity index (HI) and conformation number (CN). The results of this study are presented in this paper. The analysis specifically aimed at measuring the gain in these indices when the MLC was compared with open beams. **Results:** DVH Comparison of ten sites using open and Cobalt MLC fields showed that the use of MLC results in reduced normal tissue dose, while maintaining the GTV dose. Lower value of CI for normal structures was observed demonstrating the sparing of critical organs when MLC was used. The index HI was studied to show the significance of hot spots outside the PTV. Hot spots were observed even with MLC beams for some cases due to less number of fields. **Conclusion:** It has been demonstrated through DVH analysis that the use of the recently developed MLC for Cobalt Teletherapy machine results in benefit for the treatment of patients.

Keywords: DVH Analysis, Conformity index, Homogeneity index, Conformation number, MLC Fields, ROPS TPS

1. Introduction

Cobalt-60 treatment machines are still used in developing countries all over the world. In India there are over 200 Co-60 machines are still in operational. Unfortunately, these centers are operating in rural areas with economic disadvantage and hence cannot afford modern treatment planning or custom block fabrication. In a recent review in the red journal, Page *et al.*[1] has cited the benefit of using multileaf collimator (MLC) to make Co-60 treatments on a par with high energy treatment machines. The benefit of using MLC for cobalt-60 was also referred by several investigators[2-8]. The overall goal of our MLC project is not only to develop the MLC as a retrofit attachment to the existing cobalt machines, but also to provide a controller and a low cost treatment planning system (TPS) such as Radiation Oncology Planning System [ROPS] from TJCS (Tirumala Jyothi Computer Systems, Secunderabad, India).

The MLC for Cobalt-60 used in our investigation was previously reported through a Monte Carlo study[9-12], which had 14 leaf pairs to cover a treatment area of 14 cm ×14 cm field size. Figure1 shows the Cobalt machine and the attached MLC.

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Subsequently, another prototype with 16 leaves to cover a treatment area of 16 cm × 14 cm field size was fabricated and was used in the current study. The tungsten leaves with dimensions 7 mm wide, 4 cm high and 15 cm long with 2 cm × 2 mm tongue and groove were used. All patient plans reported here were done using dedicated CT scanner with interface to Eclipse TPS from Varian (Varian Medical Systems, Palo Alto, CA). The CT scans and complete plans from Eclipse TPS were available for export through DICOM RT files.

2. Methods and Materials

Ten different cases representing each of the tumor sites like Brain, Head & Neck, Esophagus, Stomach, Abdomen and Pelvis were taken for the study. These cases were originally planned in Eclipse treatment system and treated accordingly with open beams of Cobalt-60 unit. All the cases were re-planned in ROPS treatment planning system with MLC beams fitted to the PTV. For each case, DVH data were obtained for both plans (open and MLC beams).

The ROPS TPS is specially configured for the Cobalt MLC to adjust the MLC leaves around the irregular shape of the target with margin as well as exporting the leaf positions to the MLC controller. Since the controller is indigenously developed with hardware and software, ROPS is the only TPS that can be configured to match the MLC controller. The ROPS TPS was previously tested with TG-53 protocol[13]. This is a part of accepting testing and commissioning of TPS, which verified PDD, profiles, contour corrections, irregular fields and wedge profiles. In addition, the ROPS TPS was compared with Eclipse TPS by using 6 MV and 16 MV plans[14].

For each clinical case the tumor volumes, critical structures and beam parameters were imported from the Eclipse planning system using DICOM_RT transfer. For cobalt treatment, in general 1-1.5 cm margin was used around the clinical target volume (CTV) to make the planning target volume (PTV). If CTV is not defined, then the gross tumor volume (GTV) is chosen as the target of importance. Since there was no asymmetric jaw or MLC available for the cobalt machine, the beam boundaries in Eclipse plans covered the PTV using the collimator jaws only. In the current study, since we have the MLC for cobalt machine, the original open beam plans were compared by using the MLC to fit the PTV.

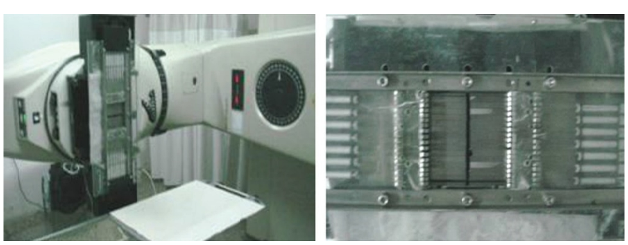

Figure 1: Prototype 1 MLC configured in ROPS TPS (reprinted with permission from Ayyangar *et al.*[10])

The DVH analysis was carried out by computing three indices viz. conformity index (CI), homogeneity index (HI) and conformation number (CN).

- The conformity index (CI) was determined as the ratio between target volume covered by the 90% or 95% isodose and the target volume (TV). While 95% isodose line is used as a standard isodose line for the definition of the indices, for cobalt-60, we have also considered 90% isodose line since 95% cannot cover the TV in some cases.

- The homogeneity index (HI) was determined as the ratio of maximum dose in the target volume to the prescription dose.

- The conformation number (CN) was defined by Arie van't Riet *et al.*[15] and was calculated using the formula:

  $CN = (TV_{iso} / TV)\ (TV_{iso} / V_{iso})$,

  where, TV_{iso} is the target volume covered by the isodose line, TV is the target volume and V_{iso} is the total volume covered by the 90% or 95% isodose line. The V_{iso} is calculated from the dose matrix and is not dependent on any structure volume. The advantage of these indices is that ideally the values need to be close to unity for the CTV or GTV while the values should be close to zero for other structures.

The CN shows that the MLC confines the dose to PTV. The value of CI close to unity for the GTV indicates that the dose uniformity of the target is achieved. Since the use of MLC decreases dose to the critical structures, lower values of CI should be expected when compared with open beam. The value of HI close to unity for the GTV indicates that there are no hotspots. However, for certain 3-field plans using Cobalt beams the dose outside the PTV causes HI > 1 especially for abdomen and pelvic sites.

3. Results

Figure 2 shows the DVH Comparison of a cervix case using open and Cobalt MLC fields. It can be seen that the use of MLC results in reduced normal tissue dose, while maintaining the GTV dose. Similar comparisons for brain and esophagus sites are shown in Figures 3 and 4 respectively. A typical beam arrangement from the ROPS 3D planning system for a three-field brain case with MLC fields is shown in Figure 5.

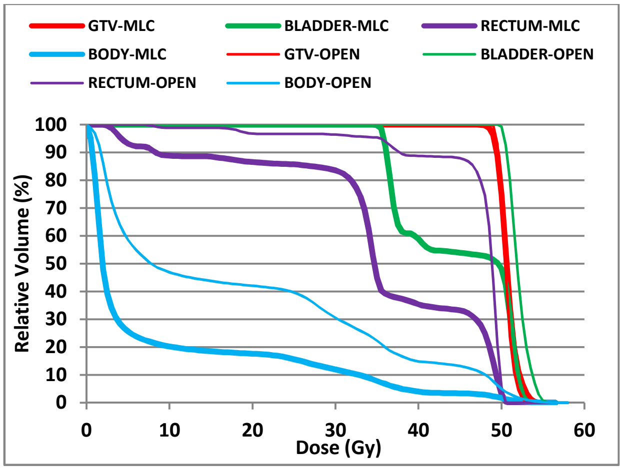

Figure 2: A Case of cervix treatment showing DVH Comparison of MLC vs. OPEN fields. Thick lines are for MLC and thin lines for OPEN beams.

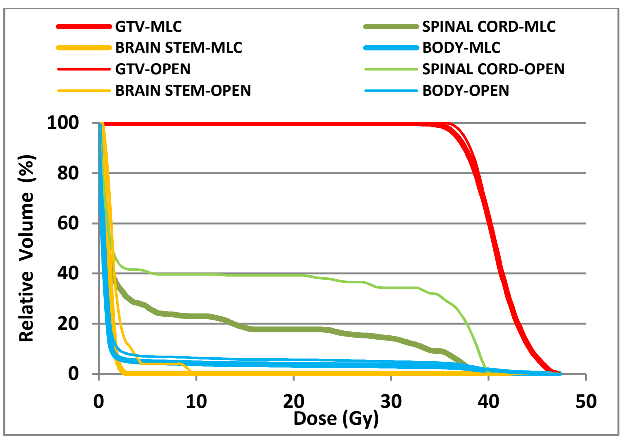

Figure 3: A Case of brain treatment showing DVH Comparison of MLC vs. Open fields. Thick lines are for MLC and thin lines for OPEN beams.

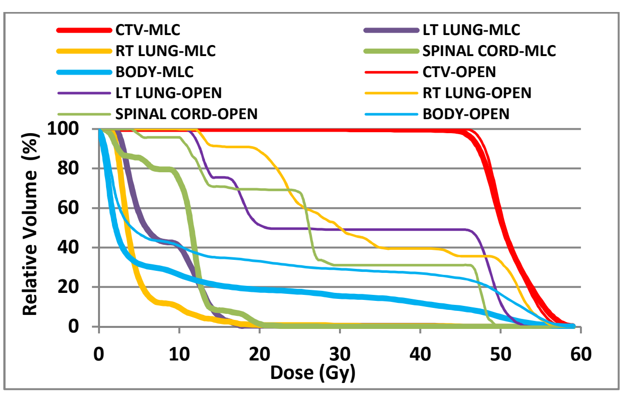

Figure 4: A Case of esophagus treatment showing DVH Comparison of MLC vs. Open fields. Thick lines are for MLC and thin lines for OPEN beams.

Table 1 shows conformity index CI for the GTV. It can be seen that both the open and MLC plans cover the GTV adequately. Due to large or irregular target shape, sometimes the 95% isodose line did not cover even the GTV adequately. In this case, the 90% isodose line covered adequately. This can be evident in the clinical of case #5 in Table 1.

The CI for critical structure is tabulated in Table 2. It can be seen that the MLC plan showed lower value compared to open beam plan. Once again, a low CI for structures other than the target is desirable.

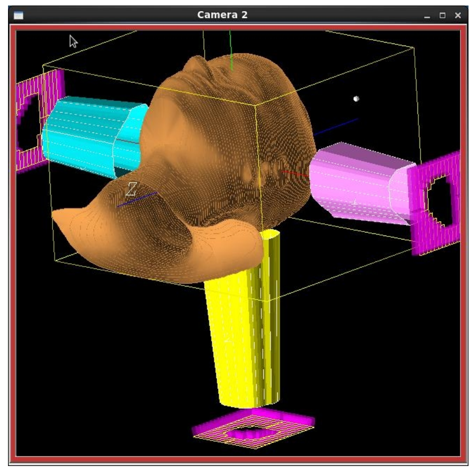

Figure 5: A typical MLC beam arrangement from the ROPS 3D planning system for a three field brain treatment is shown here.

The homogeneity index HI is tabulated in Table 3. The homogeneity index signifies the hot spot in the target volume. A value higher than 1 is undesirable since that signifies the dose outside the GTV is larger than the maximum dose in the target volume. It can be seen from table 3 that for clinical cases 4, 5, 8, 10, the hotspot is larger than in the target volume. This usually happens for three field plans and can be reduced by adding more fields. In this study, our goal was to compare with already treated plans and hence the plans were not modified.

Table 1: Conformity Index for GTV.

Case #	Open CI 95%	MLC CI 95%	Open CI 90%	MLC CI 90%
1	1	0.99	1	1
2	1	1	1	1
3	0.96	0.98	1	1
4	1	1	1	1
5	0.8	0.73	0.98	0.94
6	0.99	1	1	1
7	0.93	0.96	1	1
8	0.98	0.96	1	0.99
9	0.91	0.86	1	0.95
10	1	1	1	1

Open means without the use of MLC

Table 2: Conformity Index of critical structures.

Case #	Structure	Open CI 95%	MLC CI 95%	Open CI 90%	MLC CI 90%
1	Rectum	0.79	0.48	0.83	0.54
	Bladder	0.41	0.16	0.46	0.2
2	Rectum	0.79	0.25	0.83	0.3
	Bladder	1	0.54	1	0.55
3	Rectum	0.83	0.25	0.91	0.35
	Bladder	0.45	0.04	0.47	0.04
4	Spinal Cord	0.17	0.03	0.21	0.06
	Heart	0.38	0	0.47	0
5	Spinal Cord	0	0	0.2	0
	Lt. Kidney	0.07	0	0.38	0
	Rt. Kidney	0.33	0	0.36	0
6	Spinal Cord	0.02	0	0.05	0
7	Spinal Cord	0.43	0.03	0.54	0.07
8	Optic Nerve	0.99	0.14	0.99	0.14
9	Spinal Cord	0.18	0.05	0.28	0.09
10	Spinal Cord	0.66	0.04	0.83	0.05

Open means without the use of MLC

Table 3: Homogeneity Index for GTV.

	Homogeneity Index	
Case #	Open	MLC
1	1.01	1.01
2	1.01	1.01
3	1.01	1.01
4	1.14	1.20
5	1.12	1.15
6	1.03	1.03
7	1.05	1.07
8	1.11	1.10
9	0.97	0.89
10	1.11	1.20

Open means without the use of MLC

Lastly, Table 4 shows the results of conformation number CN. Even after using 3D plans, the conformation number was not close to unity. This is because isodose cannot conform an irregular shape of the target, unless many beams, 3D dose compensators and non-coplanar beam arrangements are used. However, marked improvement in CN can be noticed by using the MLC compared to open beams. The 90% isodose line resulted in better CN values compared to 95% isodose line.

Table 4: Conformation Number for PTV.

Case #	Open CN 95	MLC CN 95	Open CN 90	MLC CN 90
1	0.425	0.590	0.475	0.983
2	0.258	0.669	0.317	0.853
3	0.223	0.526	0.312	0.791
4	0.238	0.543	0.294	0.657
5	0.166	0.346	0.317	0.804
6	0.418	0.521	0.638	0.959
7	0.306	0.592	0.471	0.933
8	0.373	0.555	0.503	0.864
9	0.323	0.359	0.512	0.548
10	0.211	0.670	0.244	0.743

Open means without the use of MLC

4. Discussion

In conventional Telecobalt treatments, patients were treated with open beams, as a consequence of which considerable dose to normal structures are inevitable. It was unavoidable in order to treat the target volumes. Unfortunately, this leads to normal tissue complications for most of organs that were exposed to higher doses. By using shielding blocks, it takes more time to plan a case and for setting up the patient to treat. Also, there is no clear idea about the coverage of PTV and dose to normal structures. Having dedicated treatment planning (ROPS) to control the add-on MLC for existing telecobalt-60 treatment units, it is very easy to plan and treat the required PTV and at the same time, normal organs can be spared. This reduces the normal tissue complications for the patients. This has been shown by adding MLC to existing Telecobalt machines, the same treatments were re-planned in new ROPS treatment planning system. This study showed that a better target coverage and significant dose reduction to OARs could be achieved with the use of MLC.

5. Conclusion

By studying the DVH indices like conformity index, homogeneity index and conformation number, it has been shown that the values of these indices are in favor of MLC beam plans compared to that of open beams. Instead of treating the patients with open beams on old Co-60 units where there is no scope for the modification of the units, it is better to have add-on MLC for the machines. And, it has been demonstrated through DVH analysis that the use of the MLC for Cobalt Teletherapy machine results in benefit for the treatment of patients.

Conflict of interest

The authors declare that they have no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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